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The Integration of Environmental Sustainability in the Athlete's Plate Nutrition Educational Tool.

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Everybody told me a PhD was a lonely path. Moreover, when your adviser is in another continent, your country has a small PhD program, you have two jobs and the PhD program is unpaid the difficulty becomes at some points similar to a 9c-climbing wall. However, I would never say a PhD is a lonely path; it is a pathway full of mentorship, expertise, knowledge, patience, constancy and support. For those listed below but also for everyone else who helped me in one way or another, thank you for your support. This project will not be a reality without everyone who mentored me, helped me, encouraged me, challenged me, supported me and loved me all through these years. Aquest projecte també és vostre. Moltes gràcies.

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Abbreviations and Acronyms list

AP	Athlete's Plate
B	Breakfast
BM	Body Mass
CAFOs	Confined Animal Feeding Operations
CH_4	Methane
CIA	Culinary Institute of America
CO_2	Carbon Dioxide
CS- OTC	Colorado Springs Olympic Training Center
CS-USOTC	Colorado Springs United States Olympic Training Center
CSA	Community Supported Agriculture
CSOPTC	Colorado Springs Olympic and Paralympic Training Center
D	Dinner
DHA	Docosahexaenoic acid
DRV	Daily Reference Value
E	Easy
EA	Energy Availability
EAA	Essential Amino Acids
EI	Energy Intake
EPA	Eicosapentaenoic acid
F	Female
FAO	Food and Agriculture Organization
FBDG	Food-Based Dietary Guidelines
FFM	Fat Free Mass
FU	Functional Unit
GhG	Greenhouse Gas
GhGe	Greenhouse Gas emissions
GM	Genetically modified
GT	Gigatons
GWP	Global Warming potential
H	Hard
HEI	Healthy Eating Index
IDF	International Dairy Federation
IOC	International Olympic Committee
IPCC	Interdisciplinary Panel for Climate Change
ISO	International Organization for Standa
L	Lunch
LBM	Lean Body Mass
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCSA	Life Cycle Sustainable Assessment
M	Male
M	Moderate
N_2O	Nitrous Oxide
NBDG	Nutrient-Based Dietary Guidelines
NHANES	National Health and Nutrition Examination Survey
NRF	Nutrient Rich Food
PSS	Product Service Systems
RDA	Recommended Daily Allowance
TAPES	The Athlete's Plate Educational Survey
UCCS	University of Colorado, Colorado Springs
UN	United Nations
USDA	United States Department of Agriculture
USOC	United States Olympic Committee
WFP	World Food Program
WHO	World Health Organization

Abstract

Dietary choices have a direct impact on the environment, contributing to climate change, biodiversity loss and water scarcity among others. Furthermore, food choices influence health. Red meat and processed foods high in sugar, salt, are associated with chronic disease and cancer. Recent recommendations are calling for "The Great Food Transformation" with significant reductions in meat and processed food to improve both planetary and human health. While some dietary guidelines are starting to include environmental concepts in the general population, a better understanding of the environmental impact (EnvI) of food production and consumption patterns is needed to support its inclusion also in active individuals and athletes.

The aim of this research was to validate the Athlete's Plate (AP) nutrition educational tool, calculate its EnvI and integrate sustainability principles in a revised AP. The AP is a visual tool for athletes and active individuals to adjust food intake to training load. In athletes energy and nutrient needs exceed those of the general population to ensure maintenance of health and promote optimum adaptation to training. Sport nutrition guidelines are generally focused on higher energy, carbohydrate and fat intake with increased training load. Further, the quality of nutrients, especially from animal protein, is a critical element of the athlete's diet for optimal muscle development and repair. While protein recommendations are relatively modest for athletes, recent evidence and trends show higher amounts, especially from meat and dairy. This raises concern, as these foods contribute to environmental degradation. In addition, there is a significant gap in research on plant-based diets relative to muscle protein balance. Considering that animal protein has a higher EnvI than plant protein, it is important to evaluate the AP to ensure it meets sport nutrition guidelines and is practically useful in athletes, to quantify the EnvI of the AP through Life Cycle Assessment and identify hotspots to decrease impact in athletes, and to develop a revised AP that meets both guidelines for sport nutrition and sustainability.

Contribution I, *"Eat as If You Could Save the Planet and Win!" Sustainability Integration into Nutrition for Exercise and Sport* analyzes the current body of literature and highlights the need for better inclusion of sustainability in sport nutrition. Contribution II, *Validation of the Athlete's Plate Nutrition Educational Tool: Phase I,* confirms the AP as a valid sport nutrition tool for energy and macronutrients except for protein. Contribution III, *The Athlete's Plate Education Program: An Experiential Intervention,* shows that the program provides athletes sufficient knowledge to apply the AP model in a practical setting. Contribution IV, *The Environmental Impact of the Athlete's Plate Nutrition Education Tool* shows that the EnvI of the AP varies with training load, meal type, and sex, being higher by males, dinner and hard training days. It is also dependent on the animal protein content on the plates (higher with higher meat and diary), but it is not the only concern as other variables have to be taken into account such as: processing, RD variability and fresh food.

In conclusion, this study validates the AP, highlights the usefulness of the AP Educational Program, and quantifies the AP's EnVI, emphasizing the need to integrate sustainability principles into sport nutrition tools for athletes and active individuals.

KEYWORDS: Nutrition education, sport nutrition, Life Cycle Assessment, proteins, sustainability, nutrition/training periodization

Resum

Les opcions dietètiques tenen un impacte directe sobre el medi ambient, contribuint al canvi climàtic, a la pèrdua de biodiversitat i a l'escassetat d'aigua, entre d'altres. A més, les opcions alimentàries influeixen en la salut. La carn vermella i els aliments processats rics en sucre i sal, s'associen a malalties cròniques i càncer. Recomanacions recents fan una crida a "La Gran Transformació d'Aliments" amb reduccions significatives de la carn i dels aliments processats per millorar tant la salut planetària com la humana. Si bé algunes pautes dietètiques comencen a incloure conceptes mediambientals per a la població general, cal una millor comprensió de l'impacte ambiental (EnvI) dels patrons de producció i consum d'aliments per tal d'afavorir la seva inclusió també en persones actives i esportistes.

L'objectiu d'aquesta investigació era validar l'eina educativa nutricional del Plat de l'Atleta (AP), calcular el seu EnvI i integrar els principis de sostenibilitat en un AP revisat. L'AP és una eina visual per a esportistes i persones actives per a ajustar la ingesta d'aliments a la càrrega d'entrenament. En els atletes, les necessitats energètiques i de nutrients superen les de la població general per tal de poder assegurar el manteniment de la salut i promoure l'òptima adaptació als entrenaments. Les recomanacions sobre nutrició esportiva se centren generalment en una aportació més gran d'energia, hidrats de carboni i greixos amb una major càrrega d'entrenament. A més, la qualitat dels nutrients, en especial de la proteïna són un element crític de la dieta de l'atleta per a un desenvolupament i recuperació òptims del múscul. Si bé les recomanacions de proteïnes són relativament modestes per als atletes, les evidències i tendències recents mostren quantitats més elevades, especialment de la carn i els lactis.

Això suscita preocupació, ja que aquests aliments contribueixen a la degradació ambiental. A més, hi ha un buit significatiu en la investigació sobre dietes basades aliments d'origen vegetal en relació amb la síntesis proteica muscular. Tenint en compte que la proteïna animal té un EnvI més elevat que la proteïna vegetal, és important avaluar l'AP per assegurar-se que compleix les recomanacions de nutrició esportiva i és, en la pràctica, útil en atletes per quantificar l'Envl de l'AP mitjançant l'Avaluació del Cicle de Vida i identificar els punts clau per disminuir l'impacte en esportistes i per desenvolupar un AP revisat que compleixi tant pautes de nutrició esportiva com de sostenibilitat.

La Contribució I, *"Menja com Si Poguessis Salvar el Planeta i Guanyar!" La Integració de la Sostenibilitat en la Nutrició per a l'Exercici i l'Esport* analitza el corpus actual de la literatura i destaca la necessitat d'una millor inclusió de la sostenibilitat en la nutrició esportiva. La Contribució II, Validació de l'Eina Educativa de Nutrició del Plat de l'Atleta: la Fase I, confirma l'AP com a eina vàlida d'alimentació esportiva pel que fa a energia i macronutrients, llevat de proteïnes. La Contribució III, El Programa d'Educació del Plat de l'Atleta: una intervenció experiencial, demostra que el programa proporciona als esportistes coneixements suficients per aplicar el model d'AP en un entorn pràctic. La Contribució IV, L'impacte Ambiental de l'Eina d'Educació Nutricional el Plat de l'Atleta, demostra que l'Envl de l'AP augmenta amb la càrrega d'entrenament, el tipus de menjar i el sexe i és el més elevat en proteïnes animals, però no és l'única preocupació.

En conclusió, aquest estudi valida l'AP, destaca la utilitat del Programa Educatiu de l'AP i quantifica l'EnvI de l'AP, posant l'èmfasi en la necessitat d'integrar els principis de sostenibilitat en les eines de nutrició esportiva per a esportistes i persones actives.

KEYWORDS: Educació nutricional, nutrició esportiva, Anàlisi del Cicle de la Vida, proteïnes, sostenibilitat, periodització de la nutrició/entrenament.

Motivations and structure of the Thesis

Climate change is one of the greatest challenges of the XXI century. Changing food production and consumption is one of the paths to revert the actual situation on climate change. Moreover, nutrition has a direct impact on health, and it has been demonstrated that the majority of food and diet patterns with low environmental impact are also the ones with a positive effect on health. However, very few nutrition guidelines include sustainability in their recommendations and the message has not yet been expanded. In addition, some populations such athletes, with higher energy and nutrients needs, raise the dilemma on how to achieve their requirement without adding extra environmental burden. This dissertation is based on the interest to better understand and evaluate the relationship among three different constructs: sport nutrition, sustainability and nutrition education.

This PhD interconnects these three constructs and their relationships so possible pathways may be developed that help promote a more mindful society in sport exercise who chooses food not only for health and performance benefits but also considers environmental impacts. The results of this work will give rise to the sustainable Athlete's Plate which should help promote sustainable food choices in active and athletic populations.

This dissertation is structured in four main chapters:

CHAPTER 1 provides the necessary background to understand the drivers and objectives of the research. A theoretical framework of the three constructs of this research, sport nutrition, environmental sustainability and nutrition education are defined, described, and illustrated in their overlapping schemes to help the reader understand the context of the research and the importance of connecting these three constructs.

CHAPTER 2 includes the hypotheses and research objectives for each of the scientific papers included in this dissertation.

CHAPTER 3 consists of the compilation of the papers (contributions) that are the core part of this dissertation. The contents of the papers, figures and tables, already published, have been extracted from the versions of the papers submitted to the international peer-reviewed scientific journals, and adapted to the format of this dissertation. The papers that are not yet published to peer-reviewed journals have been formatted to be adapted to the format of the dissertation and will be submitted briefly adapted to the format of each selected journal.

CHAPTER 4 summarizes and synthesizes the results of each contribution providing an overview of the importance of the connection among the three constructs. It also proposes a preliminary version of the sustainable AP.

CHAPTER 5 includes this conclusions of the dissertation, providing overall recommendations, and future research.

Additionally, **appendices** are included at the end of contributions III and IV with supplementary material and at the end of this dissertation with a list of other relevant contributions and scholarships granted during this PhD.

CHAPTER

1

INTRODUCTION

“Eating is an agricultural act.”

Wendell Berry

1.1 Background:

The inclusion of sustainability to mitigate climate change is on the political agenda of many countries and their governmental and non-governmental organizations, businesses and institutions and has become of rising urgency and one of the greatest challenges of the 21st century. The United Nations (UN) Sustainable Development Agenda 2030, "Transforming Our World: The 2030 Agenda For Sustainable Development" with 17 goals, including sustainable agriculture and food security, among others, is calling for urgent action to face climate change and its global impact (UN, 2015). Acknowledging the impact of industrialized agriculture, globalized food systems and poor dietary choices on the environment, the Food and Agriculture Organization (FAO) 2016 Food Day theme was: "Climate is Changing, Food and Agriculture must too". This is a great example of the growing awareness of this topic and the mounting urge to tackle these converging problems from a global and trans-disciplinary perspective. In addition, health problems related to the nutrition transition on one hand predict a further rise in obesity and chronic disease, including environmental, social and economical burdens. On the other hand, climate change per se is expected to displace thousands of people already challenged by hunger and malnutrition, heightening disparities in food security in the developing world (FAO, IFSAD, & WFP, 2014; Tirado et al., 2013). Moreover, 2016-2026 was declared the decade of nutrition by the UN to raise awareness on health and sustainability, highlighting the global and significant magnitude of the link between these two big topics (FAO, 2016a). In 2019, The EAT-Lancet Commission on healthy diets from sustainable food systems urged everyone to consider the "Great Food Transformation" from both consumption (healthy diets) and production (sustainable food production) perspectives (Willett et al., 2019), highlighting the importance and urgency to confront this issue.

1.2 Sustainability, climate change and health

There are various definitions of sustainability, but one of the most accepted is the Brundtland's report definition from 1987: "meeting the needs of the present generation without compromising the ability of future generations to meet their needs" (Brundtland, 1987). Sustainability has also been defined with three main dimensions and their interactions: ecological, social and economical (UN, 1992). When talking about health it is important to consider the three pillars of sustainability and their interaction as they all pertain to wellness and health promotion.

One of the few models that have attempted to link health and sustainability together is by Kjærgård et al. (2013) (figure 1.1). This model defines health beyond the absence of disease and integrates health as part of "social dynamics, lifestyles and patterns of consumptions, influenced by the bio-physical environment" (Kjærgård et al., 2013; Pedersen, Land, & Kjaergard, 2015). This model conceptualizes the duality between sustainability and health, conceiving any strategy of health promotion or sustainable

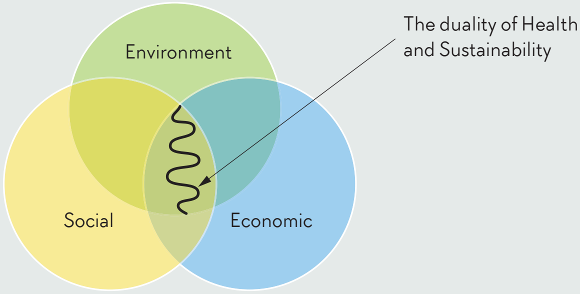

FIGURE 1.1

The duality of health and sustainability model. Obtained from Kjærgård et al. (2013).

development from both perspectives and in which none is given preference over the other. The model by Kjærgård et al. (2013), wants to ensure that strategies for health promotion include an ecological, economical, and social perspective, avoiding unintended negative consequences for one another. Hancock (1993) also considered health as a determinant of human development and prompted to use a similar model as a criteria for public policy development, defining key principles when developing sustainable, healthy programs that include the three above mentioned pillars of sustainability. Thus, this framework assimilates the definition of health by the World Health Organization (WHO), and its goal to include cross-sectoral policies, integrating effective health dimensions into other sectors such as agriculture (FAO, 2010). Moreover, the FAO has also integrated the pillar of governance as a fourth pillar into this model, considering policy, as Hancock (1993) proposed, when building guidelines to assess food and agriculture systems (FAO, 2014). These cross-sectoral policies will be considered below to link the impact of agriculture, food and nutrition on health and the environment.

Human activities contribute to climate change and this is mainly measured by greenhouse gas emissions (GhGe) and by the Global Warming Potential (GWP). While divided by economic sectors, agriculture, including deforestation with consequential land use, accounts for up to 30% of global GhGe, whereas transportation and industry account for 14% and 21%, respectively (IPPC, 2019; Vermeulen, Campbell, & Ingram, 2012). These data might vary depending on the estimated relative contributions of the different stages in the food chain, from preproduction, production, postproduction to waste (Vermeulen et al., 2012), or the well-known cradle to grave expression. This includes the production of fertilizers and pesticides, direct emissions from agriculture such as CO_2 emissions from tractors or methane from livestock. Green house gas emissions from agriculture dominate the impacts. Post-production processes such as storage, transport, and retail activities contribute the least, while food waste is often not included, but contributes significantly to the overall GhGe (Vermeulen et al., 2012). The GhGe of these activities will also vary depending on the type of agriculture (organic vs conventional), livestock production, or region (Vermeulen et al., 2012). From all the food groups, livestock, and especially ruminants, are the most significant contributors to climate change (Gerber et al., 2013; Sabaté, Sranacharoenpong, Harwatt, Wien, & Soret, 2014). The main GhGe generated by this sector are nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2). Livestock's estimated GhGe are 7.1Gt CO_2eq/yr, representing 14.5% of human-induced GhGe, and beef and cattle milk production account for 41% and 20% GhGe, respectively (Gerber et al., 2013). In addition, beef and milk cattle have a higher burden on land and water use (Gerbens-Leenes, Mekonnen, & Hoekstra, 2013; Hoekstra, Chapagain, Aldaya, & Mekonnen, 2011; Mekonnen & Hoekstra, 2012) compared with other animal and plant protein sources (Sabaté et al., 2014).

Ripple et al. (2014) examined the effects of reducing ruminant production and its positive impact on decreasing climate change and how policy makers should consider this approach when planning strategies to tackle a reduction in GhGe. Furthermore, if production is reduced, there is a need to change food choices and preferences of consumers. Scarborough et al. (2014) evaluated the effect on daily GhGe of high meat eaters (7.19 $kgCO_2eq/d$), medium meat eaters (5.63 $kgCO_2eq/d$), low meat eaters (4.67 $kgCO_2eq/d$), fish eaters (3.91 $kgCO_2eq/d$), vegetarians (3.81 $kgCO_2eq/d$) and vegans (2.89 $kgCO_2eq/d$), showing a positive relationship between dietary GhGe and the amount of animal products consumed in a standard 2,000 kilocalorie diet. Masset, Soler, Vieux, & Darmon (2014) also evaluated the environmental impact of French diets through a survey of frequently consumed foods and found that most foods with low GhGe also had a higher nutritional quality. Soret et al. (2014) also studied the environmental impact of different dietary patterns in North America and reported a yearly average GhGe of non-vegetarian diet (1113 $kgCO_2eq/y$), semi-vegetarian diet (872 $kgCO_2eq/y$) and vegetarian diet (788 $kgCO_2eq/y$). The data analysed in the study by Soret et al (2014) were from the Adventist Health Study 2 (AHS-2) and defined as non-vegetarians (consumed meat at least 1 time/week), vegetarians (rarely or never consumed meats) and semivegetarians (consumed meats more than 1 time/month but less than 1 time/week). Considering the non-vegetarians as a reference, they observed an annual GhGe decrease of 29.2% (vegetarian) and 21.6% (semi-vegetarian). This reduction in environmental impact by vegetarian and vegan dietary patterns has also been observed by others and published in several review papers relative to GhGe and land use (Aleksandrowicz, Green, Joy, Smith, & Haines, 2016; Hallström, Carlsson-Kanyama, & Börjesson, 2015), with vegan and vegetarian dietary patterns reducing various impacts by about 20 to 50%, although water savings are less certain (Aleksandrowicz et al., 2016).

One of the questions that arises often is the case of dairy products. Highly consumed in both the US and Europe (USDA, 2017; Westhoek et al., 2014) dairy products also have a significant environmental impact, although less than meat (Westhoek et al., 2014). Dairy products, however, are rich in essential amino acids and micronutrients. The study by Werner, Flysjö & Tholstrup (2014), compared the daily GhGe of eight different modeled dietary scenarios of the Danish population against nutrient loss, attempting to modify the intake of dairy products without compromising nutrient density of the diet. They suggested eight dietary scenarios with different quantities of dairy products but with the same energy content. They proposed that the milk products dietary scenario only includes milk and yogurt but not cheese. In contrast, the dairy or high dairy dietary scenario includes milk, milk products and cheese. They found the following values: average dairy (4.631 $kgCO_2eq/d$), high dairy (4.521 $kgCO_2eq/d$), milk products (4.340 $kgCO_2eq/d$), cheese products (4.826 $kgCO_2eq/d$), non-dairy (4.645 $kgCO_2eq/d$), soy drink (3.620 $kgCO_2eq/d$), vegetarian (3.063 $kgCO_2eq/d$) and vegan (2.414 $kgCO_2eq/d$). The study also compared the diet quality against the GhGe and found that dairy not only accounted for less GhGe than meat and meat products (11% for dairy vs 29% for meat), but also contributed significantly more overall to nutrient density. As a consequence, the study suggests that excluding completely dairy products from the diet would not contribute significantly to save the environment, but could have a detrimental effect on the nutritional composition of the diet. However, these scientists did not compare other food options with lower environmental impact that could be substituted for dairy, without compromising nutrient quality. Nevertheless, the results of this study still highlight that there is a significant and important difference in environmental impact between high dairy diets compared with vegetarian and vegan diets. In contrast, Westhoek et al. (2014) examined the health and environmental impacts of replacing 25-50% of animal-derived foods (meat, dairy products and eggs) with plant-based foods on a dietary energy basis assuming changes in production at the European Union. The results show a 40% reduction in nitrogen-related emissions, a 25-40% decrease in GhGe and 23% reduction in per capita less use of cropland for food production. With this different diet scenario there is a switch to a diet with higher intake of whole grains, as well as a 40% reduction in saturated fat intake, and consequently, a positive impact on cardiovascular diseases risk. Further, what should also be considered is that meat reduction using dairy and cheese substitution is not an effective strategy to reduce either GhGe, land use, or disease risk (Hallström et al., 2015). Finally, while dairy contribute some to nutrient quality, diet quality per se, without animal products, does not have to be compromised if these diets integrate a variety of plant-based foods, including soy (Lynch, Johnston, & Wharton, 2018; Melina, Craig, & Levin, 2016). These diets can be both, nutritionally rich and environmentally friendly (Tessari, Lante, & Mosca, 2016).

While the literature agrees that reducing meat and dairy production, and especially ruminant production, would reduce GhGe emissions, global consumption patterns show a different picture. Meat consumption is increasing worldwide, even in countries that traditionally had vegetarian diets (Delgado, 2003; FAO, 2010). Likewise, it seems that there is resistance from consumers to incorporate more sustainable eating patterns, specifically reducing meat intake. Macdiarmid, Douglas, & Campbell (2016) found that non-food related behaviors were viewed as more acceptable and had a higher priority to fight against climate change than reducing dietary meat consumption. Regardless, awareness about red and processed meat consumption and potential increased risk of cardiovascular disease and cancer are probably, at least in part, responsible for a steady decline in beef consumption during the last 45 years. While this is a good shift in dietary practice, the availability of chicken, yogurt and cheese has increased slightly the last years, showing no overall decrease in animal products in the US overall (Bentley, 2017). A recent paper by Poore & Nemecek (2018) suggests that both sides, from production to consumption, have to be considered when reducing the environmental impact of food. Poore & Nemecek (2018), examined pathways to reduce the environmental impact from the production and the consumption perspective proposing mitigation frameworks from the farm, processors and retailers to consumer settings and the need to integrate a framework. Further, there have been some countries that have incorporated reduced meat recommendations in their national guidelines (FAO, 2016b). In addition, there have been popular initiatives, such as *Meatless Mondays*, to reduce meat consumption (Meatless Mondays, (n.d)). The most recent changes in National dietary guidelines that incorporate sustainability will be discussed in section 1.3 of this chapter.

While food production, and especially animal protein production, has a negative effect on the environment, and thus, contributes to climate change, different authors also acknowledge the link between diet and health (Friel et al., 2009; Katz, 2016; Tilman & Clark, 2014). Having access to high quality and affordable food with appropriate nutrient content will contribute to health and wellbeing

(FAO, 2013). Malnutrition has many manifestations, in some regions of the world, the population is undernourished, while in other regions obesity and overweight prevails (FAO, 2013). The FAO reports that 12.5% of the world's population is undernourished in terms of energy and 2 billion suffer from one or more micronutrient deficiencies. In contrast, 1.4 billion people are overweight with 500 million people being obese (FAO, 2013). Overweight and obesity have become a worldwide problem and are related to an increased risk of cardiovascular disease, diabetes, hypertension and certain types of cancer (Lewis, et al. 2009). These health-related problems have been linked with high animal protein consumption, such as red and processed meats, saturated fats and processed foods high in sugar (Bouvard et al., 2015; Etemadi et al., 2017). A recent Lancet report links obesity, undernutrition and climate change as a triple burden which the authors also define as "syndemic or synergy of epidemics, because they co-occur in time and place, interact with each other to produce complex sequelae, and share common underlying societal drivers" (Swinburn et al., 2019). This report proposes different multi-level actions which include reducing red meat and processed food intake, promoting urban food systems to provide access to healthier foods, and enhancing local food production and consumption, aiming to promote peoples' well-being and improving health outcomes. However it highlights the difficulty to address this triple burden (undernutrition, obesity and climate change) as one of the greatest challenges that needs to be addressed in the 21st century and beyond.

While the global perspective is complex, some diets have shown benefits for both health and the environment: the Mediterranean Diet, the New Nordic Diet or the vegetarian diet have been identified as both, health-promoting and sustainable (Tilman & Clark, 2014). The Mediterranean Diet has often been associated with benefits for longevity, quality of life, and disease prevention. This diet has also been studied in regard to its positive effect in preventing cancer (Demetriou, Hadjisavvas, Loizidou, Vineis, & Kyriacou, 2015), obesity (Lairon, 2014), and diabetes (de Lorgeril & Salen, 2015), increasing life expectancy and decreasing inflammatory indices (Djuric, 2014). Furthermore, the Mediterranean diet has also been expressed as a multi-dimensional and inter-disciplinary framework model for a sustainable diet (Dernini, Berry, Vecchia, & Capone, 2017). Although the Mediterranean Diet is an indisputable intangible cultural heritage of humanity, declared so by the UNESCO in 2010, the adherence to the Mediterranean Diet model is decreasing due to a variety of factors, but mostly influenced by changes in the global life style and the food system (Bach-Faig et al., 2011; Batlle-Bayer, Bala, García-Herrero, et al., 2019; Dernini & Berry, 2015). Other diets, such as the New Nordic Diet, also based on a traditional Nordic dietary pattern, have shown positive effects on both the environment and health (Saxe, 2014). However, the high recommendation for fish in both the Mediterranean and the New Nordic Diets have raised some sustainability concerns (FAO, 2012). While studies recommend up to two servings of fish a week for their beneficial effects on heart disease risk (Djuric, 2014; Kris-Etherton, 2002), there is no consensus on the role of fish oil in other pathologies (Wallin et al., 2012; Xun & He, 2012). In contrast, some authors are demanding a change in dietary recommendations that permit consumers to meet dietary guidelines while also protecting and preserving fish stocks and equity worldwide to ensure coastal populations continue to have access to this critical protein source (Clonan, Holdsworth, Swift, Leibovici, & Wilson, 2012). The Low Lands Diet is an example with both, a lower fish and meat recommendation, attempting to meet nutrient requirements while not compromising sustainability (Van Dooren, Marinussen, Blonk, Aiking, & Vellinga, 2014). Additionally, when compared with a vegetarian diet, the Mediterranean Diet still has higher GhGe emission but nevertheless generates less GhGe than a high meat diet (Castañé & Antón, 2018; Pairotti et al., 2015). In fact, many studies are showing that reducing meat, and specially red meat, from the diet is one of the main pathways than can have a positive effect on both the environment and human health. In 2015, an international group of experts, organized by the WHO, published a report on the relationship between diets high in animal protein, especially coming from red and processed meat, and its carcinogenicity (Bouvard et al., 2015). The International Agency for Research on Cancer of the WHO published that 50g of processed meat eaten daily increases the risk of colorectal cancer by 18%. This report also recommends to public health organizations to decrease the intake of meat in their guidelines, balancing meat benefits and risks, to ensure the best dietary recommendations for health and sustainability (Bouvard et al., 2015). Etemadi et al. (2017) published a paper showing an increase in all-cause mortality with higher intakes of red meat (Etemadi et al., 2017). In the review by Barnard et al. (2015), they showed that the prescription of vegetarian diets can be used as a prevention and management strategy for obesity and overweight, as it has the potential to reduce body weight. Ferdowsian & Barnard (2009) also found a positive effect of 4 different types of vegetarian diets (from vegan to lacto-ovo vegetarian) in the decrease of plasma cholesterol concentrations.

Reducing the total animal protein of the diet is a good approach when aiming at a reduction in the environmental impact of diets and promoting healthier diets. However, it should not be contemplated as the only action that can contribute to a more environmentally friendly and healthy diet. This 21st Century society has led to a much more industrialized food system with changes in human consumption patterns, such as the intake of highly processed foods, that not only increases the environmental impact of the diet, but also decreases its nutritional content (Hendrie, Baird, Ridoutt, Hadjikakou, & Noakes, 2016; Monteiro et al., 2017). For this reason, a more comprehensive and global approach is needed when discussing sustainable diets. In 2019, the EAT-Lancet Commission on healthy diets from sustainable food systems, urged for the "Great Food Transformation of the 21st century". For this transformation to happen they propose five strategies: 1) International and national commitment to shift to healthier diets; 2) Re-orient agricultural priorities; 3) Intensify food production sustainably to increase high quality output; 4) Coordinated governance of land and oceans; 5) At least halve food losses (Willett et al., 2019). While the pathways from theory to practice are still on the way, there is a common understanding that a change is needed, from production to consumption, for healthier and sustainable diets around the globe.

1.3 Incorporating sustainability into nutrition guidelines

Nutrition sciences have been focused on the specific composition of nutrients in food, their interactions and impact on health, with the aim to ensure the best dietary recommendations for the population. It is has not been until recently that studies have begun to integrate the impact of these recommendations on the environment, thus, neglecting the potential for health and sustainability integration. In an attempt to incorporate these concepts in policy, local and global actions, the FAO developed the sustainable diets and biodiversity report (FAO, 2010). The definition of sustainable diets

FIGURE 1.2

The key components, determinants, factors, and processes of a sustainable diet. Obtained from Johnston et al. (2014).

in this report emphasizes the multi-disciplinary dimension that nutrition has to take in the future to embrace sustainable principles: "Sustainable diets are diets with low environmental impacts that contribute to food and nutrition security and to healthy lives for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, are nutritionally adequate, safe and healthy, and optimize natural and human resources" (FAO, 2010).

Johnston et al. (2014) further developed this model in an attempt to better define sustainable diets that include the six key components of sustainable diets described by the FAO 2010 report, with an extended description of each component. This model shows the interaction of factors and processes and creates a framework of sustainability that may be integrated into nutrition and dietary recommendations (figure 1.2). It underlines the complexity of defining sustainable diets and the multi-dimensional and trans-disciplinary approach that is needed to put dietary changes into sustainability practices. Hence, studies have analyzed the impact of food choices on the environment as well as health but very few national health organizations have incorporated these into their National Dietary Guidelines (FAO, 2016b).

National Dietary Guidelines are generally part of national food policy and provide a clear and appropriate recommendation of eating patterns to maintain good nutritional health to ensure adequate development of the country's population. National Dietary Guidelines are often composed by nutrient-based dietary guidelines (NBDG), food-based dietary guidelines (FBDG) and extra supporting materials as for example food based visual tools, such as plates or pyramids. The NBDG are related to the Daily Reference Values (DRV), which correspond to minimum and maximum nutrient intake for a healthy diet for the national population. Often, these recommendations are adapted for different age groups or stages of life (children, pregnant woman or elderly). In some cases, there are no specific nutrient recommendations for specific populations, especially for micronutrients, such as in the case of athletes. The NBDG are often converted into FBDG, which give extra information regarding portion size and consumption frequencies of different food groups and are generally easy to understand and put into practice. In many countries food-based visual tools have also been developed to help the consumer translate theory into practice in an easy way and include cultural, ethical and social considerations which makes them more acceptable (Bach-Faig et al., 2011; Fogelholm, 2016). Pyramids and plates are common ways to visually represent FBDG (Bach-Faig et al., 2011; USDA, 2015), but different visual food guides are also used, such as the traditional round house in Benin, the Japanese spinning top or the Honduras pot (FAO, 2016b). The plate model, is a widely used visual nutrition education tool in many countries and can include the country's traditional food, combination of food and specific recommendations (Forman, Colby, Gellar, Kavanagh, & Spence, 2015; Public Health England, Welsh Government, Scotland, & Food Standards Agency in Northen Ireland, 2016; Skerrett, 2011). Some food companies have also developed the plate model as an educational tool as it is easy to use and comprehend (www.nutriplatonestle.es). This model is used in individual nutrition education, group sessions, and public nutrition educational settings. While different countries around the world have their National Dietary Guidelines and specific food-based visual tools, very few of these guidelines include sustainability principles in their recommendations. Acknowledging that the agri-food system contributes to approximately 30% of GhGe, it is necessary to consider its inclusion in the National Dietary Guidelines.

A recent report by the FAO (2016b) analyzed 83 countries' National Dietary Guidelines from around the globe to evaluate which country includes sustainability concepts and how. Surprisingly, only four countries have included sustainability in their dietary guidelines. These countries are Qatar, Brazil, Sweden and Germany. In the paper Plates, Pyramids and Planet (2016), quasi-official guidelines is defined as "an integrated advice, produced by institutions that are recognized or accredited by Government but that do not sit within a ministerial department and whose recommendations do not constitute official policy". An example of a quasi-official sustainability guideline is the Nordic nutrition recommendations from the Nordic Council of Ministers an official inter-governmental body for co-operation in the Nordic Region." The UK, France, Netherlands and Estonia have incorporated quasi-official sustainability guidelines. Thus, despite the growing evidence base that sustainability and diet are connected, government action is lagging behind. One important step that governments can take to signal their commitment to a more sustainable and healthy future, is to develop and disseminate FBDG that embed health and sustainability objectives. The report identifies seven main key sections which are commonly used to incorporate sustainability: 1) fruit and vegetables; 2) meat; 3) dairy; 4) fish; 5) fat and oil; 6) processed food; 7) behavioral advice. Other recurrent sustainability topics are also frequently, as for example food waste and packaging. Following the literature stated before, the FAO report positions areas that need to be taken into account when considering a reduction in environmental impact from a dietary change starting with nutrition education actions, like limiting meat consumption, lead by each country's National Dietary Guidelines and an increase in plant based foods. Moreover, some of these guidelines also promote traditional, local and seasonal food intake and a reduction of processed foods (Monteiro et al., 2015). Some of these recommendations include guidelines on how to overcome barriers when putting the guidelines into practice (FAO, 2016b; Seed, 2017). In contrast, other countries, including the US, have not included sustainability guidelines into their newest National Dietary Guidelines, even if it was recommended by the Dietary Guidelines Advisory Committee (Nelson, Hamm, Hu, Abrams, & Griffin, 2016; USDA & US HHS, 2015). However, since the release of the FAO report and the increasingly growing interest in this topic, different countries are reviewing their National Dietary Guidelines and beginning to incorporate sustainability concepts (Dernini et al., 2017; Monteiro et al., 2015).

Protein intake, and especially animal protein, is one of the hotspots when talking about sustainability and food, as animal protein, and especially red meat and dairy have a high impact on the environment (Sabaté et al., 2014). The protein recommended Daily Allowance (RDA) for the general population is 0.8g/kg Body Mass (BM)/day. However, some groups might have increased needs as for example athletes or the elderly. In older adults, protein recommendations are higher to prevent sarcopenia (Paddon-Jones et al., 2015), while in athletes, protein recommendations are almost twice as high compared with the RDA, to promote muscle growth and recovery (Thomas, Erdman, & Burke, 2016; Wolfe, 2012). Some authors have also recommended high protein diets for weight loss strategies (Te Morenga & Mann, 2012) .As a consequence, the quality and type of protein should also be considered when giving nutrition recommendations (Stehfest et al., 2009). In the past years, some attention has been drawn to the considerations of the environmental impact of protein on the diet (Kårlund et al., 2019; Lynch et al., 2018). The research in this field is very limited and the majority of the protein recommendations for these populations do not integrate sustainability guidelines into their specific dietary recommendations. Considering the high impact of animal protein on the environment as discussed earlier, the inclusion of sustainable guidelines is needed, especially when recommending higher daily protein intakes in these populations.

Regarding sport nutrition recommendations for protein, Phillips & Van Loon (2011) provide some guidance for what the protein intake for the athletic population should be to optimize protein synthesis and training adaptation. In this review, Phillips & Van Loon (2011) evaluated three different levels of protein intake and their effect on protein balance: low (0.86 g/kg BM/day), medium (1.4 g/kg BM/day) and high (2.4 g/kg BM/day). From their analysis, 0.86 g/kg BM/day was not sufficient to allow maximal rates of protein synthesis in the athlete population, showing that protein intakes for athletes have to be higher than the RDA. For that reason this low protein category is not considered adequate for the athletes to promote muscle adaptation. In the review, these authors recommend a minimum protein intake of 1.3 g/kg BM/day for athletes with an increased need during times of weight loss, with a recommended protein intake of 1.8 g/kg BM/day, to prevent lean mass loss in athletes. Other studies support these findings, where an increase in protein intake is needed to prevent lean mass loss in periods of energy restriction where the goal is fat loss in athletes (Mettler, Mitchell, & Tipton, 2010). Thomas et al. (2016) also considered a recommended intake of protein for athletes and active individuals of 1.2 - 2g/kg BM/day, with 1.6g/kg BM/Day being a general recommendation for protein intake for this population.

While the quantity of protein is important, the quality is also critical, as it helps to optimize protein synthesis and muscle recovery (Moore et al., 2015; Phillips, Tang, & Moore, 2009). Regarding the quality of protein, the majority of studies in sport nutrition, consider meat and dairy as a complete protein and optimal for recovery, especially post-exercise (Burd, Gorissen, van Vliet, Snijders, & van

Loon, 2015; Kanda et al., 2016). Moreover, active individuals and athletes often use protein supplements aiming to enhance and optimize muscle recovery. Only few studies have evaluated the effects of plant protein sources and their effects on net protein balance post-exercise (Babault et al., 2015; Phillips et al., 2009). Due to this gap in the literature, there is a persistent focus on animal sources, especially milk proteins, to promote muscle protein synthesis. In addition, this lack of data is often misinterpreted by the lay public, believing that only animal-based protein will lead to muscle protein synthesis and recovery. Thus, unless future research includes alternative sources of protein with a lower environmental impact (including insects), athletes and their support staff will likely continue to resist including a variety of protein sources.

While common belief and practice in active and athletic populations continues to favor higher protein intakes for a variety of reasons, the recent focus on the gut microbiome and its impact on health and performance might change this. A healthy gut has previously been associated with athletic performance (Clark & Mach, 2016). The gut microbiota contribute to amino acid absorption and synthesis as well as in skeletal muscle metabolism (Grosicki, Fielding, & Lustgarten, 2018). However, more does not seem to be better. A recent paper by Kårlund et al. (2019) questions and cautions trends in high protein intakes and the ingestion of protein supplements as they may results in higher fermentation levels in the gastrointestinal tract, promoting inflammation, damage, and dysfunction (Kårlund et al., 2019). Thus, high protein diets of athletes (Della Guardia, Cavallaro, & Cena, 2015; Spendlove et al., 2015) and similar diets, also described by Garnett (2016) as the "diets of the healthy and wealthy" begin to raise a level of urgency for more research and education. During the last years, there has been an increasing interest in this topic in sport nutrition as recently published by Lynch et al. (2018) and Meyer & Reguant-Closa (2017).

While decreasing animal protein is one of the main actions to consider to lower the environmental impact of food, other actions are also important. The International Olympic Committee (IOC) has developed the Sustainability and Legacy Commission, which aims at increasing awareness and inclusion of sustainability considering the Olympic Movement. Following this goal during 1999, the IOC developed the Olympic Movement's Agenda 21: Sport for sustainable development with the objective to encourage members of the movement to play an active part in the sustainable development of the planet (International Olympic Committee, 1999). This document included sections for health and access to healthy food, but did not specify concepts related to sustainable diets. During the London 2012 and Rio 2016 Olympic Games, sustainability initiatives pertaining to food procurement and diet design were instated for the first time. The London Organizing Committee for the Olympic Games published a food vision with sustainability guidelines during the games. Conversely, Pelly, Meyer, Pearce, Burkhart, & Burke (2014), evaluated the food provision and nutrition support at the London 2012 Olympic Games by the perspective of sport dietitians and found that very few were aware of the inclusion of sustainability. Moreover, the majority of the participants believed that the Olympic and Paralympic food service organization should follow sustainability guidelines. For the 2016 Rio Olympic Games, a similar document was created by different institutes and societies that work on sustainable food systems, which included the diagnostic analysis of the supply of healthy and sustainable food for the 2016 Rio Olympic and Paralympic games (Rio Food Vision, 2014). This document was designed first, to serve as a guide for sport organization on how and from where to source their food and second, to serve as inspiration for other organizations and governmental bodies to adopt such guidelines. Unfortunately, a recent paper by Pelly & Parker Simmons, (2019) was published on the food provision at the Rio 2016 Olympic Games but did not include any reference to sustainability guidelines. This fact highlights the big opportunity for change as well as the need for education in this setting for both the health and nutrition professional and the athlete.

Dietary guidelines and nutrition education tools provide general recommendations that dietitians and health professionals use to help the population eat healthier. As mentioned previously, very few of these guidelines and nutrition tools include sustainability and even less integrate the environmental impact of food choices in a quantifiable manner, such that healthy and sustainable dietary guidelines could be developed side by side, not only improving nutritional quality of the diet but also promoting environmental sustainability. Thus, there is a great need for the integration of sustainability considerations in dietary guidelines and effective educational tools, specifically for active and athletic individuals to promote "WIN-WIN-WIN" solutions for healthy eating, athletic performance, and sustainable development.

1.4 Measuring the environmental impact of diets through Life Cycle Assessment

As stated in the early sections of this chapter one, agricultural production and food consumption have a significant impact on the environment. However, due to the complex globalized food system, the quantification is difficult. Life Cycle Assessment (LCA), is the most used and accepted methodology to assess sustainability impacts of products. It is a standardized methodology regulated by the International Organization for Standarization (ISO). 14040:2006 and 14044:2006 standards, and is defined as "the compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system through its life cycle" (ISO, 14040:2006 and 14044:2006). The purpose of LCA is to identify resource use and pollution related to a product or a service through its lifecycle. While LCA can be applied to any industrial sector, it poses specific challenges, when it is applied in the agri-food sector (Nemecek, Jungbluth, Canals, & Schenck, 2016).

Life Cycle Assessment is used to assess the environmental impacts of a product or service. During the last years, its scope has been extended to cover other dimensions of sustainability in a Life Cycle Sustainability Assessment (LCSA), but this methodology is still at a developmental stage of research (Zamagni, Pesonen, & Swarr, 2013). Nevertheless, many studies include economical aspects in combination with LCA (Auestad & Fulgoni, 2015; Saxe & Jensen, 2014) and also social aspects, such as animal welfare and biodiversity, are beginning to be recognized as important for comprehensive LCA (Nemecek et al., 2016).

Traditionally, LCA was centered on one food or food group (example: meat), but – as LCA data on food become more readily available – recent research is also evaluating the environmental impacts on the diet level (Scarborough et al., 2014). As humans we do not eat single products but a portion, or edible portions of a combination of foods, raising the need for quantification of the whole diet using LCA.

Moreover, when talking about LCA and food, the trend in the past years has been on identifying so called "hotspots", where a change in food consumption and/or production, would have a significant impact on climate change. Thus, a critical interpretation of LCA could help to select hotspots that will cause a positive change in the system. Moreover, when talking about diets, we cannot forget the nutritional quantity and quality of the diet for an optimal health status. As a consequence, there has been an increase in studies focusing on both LCA and nutrition to address both sustainable production and healthy consumption (Batlle-Bayer, Bala, García-Herrero, et al., 2019; Castañé & Antón, 2018; Saarinen, Fogelholm, Tahvonen, & Kurppa, 2017; U. G. Sonesson et al., 2016).

To perform an LCA analysis, the ISO 14040/44:2006 guideline defines 4 main phases (see also figure 1.3):

1. **Goal and scope definition.** This phase, defines the aim of the study, the system boundaries, and the functional unit (FU) or units. It also includes the methodological decision regarding the selection of impact categories and the methods to calculate impact indicators. All methodological decisions must be consistent with the goal of the study.

2. **The Life Cycle Inventory (LCI).** At this point, all data inputs and outputs of the system studied will be collected. A flow chart can be created that reflects the measurements, calculations and modeling of the emissions of the different phases of the life cycle. Background data are taken from LCI databases. Whenever different databases are used, their consistency must be checked and – if necessary – adaptations need to be performed.

3. **The life cycle impact assessment (LCIA).** In this phase the environmental impact indicators are calculated from the LCI results. In the classification step, the emissions or resources relevant for an impact category are selected. In the characterization step, the contribution of each emission to the impact category is quantified by means of characterization factors. Impact indicators operating at this level are the midpoint indicators, they do not give information about the change or damage in the target environmental system but represent potential impacts. In the next step, normalization and aggregation of the midpoint impacts can also be done. Then the impact assessment is based on endpoint indicators which show the change in the target environmental system.

4. **The interpretation phase.** This final step will summarize the results obtained by LCI and LCIA and discuss them for further recommendations and applications. To interpret correctly the impacts of a system, an assessment and interpretation of midpoints and endpoints is necessary.

The LCA of a food product encompasses agricultural production including all upstream stages up to the farm gate and considering all processes of transport, storage, processing, cooking and waste (Notarnicola, Tassielli, Renzulli, & Lo Giudice, 2015). The system boundary of the system analyzed is defined as the limits of processes that are included when analyzing a product and will determine which stages of the life cycle is included. A typical system boundary scenario in LCA is to analyze all the processes involved on the production of a food product up to the farm gate which will include the machinery, pesticides, herbicides or buildings of the production of a crop but none of the processing after that. While traditionally LCA studies on food production have only considered the impacts up to farm gate, more recent studies include other processes of the production chain, such as storage, transport, packaging, processing, cooking and waste (Nemecek et al., 2016; Reynolds, 2017; Sjörs et al., 2016). While it is true that the agricultural stage of production has the biggest impact on the total environmental impact of food, when considering entire diets, other stages also need to be considered (Batlle-Bayer, Bala, García-Herrero, et al., 2019).

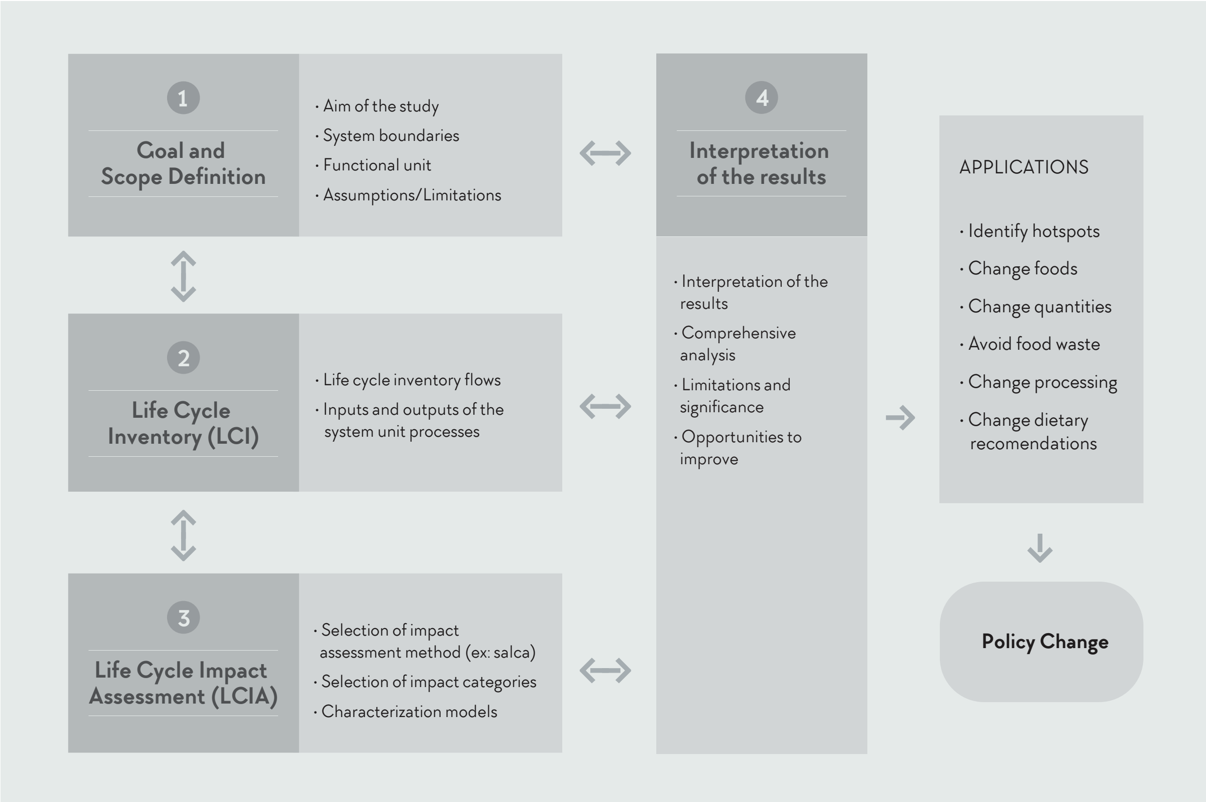

FIGURE 1.3

Life Cycle Assessment phases. Adapted from ISO 14040:2006

Moreover, food waste, also has an impact on the global GhGe and 25-30% of total food produced is wasted (IPCC, 2019). Waste is further distinguished into avoidable (such as vegetables not harvested due to lack of demand and/or labor, or consumable food thrown away) and unavoidable waste, such as nut shells or orange skins. Food waste can occur in every stage of the production from agriculture to household. For this reason waste should also be considered (Gunders, 2012; Gustavsson, Cederberg, & Sonesson, 2011; Jörissen, Priefer, & Bräutigam, 2015).

Agricultural systems need to be optimized to feed the growing population in the world and a consequential increase in food production demand is required while reducing food waste. However, agricultural production and the food processing industry generate significant environmental impacts, which contribute to global warming, acidification, eutrophication and ecotoxicity among others (Notarnicola, Tassielli, Alexander, Castellani, & Sala, 2017). The impact categories and impact indicators selected should represent all relevant environmental issues. Factors determining the environmental impact of the food include, among others, the type of food (Tilman & Clark, 2014), the origin of the food (Vermeulen et al., 2012) the food production system, such as organic versus conventional (Theurl, Haberl, Erb, & Lindenthal, 2014), the processing of the food, the transport, storage and cooking, each stage contributing to the environmental impact of the product. In addition, it is very important to choose a representative indicator that will describe adequately the reality of the system and is consistent with the goal. Different methods can be used to measure the environmental impact from single scores to complex indicators (Nemecek et al., 2016). Many studies use footprint methodologies focusing on a single indicator only, such as GhGe, due to its feasibility and data availability. However, the environmental impact of food extends beyond GhGe and authors are encouraged to discuss other environmental impacts when considering the interpretation of the environmental impacts of entire diets (Nemecek et al., 2016). Studies are also starting to include indicators that measure land use, resource depletion, biodiversity, eco- and human toxicity, soil quality, eutrophication and acidification to have a wider picture of the impact of diets on the environment and also on human health. In fact, scientists are beginning to quantify both environmental impacts of diets and the diets' links to health and disease in an attempt to capture both topics when recommending sustainable and healthy diets for the population (Stylianou et al., 2016; Willett et al., 2019).

One of the most delicate and time-consuming phases of an LCA is the creation of an Inventory of LCA (LCI), where all the flows of inputs and outputs of the system are shown. This include inputs of water, energy and primary materials and the emissions into the atmosphere, the soil, and the water. This flow system will be represented in a flow chart to give a clear image of the limits of the system. Different databases are available (public and private) such as ecoinvent, Agri-BALYSE, World Food LCA database or the NREL (Notarnicola et al., 2016) to build the inventory for the LCA analysis. To measure the environmental impact of the product, all flows of the system of each inventory will be transformed according to the selected methodology in potential impacts that will be translated into the characterization of the impacts or impact categories (ecotoxicity, eutrophication, acidification, GWP, etc.). In case of meals and diets, this is very challenging due to the multitude of ingredients, origins, production and processing methods. Due to the complexity of LCA, results vary greatly depending on the chosen methodology. For a detailed update on LCA and food see Nemecek et al. (2016).

There are different environmental indicators that are widely used:

1. **Global Warming Potential (GWP).** This is a natural process in which GhGe absorb the energy and slowly release this radiation, causing the atmosphere to warm. The main GhG contributing to GWP from food systems include CO_2, methane (CH_4), Nitric Oxide (N_2O). For industrial processes, hydrocarbons can also contribute. The GhG are transformed into Co_2 equivalents to sum up their contribution to global warming. Human activities such as the use of fossil fuels, ruminant intensive production or organic matter decomposition, increase GhGe and their effect leads to climate change. The indicator of GWP over 100 years is considered as a complete indicator since it contains characterization factors for all important GhGe and it has become an established and standard indicator for climate impact (IPCC, 2013).

2. **Eutrophication.** Plant growth requires a range of nutrients to ensure productivity such as nitrogen and phosphorus. However, if there is an increase of these nutrients emitted to air and water, for example due to the application of fertilizers, this can produce undesirable effects into the

system. It can lead to strong algae growth and the decomposition of organic matter from algae can lead to an oxygen deficiency in water bodies. Acidification is often highly correlated to eutrophication, and for this reason it is only necessary to include one of these two indicators when evaluating the comprehensive sustainability assessment of a system (Hauschil M.Z & Pooting J, 2005; Roesch et al., 2017).

3. **Exergy.** Exergy represents the amount of "useful work" that can be performed with a resource. The indicator can be used to represent all renewable and non-renewable resources that are employed when making a product or, in this case, when producing food. Exergy covers the use of land, water, energy carriers (renewable and non-renewable), minerals, metals, as well as biomass extracted from natural systems (e.g. during deforestation) (Bösch, Hellweg, Huijbregts, & Frischknecht, 2007; Dewulf et al., 2007).

4. **Ecotoxicity.** This impact category determines the toxicity for different species in different compartments. The toxic effect of a substance depends on: 1) its environmental chemistry (exposure) and 2) the effects of the substance on the organisms that come into contact with it. This environmental indicator takes into account the potential impact on human toxicity and the toxicity of ecosystems. The impact is evaluated depending on the quantity of product on the final destiny, the exposition to the substance and the effect on human health or the ecosystem. When referred to the food production, toxicity is generally affected by the use of pesticides or heavy metals mainly included in the phosphorous fertilizers (Fantke & Jolliet, 2016; Guinée et al., 2001; Hayer et al., 2010).

While the selection of the environmental impact categories is critical, the selection of the functional unit (FU) is also an important factor to consider in LCA, as a common FU, as well as using a consistent methodological process. Choosing the FU is a critical decision in LCA as it affects directly the outcome and interpretation of the study (Masset et al., 2014; Saarinen et al., 2017; Van Kernebeek, Oosting, Feskens, Gerber, & De Boer, 2014). The choice of FU is largely dependent on the goal of the study (Nemecek et al., 2016). Comparing data using different FUs might also provide insights by food groups and their various functions in the human diet (U. Sonesson, Davis, Hallström, & Woodhouse, 2019)

In agricultural research, environmental impacts are typically expressed per unit of product by weight (kg), volume (L) or per area used (acre or hectare) in the production system. When integrating LCA up to the level of consumption, such as in the case of entire diets, other FUs have to be considered. Heller, Keoleian & Willett (2013) recommend trans-disciplinary work between environmental and nutritional sciences when measuring diets in order to link environmental and health objectives. In general, nutrient dense foods or diets are those that provide higher nutrient content than calories (Drewnowski, 2005). To measure the nutrient quality of foods and diets, different indices are used (Waijers, Feskens, & Ocké, 2007) but the most common ones are the Healthy Eating Index (HEI) 2010 (HEI-2010) or various Nutrient Rich Food indices (NRF) (Drewnowski & Fulgoni, 2011; Fulgoni, Keast, & Drewnowski, 2009). The Healthy Eating Index is a measure of diet quality in terms of conformance to US dietary guidelines and is an accepted measure of diet quality. Nutrient Rich Food indices are a formal scoring system, ranking food on the basis of their nutrient content with nutrients to limit, encourage or a combination of both (Drewnowski & Fulgoni, 2011; Fulgoni et al., 2009). Fulgoni et al. (2009) validated the diet scores of different NRF indices (LIM, NRF6.3, NRF9.3, NRF11.3, NRF15.3) against HEI and found a significant relationship between the HEI and nutrient combinations of the different NRF. The highest correlation was found with the NRF9.3, using 9 positive and 3 negative nutrients (Fulgoni et al., 2009).

Several recent studies have linked LCA analysis and these nutrient scores, with the aim to better integrate diet quality with sustainability. Some studies have even attempted to use indices for nutrition as FU in LCA to better account for nutrient quality of food, diet or a meal. Different FUs have been used, including calories, grams, portion size and nutrient quality indices. Still, there is no consensus about which of these is the best to use and clearly the choice depends on the study's purpose (Nemecek et al., 2016). Masset et al. (2014), analyzed 363 of the most commonly consumed foods in the French diet from an environmental, nutritional and price perspective. Environmental sustainability was evaluated by three environmental impact indicators: GhGe, air acidification and freshwater eutrophication. Nutritional quality was evaluated by two scores: the nutrient adequacy of individual foods (SAIN) and the score of disqualifying nutrients (LIM). The price of the foods evaluated the affordability dimension. They found that all foods with higher environmental impact had lower nutritional quality and higher price. Similar results were found by Drewnowski et al. (2015), with higher GhGe values associated with higher nutrient density by 100g but decreasing these values when translating to 100kcal. Drewnowski & Fulgoni (2014) evaluated the nutrient density of participants in the 1999-2002 NHANES survey, in which the low energy food group (as for example, vegetables) benefit the most from a 100 kcal approach while the high energy foods (as nuts and seeds), benefit the most from a 100g approach. Including protein quality and quantity in the FU has also been considered when examining the environmental impact of diets (Berardy, Johnston, Plukis, Vizcaino, & Wharton, 2019; U. Sonesson, Davis, Flysjö, Gustavsson, & Witthöft, 2017). As animal protein has a higher environmental impact but generally, a better amino acid profile, this FU might be a good option when examining different protein sources. However, there is still a larger room for improvements and more research in this area. In addition, we have to consider that a good diet has to fulfill the adequate requirements of energy and all nutrients and not only proteins. Batlle-Bayer, et al. (2019) proposed a novel FU that accounts for the energy intake as well as the nutrient quality of the diet. This approach could also be interesting when considering the different energy and nutrient requirements of different populations (athletes, active population, adolescents, etc.).

In summary, FU should depend on the intended application and when considering LCA of diets, some FU are used as 100kcal, 100g, edible protein, or density nutrient indexes. However, in some cases, specific FU could be developed to fulfill the aim of the system. For example, when discussing athletes, an energy expenditure FU could be considered relating the energy as FU that will fulfill energy expenditure for specific training loads for athletes and active populations. However, creating a specific FU, could be considered problematic when comparing different study results. In conclusion, there seems to be a consensus about the fact that other FU different from Kcal or Kg are needed when evaluating food and diets, which include nutritional quality.

All things considered, while measuring the environmental impact of diets is complex, there is a need of integration of nutrition recommendations. Registered dietitians and nutrition professionals in general are often uninformed and uneducated on the environmental impacts of foods. While more professional institutions, associations and universities are beginning to include environmental impacts and an introduction into LCA methods in their curricula, there is great need for improvement and trans-disciplinary collaboration. While the latter is not always easy, considering nutrition and environmental sustainability together is necessary to ensure production and consumption patterns are being addressed side-by-side in future years.

The goal of this dissertation is to integrate sustainability into sport nutrition and specifically the Athlete's Plate nutrition education tool. First, a review was carried out on the current state of integrating sustainability into sport nutrition. Second, a validation of the Athlete's Plate nutrition education tool was developed to ensure the plates meet current sport nutrition recommendations and athletes understand how to use them. Third, an LCA of the plates from the Athlete's Plate validation was performed. Finally, suggestions are provided on how to integrate environmental sustainability into the Athlete's Plate nutrition education tool and begin the design process of a new "sustainable" Athlete's Plate.

1.5 References

Aleksandrowicz, L., Green, R., Joy, E. J. M., Smith, P., & Haines, A. (2016). The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: A systematic review. *PLoS ONE*, *11*(11), 1–16. https://doi.org/10.1371/journal.pone.0165797

Auestad, N., & Fulgoni, V. L. (2015). What current literature tells us about sustainable diets: emerging research linking dietary patterns, environmental sustainability, and economics. *Advances in Nutrition (Bethesda, Md.)*, *6*(1), 19–36. https://doi.org/10.3945/an.114.005694

Babault, N., Païzis, C., Deley, G., Guérin-Deremaux, L., Saniez, M.-H., Lefranc-Millot, C., & Allaert, F. A. (2015). Pea proteins oral supplementation promotes muscle thickness gains during resistance training: a double-blind, randomized, Placebo-controlled clinical trial vs. Whey protein. *Journal of the International Society of Sports Nutrition*, *12*(1), 3. https://doi.org/10.1186/s12970-014-0064-5

Bach-Faig, A., Berry, E. M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., … Serra-Majem, L. (2011). Mediterranean diet pyramid today. Science and cultural updates. *Public Health Nutrition*, *14*(12A), 2274–2284. https://doi.org/10.1017/S1368980011002515

Barnard, N. D., Levin, S. M., & Yokoyama, Y. (2015). A systematic review and meta-analysis of changes in body weight in clinical trials of vegetarian diets. *Journal of the Academy of Nutrition and Dietetics*, *115*(6), 954–969. https://doi.org/10.1016/j.jand.2014.11.016

Batlle-Bayer, L., Bala, A., García-Herrero, I., Lemaire, E., Song, G., Aldaco, R., & Fullana-i-Palmer, P. (2019). The Spanish Dietary Guidelines: A potential tool to reduce greenhouse gas emissions of current dietary patterns. *Journal of Cleaner Production*, *213*, 588–598. https://doi.org/10.1016/j.jclepro.2018.12.215

Batlle-Bayer, L., Bala, A., Lemaire, E., Albertí, J., García-Herrero, I., Aldaco, R., & Fullana-i-Palmer, P. (2019). An energy and nutrient corrected functional unit to compare LCAs of diets. *Science of the Total Environment*, *671*, 175–179. https://doi.org/10.1016/j.scitotenv.2019.03.332

Bentley, J. (2017). USDA ERS - U.S. Per Capita Availability of Red Meat, Poultry, and Fish Lowest Since 1983. Retrieved October 16, 2019, from https://www.ers.usda.gov/amber-waves/2017/januaryfebruary/us-per-capita-availability-of-red-meat-poultry-and-fish-lowest-since-1983/

Berardy, A., Johnston, C. S., Plukis, A., Vizcaino, M., & Wharton, C. (2019). Integrating protein quality and quantity with environmental impacts in life cycle assessment. *Sustainability, 11, 2747*. https://doi.org/10.3390/su11102747

Bösch, M. E., Hellweg, S., Huijbregts, M. A. J., & Frischknecht, R. (2007). Applying cumulative exergy demand (CExD) indicators to the ecoinvent database. *The International Journal of Life Cycle Assessment*, *12*(3), 181–190. https://doi.org/10.1065/lca2006.11.282

Bouvard, V., Loomis, D., Guyton, K. Z., Grosse, Y., Ghissassi, F. El, Benbrahim-Tallaa, L., … Bandaletova, T. (2015). Carcinogenicity of consumption of red and processed meat. *The Lancet Oncology*, *16*(16), 1599–1600. https://doi.org/10.1016/S1470-2045(15)00444-1

Brundtland, G. (1987). Report of the World Commision on Environement and Development: Our Common Future. *Oxford Paperbacks*, 400. https://doi.org/10.2307/2621529

Burd, N. A., Gorissen, S. H., van Vliet, S., Snijders, T., & van Loon, L. J. (2015). Differences in postprandial protein handling after beef compared with milk ingestion during postexercise recovery: a randomized controlled trial. *American Journal of Clinical Nutrition*, *102*(4), 828–836. https://doi.org/10.3945/ajcn.114.103184

Castañé, S., & Antón, A. (2018). Assessment of the nutritional quality and environmental impact of two food diets: A Mediterranean and a vegan diet. *Journal of Cleaner Production*, *167*, 929–937. https://doi.org/10.1016/j.jclepro.2017.04.121

Clark, A., & Mach, N. (2016). Exercise-induced stress behavior, gut-microbiota-brain axis and diet: A systematic review for athletes. *Journal of the International Society of Sports Nutrition*, *13*(1), 1–21. https://doi.org/10.1186/s12970-016-0155-6

Clonan, A., Holdsworth, M., Swift, J. a, Leibovici, D., & Wilson, P. (2012). The dilemma of healthy eating and environmental sustainability: the case of fish. *Public Health Nutrition*, *15*(02), 277–284. https://doi.org/10.1017/S1368980011000930

de Lorgeril, M., & Salen, P. (2015). *The Mediterranean Diet to Prevent Type 2 Diabetes and its Complications*. *The Mediterranean Diet*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-407849-9.00031-2

Delgado, L. C. (2003). Animal source foods to improve micronutrient nutrition and human function in developing countries. *The Journal of Nutrition*, *133*(5), 3875S-4061S. https://doi.org/0022-3166/03

Della Guardia, L., Cavallaro, M., & Cena, H. (2015). The risks of self-made diets: the case of an amateur bodybuilder. *Journal of the International Society of Sports Nutrition*, *12*(1), 16. https://doi.org/10.1186/s12970-015-0077-8

Demetriou, C. A., Hadjisavvas, A., Loizidou, M. A., Vineis, P., & Kyriacou, K. (2015). *The Mediterranean Diet and Breast Cancer Risk*. *The Mediterranean Diet*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-407849-9.00037-3

Dernini, S., & Berry, E. M. (2015). Mediterranean Diet: From a Healthy Diet to a Sustainable Dietary Pattern. *Frontiers in Nutrition*, *2*(May), 15. https://doi.org/10.3389/fnut.2015.00015

Dernini, S., Berry, E. M., Vecchia, C. La, & Capone, R. (2017). Review Article Med Diet 4. 0 : the Mediterranean diet with four sustainable bene fi ts Public Health Nutrition, 6–14. https://doi.org/10.1017/S1368980016003177

Dewulf, J., Bösch, M. E., Meester, B. De, Vorst, G. Van der, Langenhove, H. Van, Hellweg, S., & Huijbregts, M. A. J. (2007). Cumulative Exergy Extraction from the Natural Environment (CEENE): a comprehensive Life Cycle Impact Assessment method for resource accounting. *Environmental Science & Technology*, *41*(24), 8477–8483. https://doi.org/10.1021/es0711415

Djuric, Z. (2014). *Reducing Proinflammatory States with the Mediterranean Diet: Possible Mechanism for Cancer Prevention*. *The Mediterranean Diet: An Evidence-Based Approach*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-407849-9.00041-5

Drewnowski, A. (2005). Concept of a nutritious food: Toward a nutrient density score. *American Journal of Clinical Nutrition*, *82*(4), 721–732.

Drewnowski, A., & Fulgoni, V. (2011). Comparing the Nutrient Rich Foods Index with "Go," "Slow," and "Whoa" Foods. *Journal of the American Dietetic Association*, *111*(2), 280–284. https://doi.org/10.1016/j.jada.2010.10.045

Drewnowski, A., & Fulgoni, V. L. (2014). Nutrient density: Principles and evaluation tools. *American Journal of Clinical Nutrition*, *99*(5), 1–6. https://doi.org/10.3945/ajcn.113.073395

Drewnowski, A., Rehm, C. D., Martin, A., Verger, E. O., Voinnesson, M., & Imbert, P. (2015). Energy and nutrient density of foods in relation to their carbon footprint. *American Journal of Clinical Nutrition*, *101*(1), 184–191. https://doi.org/10.3945/ajcn.114.092486

Etemadi, A., Sinha, R., Ward, M. H., Graubard, B. I., Inoue-choi, M., Dawsey, S. M., & Abnet, C. C. (2017). Mortality from different causes associated with meat, heme iron, nitrates, and nitrites in the NIH-AARP Diet and Health Study : population based cohort study. https://doi.org/10.1136/bmj.j1957

Fantke, P., & Jolliet, O. (2016). Life cycle human health impacts of 875 pesticides, *21*(5), 722–733. https://doi.org/10.1007/s11367-015-0910-y

FAO. (2010). *Sustainable diets and biodiversity*. Rome: Food and Agriculture Organisation of the United Nations (FAO). https://doi.org/10.1017/S002081830000607X

FAO. (2012). *The State of World Fisheries and Aquaculture 2012*. *Sofia*. https://doi.org/10.5860/CHOICE.50-5350

FAO. (2013). *The state of food and agriculture, 2013. Food and Agriculture Oraganization of the United Nations (FAO)*. ROME: Food and Agriculture Organisation of the United Nations (FAO). https://doi.org/ISBN: 978-92-5-107671-2 I

FAO. (2014). *Sustainability Assessment of Food and Agriculture Systems (SAFA) Guidelines* (3.0). ROME: Food and Agriculture Organisation of the United Nations (FAO).

FAO. (2016a). Food and Agriculture Organization of the United Nations (2016) UN General Assembly proclaims Decade of Action on Nutrition. Retrieved March 1, 2017, from http://www.fao.org/news/story/en/item/ 408970/icode/ (accessed March 2017).e

FAO. (2016b). *Plates, pyramids, planets. Developments in national healthy and sustainable dietary guidelines: a state of play assessment*. Food and Agriculture Organisation of the United Nations (FAO) and the Food Climate Research Network at The University of Oxford (FCRN).

FAO, IFSAD, & WFP. (2014). *The State of Food Insecurity in the World 2014. Strengthening the enabling environment for food security and nutrition*. Rome: Food and Agriculture Organisation of the United Nations (FAO). Retrieved from ISBN 978-92-5-108542-4

Ferdowsian, H. R., & Barnard, N. D. (2009). Effects of plant-based diets on plasma lipids. *The American Journal of Cardiology*, *104*(7), 947–956. https://doi.org/10.1016/j.amjcard.2009.05.032

Fogelholm, M. (2016). Nutrition recommendations and science: next parallel steps. *Journal of the Science of Food and Agriculture*, *96*(4), 1059–1063. https://doi.org/10.1002/jsfa.7479

Forman, A., Colby, S. E., Gellar, L., Kavanagh, K., & Spence, M. (2015). My Painted Plate: Art Enhances Nutrition Education with Children. *Journal of Nutrition Education and Behavior*, *47*(4), S57. https://doi.org/10.1016/j.jneb.2015.04.152

Friel, S., Dangour, A. D., Garnett, T., Lock, K., Chalabi, Z., Roberts, I., … Haines, A. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. *The Lancet*, *374*(9706), 2016–2025. https://doi.org/10.1016/S0140-6736(09)61753-0

Fulgoni, V. L., Keast, D. R., & Drewnowski, A. (2009). Development and validation of the nutrient-rich foods index: a tool to measure nutritional quality of foods. *The Journal of Nutrition*, *139*(8), 1549–1554. https://doi.org/10.3945/jn.108.101360

Garnett, T. (2016). Plating up solutions, *353*(6305).

Gerbens-Leenes, P. W., Mekonnen, M. M., & Hoekstra, A. Y. (2013). The water footprint of poultry, pork and beef: A comparative study in different countries and production systems. *Water Resources and Industry*, *1–2*, 25–36. https://doi.org/10.1016/j.wri.2013.03.001

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., … Tempio, G. (2013). *Tackling Climate Change Through Livestock-A global assessment of emissions and mitigation opportunities*. *FAO, Rome*. Rome.

Grosicki, G. J., Fielding, R. A., & Lustgarten, M. S. (2018). Gut Microbiota Contribute to Age-Related Changes in Skeletal Muscle Size, Composition, and Function: Biological Basis for a Gut-Muscle Axis. *Calcified Tissue International*, *102*(4), 433–442. https://doi.org/10.1007/s00223-017-0345-5

Guinée, J., Gorrée, M., Heijungs, R., Huppes, G., Klejin, R., de Koning, A., … Weidema, B. (2001). *Life cycle assessment - An operational guide to the ISO standards.* Den Haag and Leiden, Netherlands.

Gunders, D. (2012). Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill. *NRDC Issue Paper*, (August), 1–26. https://doi.org/12-06-B

Gustavsson, J., Cederberg, C., & Sonesson, U. (2011). *Global food losses and food waste - Extent, causes and prevention*. *FAO*. Rome, Italy.

Hallström, E., Carlsson-Kanyama, A., & Börjesson, P. (2015). Environmental impact of dietary change: a systematic review. *Journal of Cleaner Production*, *91*, 1–11. https://doi.org/10.1016/j.jclepro.2014.12.008

Hancock, T. (1993). Health, human development and the community ecosystem: three ecological models. *Health Promotion International*, *8*(1), 41–47. https://doi.org/10.1093/heapro/8.1.41

Hauschil M.Z, & Pooting J. (2005). *Spatial differentiation in life cycle impact assessment. The EDIP 2003 methodology. The Danish Minsitry of the Environment, Environmental Protection Agency,.* Copenhagen. Retrieved from https://www2.mst.dk/udgiv/publications/2005/87-7614-579-4/pdf/87-7614-580-8.pdf

Hayer, F., Bockstaller, C., Gaillard, G., Mamy, L., Nemecek, T., & Strassemeyer, J. (2010). Multi-criteria comparison of eco-toxicity models focused on pesticides. *7th Int. Conf. on LCA in the Agri-Food Sector, Noranicola, B. (Eds). Bari, Italy*, 305–310.

Heller, M. C., Keoleian, G. A., & Willett, W. C. (2013). Toward a life cycle-based, diet-level framework for food environmental impact and nutritional quality assessment: A critical review. *Environmental Science and Technology*, *47*(22), 12632–12647. https://doi.org/10.1021/es4025113

Hendrie, G. A., Baird, D., Ridoutt, B., Hadjikakou, M., & Noakes, M. (2016). Discretionary Food Intake Inflates Dietary Greenhouse Gas Emissions in Australia. https://doi.org/10.3390/nu8110690

Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., & Mekonnen, M. M. (2011). *The Water Footprint Assessment Manual. London, UK: Earthscan*. https://doi.org/978-1-84971-279-8

International Olympic Committee. (1999). Olympic Movement ' S Agenda 21. *Environment*.

IPCC, Stocker, T.F. et al. (eds). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York. 1535.

IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson- Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

ISO 14040:2006. Environmental management - Life Cycle Assessment - Principles and Framework. 12020:2006 (2006).

Poore, J & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Johnston, J. L., Fanzo, J. C., & Bogil, B. (2014). Understanding Sustainable Diets : A Descriptive Analysis of the Determinants and Processes That In fl uence Diets and Their Impact on Health, Food. *Adv. Nutr*, (4), 418–429. https://doi.org/10.3945/an.113.005553.418

Jörissen, J., Priefer, C., & Bräutigam, K.-R. (2015). Food Waste Generation at Household Level: Results of a Survey among Employees of Two European Research Centers in Italy and Germany. *Sustainability*, *7*(3), 2695–2715. https://doi.org/10.3390/su7032695

Kanda, A., Nakayama, K., Sanbongi, C., Nagata, M., Ikegami, S., & Itoh, H. (2016). Effects of Whey, Caseinate, or Milk Protein Ingestion on Muscle Protein Synthesis after Exercise. *Nutrients*, *8*(6), 339. https://doi.org/10.3390/nu8060339

Kårlund, A., Gómez-Gallego, C., Turpeinen, A. M., Palo-Oja, O. M., El-Nezami, H., & Kolehmainen, M. (2019). Protein supplements and their relation with nutrition, microbiota composition and health: Is more protein always better for sportspeople? *Nutrients*, *11*(4), 1–19. https://doi.org/10.3390/nu11040829

Katz, D. L. (2016). The Mass of Humanity and the Weight of the World : Obesity and the Environment at a Confluence of Causes. *Current Obesity Reports*, 386–388. https://doi.org/10.1007/s13679-016-0236-5

Kjaer, L. L., Pagoropoulos, A., Schmidt, J. H., & McAloone, T. C. (2016). Challenges when evaluating Product/Service-Systems through Life Cycle Assessment. *Journal of Cleaner Production*, *120*, 95–104. https://doi.org/10.1016/j.jclepro.2016.01.048

Kjærgård, B., Land, B., & Pedersen, K. B. (2013). Health and sustainability. *Health Promotion International*, *29*(3), 558–568. https://doi.org/10.1093/heapro/das071

Kris-Etherton, P. M. (2002). Fish Consumption, Fish Oil, Omega-3 Fatty Acids, and Cardiovascular Disease. *Circulation*, *106*(21), 2747–2757. https://doi.org/10.1161/01.CIR.0000038493.65177.94

Lairon, D. (2014). *The Mediterranean Diet and Adiposity*. *The Mediterranean Diet: An Evidence-Based Approach*. Elsevier Inc. https://doi.org/10.1016/B978-0-12-407849-9.00028-2

Lewis, C. E., McTigue, K. M., Burke, L. E., Poirier, P., Eckel, R. H., Howard, B. V, … Pi-Sunyer, F. X. (2009). Mortality, health outcomes, and body mass index in the overweight range: a science advisory from the American Heart Association. *Circulation*, *119*(25), 3263–3271. https://doi.org/10.1161/CIRCULATIONAHA.109.192574

Lynch, H., Johnston, C., & Wharton, C. (2018). Plant-based diets: Considerations for environmental impact, protein quality, and exercise performance. *Nutrients*, *10*(12). https://doi.org/10.3390/nu10121841

Macdiarmid, J. I., Douglas, F., & Campbell, J. (2016). Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite*, *96*, 487–493. https://doi.org/10.1016/j.appet.2015.10.011

Masset, G., Soler, L. G., Vieux, F., & Darmon, N. (2014). Identifying sustainable foods: The relationship between environmental impact, nutritional quality, and prices of foods representative of the french diet. *Journal of the Academy of Nutrition and Dietetics*, *114*(6), 862–869. https://doi.org/10.1016/j.jand.2014.02.002

Meatless Mondays. Retrieved August 10, 2016, from (www.meatlessmonday.com)

Mekonnen, M. M., & Hoekstra, A. Y. (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems*, *15*(3), 401–415. https://doi.org/10.1007/s10021-011-9517-8

Melina, V., Craig, W., & Levin, S. (2016). Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. *Journal of the Academy of Nutrition and Dietetics*, *116*(12), 1970–1980. https://doi.org/10.1016/j.jand.2016.09.025

Mettler, S., Mitchell, N., & Tipton, K. D. (2010). Increased protein intake reduces lean body mass loss during weight loss in athletes. *Medicine and Science in Sports and Exercise*, *42*(2), 326–337. https://doi.org/10.1249/MSS.0b013e3181b2ef8e

Meyer, NL., & Reguant-Closa, A. (2017). " Eat as If You Could Save the Planet and Win !" Sustainability Integration into Nutrition for Exercise. *Nutrients*, *9*(412). https://doi.org/10.3390/nu9040412

Monteiro, C. A., Cannon, G., Moubarac, J., Levy, R. B., Louzada, M. L. C., & Jaime, P. C. (2017). Commentary The UN Decade of Nutrition, the NOVA food classi fi cation and the trouble with ultra-processing, 1–13. https://doi.org/10.1017/S1368980017000234

Monteiro, C. A., Cannon, G., Moubarac, J., Paula, A., Martins, B., Martins, C. A., … Jaime, P. C. (2015). Dietary guidelines to nourish humanity and the planet in the twenty- first century. A blueprint from Brazil, *18*(13), 2311–2322. https://doi.org/10.1017/S1368980015002165

Moore, D. R., Churchward-Venne, T. A., Witard, O., Breen, L., Burd, N. A., Tipton, K. D., & Phillips, S. M. (2015). Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *70*(1), 57–62. https://doi.org/10.1093/gerona/glu103

Nelson, M. E., Hamm, M. W., Hu, F. B., Abrams, S. A., & Griffin, T. S. (2016). Alignment of Healthy Dietary Patterns and Environmental Sustainability : A Systematic Review. *Advances in Nutrition: An International Review Journal*, (3). https://doi.org/10.3945/an.116.012567.rather

Nemecek, T., Jungbluth, N., Canals, L. M., & Schenck, R. (2016). Environmental impacts of food consumption and nutrition: where are we and what is next? *The International Journal of Life Cycle Assessment*, 607–620. https://doi.org/10.1007/s11367-016-1071-3

Notarnicola, B., Sala, S., Anton, A. O., Mclaren, S. J., Saouter, E., & Sonesson, U. (2016). The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.06.071

Notarnicola, B., Tassielli, G., Alexander, P., Castellani, V., & Sala, S. (2017). Environmental impacts of food consumption in Europe. *Journal of Cleaner Production*, *140*, 753–765. https://doi.org/10.1016/j.jclepro.2016.06.080

Notarnicola, B., Tassielli, G., Renzulli, P. A., & Lo Giudice, A. (2015). Life Cycle Assessment in the agri-food sector: an overview of its key aspects, international initiatives, certification, labelling schemesand methodological issues. In *Life Cycle Assessment in the Agri-food Sector* (pp. 1–56). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-11940-3_1

Paddon-Jones, D., Campbell, W. W., Jacques, P. F., Kritchevsky, S. B., Moore, L. L., Rodriguez, N. R., & van Loon, L. J. (2015). Protein and healthy aging. American Journal of Clinical Nutrition, 101(6), 1339S-1345S. https://doi.org/10.3945/ajcn.114.084061

Pairotti, M. B., Cerutti, A. K., Martini, F., Vesce, E., Padovan, D., & Beltramo, R. (2015). Energy consumption and GHG emission of the Mediterranean diet: A systemic assessment using a hybrid LCA-IO method. *Journal of Cleaner Production*, *103*, 507–516. https://doi.org/10.1016/j.jclepro.2013.12.082

Pedersen, K., Land, B., & Kjaergard, B. (2015). Duality of Health Promotion and Sustainable Development: perspectives on food waste reduction strategies. The Journal of Transdisciplinary Environmental Studies, 14(2), 5–18. Retrieved from http://forskningsbasen.deff.dk/Share.external?sp=S932e1a32-2c67-4aba-8d6b-f631c-fab0e6c&sp=Sruc

Pelly, F., Meyer, N. L., Pearce, J., Burkhart, S. J., & Burke, L. M. (2014). Evaluation of Food Provision and Nutrition Support at the London 2012 Olympic Games: The Opinion of Sports Nutrition Experts. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(6), 674–683. https://doi.org/10.1123/ijsnem.2013-0218

Pelly, F., & Parker Simmons, S. (2019). Food Provision at the Rio 2016 Olympic Games: Expert Review and Future Recommendations. *International Journal of Sport Nutrition and Exercise Metabolism*, 1–6. https://doi.org/10.1123/ijsnem.2018-0175

Phillips, S. M., Tang, J. E., & Moore, D. R. (2009). The role of milk- and soy-based protein in support of muscle protein synthesis and muscle protein accretion in young and elderly persons. *Journal of the American College of Nutrition*, *28*(4), 343–354. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20368372

Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. *Journal of Sports Sciences*, *29*(sup1), S29–S38. https://doi.org/10.1080/02640414.2011.619204

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Public Health England, Welsh Government, Scotland, F. S., & Food Standards Agency in Northen Ireland. (2016). *Eat Well Guide*. Retrieved from https://www.gov.uk/government/publications/the-eatwell-guide

Reynolds, C. J. (2017). Energy embodied in household cookery: The missing part of a sustainable food system? Part 1: A method to survey and calculate representative recipes. In G. B. & T. S.A. (Eds.), *1st International Conference on Sustainable Energy and Resource Use in Food Chains, ICSEF 2017* (Vol. 123, pp. 220–227). University of Sheffield, Department of Geography, Faculty of Social Sciences, Winter Street, Sheffield, S3 7ND, United Kingdom: Elsevier Ltd. https://doi.org/10.1016/j.egypro.2017.07.245

Rio Food Vision. (2014). *Diagnostic Analysis for the Supply of Healthy and Sustainable Food for the 2016 Rio Olympic and Paralympic Games*. Rio de Janeiro. Retrieved from www.riofoodvision.org

Ripple, W. J., Smith, P., Haberl, H., Montzka, S. A., McAlpine, C., & Boucher, D. H. (2014). Ruminants, climate change and climate policy. *Nature Climate Change*, 4(1), 2–5. https://doi.org/10.1038/nclimate2081

Roesch, A., Gaillard, G., Isenring, J., Jurt, C., Keil, N., Nemecek, T., … Roesch, A. (2017). Comprehensive Farm Sustainability Assessment. Zurich, Switzerland. Retrieved from www.agroscope.ch/science

Saarinen, M., Fogelholm, M., Tahvonen, R., & Kurppa, S. (2017). Taking nutrition into account within the life cycle assessment of food products. *Journal of Cleaner Production*, *149*, 828–844. https://doi.org/10.1016/j.jclepro.2017.02.062

Sabaté, J., Sranacharoenpong, K., Harwatt, H., Wien, M., & Soret, S. (2014). The environmental cost of protein food choices. *Public Health Nutrition*, *18*(11), 1–7. https://doi.org/10.1017/S1368980014002377

Saxe, H. (2014). The New Nordic Diet is an effective tool in environmental protection: It reduces the associated socioeconomic cost of diets. *American Journal of Clinical Nutrition*, *99*(5), 1117–1125. https://doi.org/10.3945/ajcn.113.066746

Saxe, H., & Jensen, J. D. (2014). Does the environmental gain of switching to the healthy New Nordic Diet outweigh the increased consumer cost ? In *9th International Conference LCA of Food*.

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Climatic Change*, *125*(2), 179–192. https://doi.org/10.1007/s10584-014-1169-1

Seed, B. (2017). Sustainability in the Qatar national dietary guidelines, among the first to incorporate sustainability principles, *18*(13), 2303–2310. https://doi.org/10.1017/S1368980014002110

Sjörs, C., Raposo, S. E., Sjölander, A., Bälter, O., Hedenus, F., & Bälter, K. (2016). Diet-related greenhouse gas emissions assessed by a food frequency questionnaire and validated using 7-day weighed food records. *Environmental Health: A Global Access Science Source*, *15*(1). https://doi.org/10.1186/s12940-016-0110-7

Skerrett, P. J. (2011). Harvard to USDA: Check out the Healthy Eating Plate. *Harvard Health Blog*. Retrieved from http://www.health.harvard.edu/blog/harvard-to-usda-check-out-the-healthy-eating-plate-201109143344

Sonesson, U., Davis, J., Flysjö, A., Gustavsson, J., & Witthöft, C. (2017). Protein quality as functional unit – A methodological framework for inclusion in life cycle assessment of food. *Journal of Cleaner Production*, *140*, 470–478. https://doi.org/10.1016/j.jclepro.2016.06.115

Sonesson, U., Davis, J., Hallström, E., & Woodhouse, A. (2019). Dietary-dependent nutrient quality indexes as a complementary functional unit in LCA: A feasible option? *Journal of Cleaner Production*, *211*, 620–627. https://doi.org/10.1016/j.jclepro.2018.11.171

Sonesson, U. G., Lorentzon, K., Andersson, A., Barr, U. K., Bertilsson, J., Borch, E., … Wall, H. (2016). Paths to a sustainable food sector: integrated design and LCA of future food supply chains: the case of pork production in Sweden. *International Journal of Life Cycle Assessment*, *21*(5), 664–676. https://doi.org/10.1007/s11367-015-0969-5

Soret, S., Mejia, A., Batech, M., Jaceldo-Siegl, K., Harwatt, H., & Sabaté, J. (2014). Climate change mitigation and health effects of varied dietary patterns in real-life settings throughout North America. *American Journal of Clinical Nutrition*, *100*(SUPPL. 1), 490–495. https://doi.org/10.3945/ajcn.113.071589

Spendlove, J., Mitchell, L., Gifford, J., Hackett, D., Slater, G., Cobley, S., & O'Connor, H. (2015). Dietary Intake of Competitive Bodybuilders. *Sports Medicine (Auckland, N.Z.)*, *45*(7), 1041–1063. https://doi.org/10.1007/s40279-015-0329-4

Stehfest, E., Bouwman, L., van Vuuren, D. P., den Elzen, M. G. J., Eickhout, B., & Kabat, P. (2009). Climate benefits of changing diet. *Climatic Change*, *95*(1–2), 83–102. https://doi.org/10.1007/s10584-008-9534-6

Stylianou, K. S., Heller, M. C., Fulgoni, V. L., Ernstoff, A. S., Keoleian, G. A., & Jolliet, O. (2016). A life cycle assessment framework combining nutritional and environmental health impacts of diet: a case study on milk. *The International Journal of Life Cycle Assessment*, *21*(5), 734–746. https://doi.org/10.1007/s11367-015-0961-0

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., … Dietz, W. H. (2019). The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. *The Lancet*, *393*(10173), 791–846. https://doi.org/10.1016/S0140-6736(18)32822-8

Te Morenga, L., & Mann, J. (2012). The role of high-protein diets in body weight management and health. *British Journal of Nutrition*, *108*(S2), S130–S138. https://doi.org/10.1017/S0007114512002437

Tessari, P., Lante, A., & Mosca, G. (2016). Essential amino acids: master regulators of nutrition and environmental footprint? *Scientific Reports*, *6*(April), 26074. https://doi.org/10.1038/srep26074

Theurl, M. C., Haberl, H., Erb, K. H., & Lindenthal, T. (2014). Contrasted greenhouse gas emissions from local versus long-range tomato production. *Agronomy for Sustainable Development*, *34*, 593–602. https://doi.org/10.1007/s13593-013-0171-8

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Nutrition and Athletic Performance. *Medicine & Science in Sports & Exercise*, *48*(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518–522. https://doi.org/10.1038/nature13959

Tirado, M. C., Crahay, P., Mahy, L., Zanev, C., Neira, M., Msangi, S., … Müller, A. (2013). Climate change and nutrition: Creating a climate for nutrition security. *Food and Nutrition Bulletin*, *34*(4), 533–547. https://doi.org/00000034/00000004/art00015

United Nations (1992). *Earth Summit: Rio Declaration on environment and development*.

United Nations (2015). Transforming our world: the 2030 Agenda for Sustainable Developmentt. *New York: United Nations*, (1), 1–41. https://doi.org/10.1007/s13398-014-0173-7.2

USDA. (2015). 2015 – 2020 Dietary Guidelines for Americans. *U.S. Department of Health and Human Services and U.S. Department of Agriculture*, 18. https://doi.org/10.1097/NT.0b013e31826c50af

USDA ERS - Food Availability and Consumption. (n.d.). Retrieved October 16, 2019, from https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-availability-and-consumption/

USDA, & US HHS. (2015). *Scientific Report of the 2015 Dietary Guidelines Advisory Committee. USDA and US Department of Health and Human Services* (Vol. 53). Washington (DC). https://doi.org/10.1017/CBO9781107415324.004

Van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., & Vellinga, P. (2014). Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns. *Food Policy*, *44*, 36–46. https://doi.org/10.1016/j.foodpol.2013.11.002

Van Kernebeek, H. R. J., Oosting, S. J., Feskens, E. J. M., Gerber, P. J., & De Boer, I. J. M. (2014). The effect of nutritional quality on comparing environmental impacts of human diets. *Journal of Cleaner Production*, *73*, 88–99. https://doi.org/10.1016/j.jclepro.2013.11.028

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate Change and Food Systems. *Annual Review of Environment and Resources*, *37*(1), 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

Waijers, P. M. C. M., Feskens, E. J. M., & Ocké, M. C. (2007). A critical review of predefined diet quality scores. *British Journal of Nutrition*, *97*(2), 219–231. https://doi.org/10.1017/S0007114507250421

Wallin, A., Di Giuseppe, D., Orsini, N., Patel, P. S., Forouhi, N. G., & Wolk, A. (2012). Fish Consumption, Dietary Long-Chain n-3 Fatty Acids, and Risk of Type 2 Diabetes: Systematic review and meta-analysis of prospective studies. *Diabetes Care*, *35*(4), 918–929. https://doi.org/10.2337/dc11-1631

Werner, L. B., Flysjö, A., & Tholstrup, T. (2014). Greenhouse gas emissions of realistic dietary choices in Denmark: The carbon footprint and nutritional value of dairy products. *Food and Nutrition Research*, *58*, 1–16. https://doi.org/10.3402/fnr.v58.20687

Westhoek, H., Lesschen, J. P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., … Oenema, O. (2014). Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Global Environmental Change*, *26*, 196–205. https://doi.org/10.1016/j.gloenvcha.2014.02.004

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., … Murray, C. J. L. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*. https://doi.org/10.1016/S0140-6736(18)31788-4

Wolfe, R. R. (2012). The role of dietary protein in optimizing muscle mass, function and health outcomes in older individuals. *British Journal of Nutrition*, *108*(S2), S88–S93. https://doi.org/10.1017/S0007114512002590

Xun, P., & He, K. (2012). Fish consumption and incidence of diabetes: Meta-analysis of data from 438,000 individuals in 12 independent prospective cohorts with an average 11-year follow-up. *Diabetes Care*, *35*(4), 930–938. https://doi.org/10.2337/dc11-1869

Zamagni, A., Pesonen, H. L., & Swarr, T. (2013). From LCA to Life Cycle Sustainability Assessment: Concept, practice and future directions. *International Journal of Life Cycle Assessment*, *18*(9), 1637–1641. https://doi.org/10.1007/s11367-013-0648-3

CHAPTER

2

OBJECTIVES AND HYPOTHESES

“La cuina és el paisatge
posat a la cassola”

Josep Pla

2.1 Research objectives and hypotheses

This dissertation aims to validate the Athlete's Plate Nutrition Tool and its use by athletes and to evaluate its environmental impact. The overall goal of this dissertation is to develop sustainability principles applicable to athletes that may be integrated into practical guidelines aligned with periodized sport nutrition concepts using the Athlete's Plate Nutrition Tool.

2.1.1 Research Questions

The validation of educational tools in nutrition is necessary to ensure they meet nutritional guidelines for the population they are intended, are understandable by the target population so they may be used in practical settings, and are aligned with contemporary issues in nutrition, such as sustainability.

The following research questions will be answered in this dissertation.

1. What is the current state of inclusion of sustainability considerations in sport nutrition recommendations pertaining to active and athletic individuals?

Paper I "Eat as If You Could Save the Planet and Win!" Sustainability Integration into Nutrition for Exercise and Sport analyzes the current body of literature and inclusion of sustainability in nutrition and sport nutrition guidelines.

2. Does the AP meet current sport nutrition recommendations?

Paper II "Validation of the Athlete's Plate Nutrition Educational Tool: Phase I" validates the AP against current sport nutrition recommendations.

3. Do athletes understand how to use the AP?

Paper III "The Athlete's Plate Education Program: An Experiential Intervention" evaluates athletes' understanding and use of the AP in a practical setting.

4. What is the environmental impact of the AP?

Paper IV "The Environmental Impact of the Athlete's Plate Nutrition Education Tool" analyzes the environmental impact of the plates using the data collected during the validation of the AP to identify environmental hotspots and develop sport nutrition concepts that include sustainability and are aligned with the AP.

2.1.2 Hypotheses:

1. It is hypothesized that sustainability concepts are currently not integrated into nutrition guidelines and educational tools targeting active and athletic groups.

2. It is hypothesized that the AP is a valid sport nutrition tool for athletes to meet sport nutrition guidelines for energy and macronutrients at variable training loads.

3. It is hypothesized that the AP can be used by athletes in practical settings.

4. It is hypothesized that animal protein content of the AP generates the greatest environmental impact, although it is not the only environmental concern of the AP.

2.2 Contributions

Contribution I:

Meyer, NL., & **Reguant-Closa, A.** (2017) "Eat as If You Could Save the Planet and Win!" Sustainability Integration into Nutrition for Exercise and Sport. *Nutrients,* Apr 21;9(4).

Contribution II:

Reguant-Closa, A., Harris, MM., Lohman, TG., & Meyer, NL. (2019) Validation of the Athlete's Plate Nutrition Educational Tool: Phase I. *International Journal of Sports Nutrition and Exercise Metabolism*, May 29:1-26.

Contribution III:

Reguant-Closa, A.; Hubbell, ED., Kluge, MA., Viner RT., & Meyer, NL. The Athlete's Plate Education Program: An Experiential Intervention. Manuscript in preparation for submission.

Contribution IV:

Reguant-Closa, A., Roesch, A., Lansche, J., Nemecek, T., Lohman, TG., & Meyer NL. (2020). The Environmental Impact of the Athlete's Plate Nutrition Education Tool. Nutrients, Aug 18; 12(8):E2484.

CHAPTER

3

CONTRIBUTIONS

I. "Eat as If You Could Save the Planet and Win!" Sustainability Integration into Nutrition for Exercise and Sport.

II. Validation of the Athlete's Plate Nutrition Educational Tool: Phase I.

III. The Athlete's Plate Education Program: An Experiential Intervention.

IV. The Environmental Impact of the Athlete's Plate Nutrition Education Tool

"Let things taste of what they are"

Alice Waters

CONTRIBUTION I:

“Eat as if you could save the Planet and Win!” Sustainability Integration into Nutrition for Exercise and Sport

Authors: **Meyer NL. & Reguant-Closa A.**

Submitted to: Nutrients
Current state: Published April 2017

Abstract

Today's industrial food production contributes significantly to environmental degradation. Meat production accounts for the largest impact, including greenhouse gas emissions, land and water use. While food production and consumption are important aspects when addressing climate change, this article focuses predominantly on dietary change that promotes both health for planet and people with focus on athletes. Healthy, sustainable eating recommendations begin to appear in various governmental guidelines. However, there remains resistance to the suggested reductions in meat consumption. While food citizens are likely to choose what is good for them and the planet, others may not, unless healthy eating initiatives integrate creative food literacy approaches with experiential learning as a potential vehicle for change. This concept paper is organized in three sections: (1) Environmental impact of food; (2) health and sustainability connections; and (3) application in sport and exercise. For active individuals, this article focuses on the quantity of protein, highlighting meat and dairy, and quality of food, with topics such as organic production and biodiversity. Finally, the timing of when to integrate sustainability principles in sport nutrition is discussed, followed by practical applications for education and inclusion in team, institutional, and event operations.

KEYWORDS: sustainability; food; environment; sport nutrition; athlete; health; sustainable diet; food literacy

1. Introduction

There is an urgent need to reduce the degradation of natural resources and limit global warming, while providing healthy and sustainably produced food to a growing population. Agriculture contributes greatly to climate change and resource extraction, with animal-based foods playing a major role in greenhouse gas (GhG) emissions, loss of land, water, and biodiversity (FAO, 2006; FAO, 2014; Gerber et al., 2013; Sutton & Dibb, 2013) Further, current dietary patterns contribute to chronic disease through inadequate intakes of plant-based foods and high consumption of red and processed meat (Pan et al., 2012; Richman et al., 2010). In addition, climate change itself will negatively affect food production should temperatures continue to rise, resulting in reduced yields (Gornall et al., 2010; IPPC, 2014) possibly as much as 30%–40% loss by the turn of the century. Adding to this, the consequential sea level rise due to ice melt in the Arctic, displacing not only people but also valuable agricultural land (Hansen et al., 2016), and thus, indicating that food security will likely become the major threat to humans on earth. While agriculture itself must assume more sustainable practices, despite the continued need for intensification (Rockström et al., 2017), strategies for adopting diets with lower environmental impact that are healthy, economically viable, and socially and culturally acceptable are also needed. Thus, for the first time in the history of dietary guidance, food and climate change are crossing paths, and promoting a sustainable, healthful diet, also fit for the athlete, is now more than ever arising as an urgent public and planetary message.

This concept paper is organized in three sections: (1) Environmental impact of food; (2) health and sustainability connections; and (3) application in sport and exercise. For active individuals, this article focuses on the quantity of protein, highlighting meat and dairy, and the quality of food, with topics such as organic production and biodiversity. Finally, the timing of when to integrate sustainability principles in sport nutrition is discussed, followed by practical applications for education and inclusion in team, institutional, and event operations.

1.1. Environmental Impact of Food

The environmental impact of food production affects both terrestrial and marine environments. Agriculture uses about one third of arable land, almost three fourths of global water resources, and one fifth of energy. Thus, agriculture is a major contributor to resource depletion (Smil, 2000). Agriculture also emits large quantities of GhGs. Agriculture accounts for 30% of total GhG emissions from pre-production, production, to post-production (IPPC, 2014; David Tilman & Clark, 2014; Vermeulen, Campbell, & Ingram, 2012),with direct emissions from agriculture contributing the most (IPPC, 2014).

Greenhouse gas emissions are quantified in terms of carbon dioxide equivalents (CO_2eq), collectively also known as global warming potential. Carbon dioxide (CO_2) is the most prominent anthropogenic GhG with a global warming potential of 1. Nitrous oxide (N_2O) and methane (CH_4) are the other two major GhGs, with global warming potential of over 300 and 25 times that of CO_2, respectively, expressed over a 100-year lifespan (Kibria, Yousuf Haroon, Nugegoda, & Rose, 2010). Thus, these GhGs contribute significantly to global warming, and therefore, are at least as important to mitigate as CO_2.

Direct emissions from agriculture account for the largest fraction in agriculture-related GhG emissions, by generating CO_2, N_2O, and CH_4 directly on the farm (IPPC, 2014). Nitrous oxide arises from fertilizer applied to soil, as part of the denitrification process. Agriculture produces 65% of all N_2O (Bajželj et al., 2014; Miranda, Tuomisto, & McCulloch, 2015). Methane is generated in large quantities from enteric fermentation and manure from ruminants (Eshel, Shepon, Makov, & Milo, 2014; Gerber et al., 2013; Miranda et al., 2015; Ripple et al., 2014) and, to a smaller extent, from rice production (Vermeulen et al., 2012). Further direct, on-farm emissions originate from fossil fuel dependence to run tractors and machinery, which release CO_2 (IPPC, 2014; Nemecek, Dubois, Huguenin-Elie, & Gaillard, 2011). Adding to this the high demand for animal feed, such as corn and soy, from agriculture, animal agriculture (especially ruminant) plays the biggest role in food-generated GhG emissions and global warming potential (Eshel et al., 2014), exceeding the production of vegetables, grains, and legumes (Auestad & Fulgoni, 2015; Sabaté, Sranacharoenpong, Harwatt, Wien, & Soret, 2014). While direct emissions from agriculture contribute the greatest in global warming potential, pre-production processes also include resource-intensive fertilizer, pesticide and herbicide production, which emit GhGs (Vermeulen et al., 2012). Climate change mitigation, especially from direct emissions, is critical, as estimates indicate an additional 35%–60% rise in CH_4 and N_2O already by 2030 (Tilman, 1999). Table 3.1 shows GhG emissions per kilogram of various foods.

TABLE 3.1
Greenhouse gas (GhGs) emissions in food.

LOW GHGS	MEDIUM GHGS	HIGH GHGS
<1 kg CO_2 eq/kg edible weight	1–4 kg CO_2 eq/kg edible wt	>4 kg CO_2 eq/kg edible weight
Potatoes	Chicken	* Beef
Pasta	Milk, butter, yogurt	* Lamb
Bread	Eggs	Pork
Oats and other grain	Rice	Turkey
Vegetables (e.g., onions, peas, carrots, corn, brassica)	Breakfast cereals	Fish
Fruits (e.g., apples, pears, citrus, plums, grapes)	Spreads	Cheese
Beans/lentils	Nuts/Seeds	
Confectionary	Biscuits, cakes, dessert	
Savory Snacks	Fruit (e.g., berries, banana, melons, salad)	
	Vegetables (e.g., salad, mushrooms, green beans, cauliflower, broccoli, squash)	

* May be as high as 20–50 kg CO_2 eq/kg edible weight. Average CO_2 emissions for driving car are 0.186 kg CO_2 eq/km driven. Adapted from Aiking (2014).

Food production requires arable land, but there are not unlimited resources. About 33% of Earth's ice-free surface is used for agriculture (Smil, 2000). Animal agriculture requires large amounts of land —approximately half of all of agriculture— not only for the animals, but also to produce their feed (Eshel et al., 2014; Gerber et al., 2013; Herrero et al., 2013). Agriculture has negatively affected the land, with excessive chemical input, causing poor soil health and pollution, with potential adverse human health effects (Fantke & Jolliet, 2016; Guyton et al., 2015; O'Kane, 2012; Raanan et al., 2015; Samsel & Seneff, 2013b, 2013a; L. J. Stein et al., 2016; Viel et al., 2015). While meat production has become industrial and inexpensive, its impact on animals and people have been largely neglected (Bassett, Gunther, & Mundy, 2013; Carlsson-Kanyama & González, 2009; Eshel et al., 2014). To meet a rising demand for food, especially meat, ecosystems continue to be compromised to clear more land (Gerber et al., 2013; IPPC, 2014). This land clearing is also called deforestation and is an indirect but large contributor to agriculture's impact on the environment, including the loss of biodiversity (FAO, 2006; Gerber et al., 2013; Sutton & Dibb, 2013).

Post-production GhG emissions include emissions from food storage, packaging, distribution, transport, and end-consumer effects (e.g., waste). Compared to agriculture's direct emissions, post-production GhG emissions are considered small (Gustavsson, Cederberg, & Sonesson, 2011; Vermeulen et al., 2012). Taken together, direct (on farm) and indirect (deforestation) effects of agriculture contribute the largest part of all food-related GhG emissions and land use.

Although not always counted in environmental food studies, post-production includes waste. Globally, about one third of food produced is discarded per year (Gustavsson et al., 2011) with enormous global warming potential (FAO, 2013). Food loss can occur along the entire supply chain, from harvest to consumer-level discards. The amount of food waste is generally higher in developed countries, although developing nations also show food loss, especially during production and harvest (Reynolds, Wulster-Radcliffe, Aaron, & Davis, 2015). In developed nations, consumer-level food waste (e.g., households) is significant (Parfitt, Barthel, & Macnaughton, 2010). In the US, food waste from households has increased by 50% since the 1970s (Hall, Guo, Dore, & Chow, 2009). On average, 40% of food in the US is wasted each year (Gunders, 2012). This amounts to 9 kg of food wasted per person per month or 200 kg of food per 4-person household per year. This has been estimated to cost the American family at least $589 and the entire country $165 billion per year (Jones, 2004). Food waste is a significant contributor to resource depletion, considering energy, water, and land are needed for production, distribution, and storage of the food that goes uneaten. Moreover, discarding the food adds a further burden to the environment, accounting for 25% of landfill-generated CH_4 (Gunders, 2012). Thus, besides the energy-costly inputs and GhG emissions from food produced that is unconsumed, wasting it contributes to environmental degradation.

Finally, a significant impact of agriculture on the environment is also its water use. About 70% of all surface and ground water goes to agriculture, with many aquifers showing diminishing reserves (Konikow, 2013). As water resources are becoming equally scarce as land, it is important to consider the significantly greater water footprint of beef production as compared with alternative meat and plant sources (Eshel et al., 2014; Mekonnen & Hoekstra, 2012; Sabaté et al., 2014), although there are some exceptions (David Tilman & Clark, 2014).

Studies that focus on food and the environment use Life Cycle Assessment (LCA) to quantify global warming potential of the entire food supply chain—from cradle to grave, including all resources used and all emissions to air, soil, and water. While GhG emissions specific to agriculture are commonly reported, comprehensive LCA studies also include land and water use, toxicity to ecosystems and human health, biodiversity loss, eutrophication, and ocean acidification (*ISO 14040:2006. Environmental management - Life Cycle Assessment - Principles and Framework*, 2006). Although beyond the scope of this paper, the reader is encouraged to consult further literature on this topic (Charles, Godfray, & Garnett, 2014; IPPC, 2014; Springmann, Godfray, Rayner, & Scarborough, 2016; David Tilman & Clark, 2014; Vermeulen et al., 2012).

1.2. Dietary Change to Reduce Environmental Impact

Studies have shown that dietary change can play a significant role in reducing the impact of agriculture on global warming potential, land and water use. Recently, scientists have also linked environmental impact, nutrition, and health in the discourse of dietary change (Hallström, Carlsson-Kanyama, & Börjesson, 2015; Macdiarmid, 2013; Nemecek, Jungbluth, Canals, & Schenck, 2016; David Tilman & Clark, 2014). When considering dietary change as a realistic pathway for the reduction in GhG emissions, land and water use, one of the simplest approaches is to follow healthy dietary guidelines, including a reduction in calories (Hallström et al., 2015; Masset et al., 2014). This should not be underestimated since reducing calories, especially if achieved by increasing fruit, vegetables, and dietary fiber at the expense of meat, would result in weight loss and improved health, with enormous impacts on society, including health care cost (de Boer, de Witt, & Aiking, 2016; Friel et al., 2009; Masset et al., 2014; Sabaté, Harwatt, & Soret, 2016; Westhoek et al., 2014).

Animal agriculture is the most costly for the environment (Eshel et al., 2014; Friel et al., 2009; Sabaté et al., 2014). Eshel et al. 2014 have demonstrated that ruminant (beef) production requires 28 and 11 times more land and water and emits 5 times more GhG, compared with the production of non-ruminant protein sources (e.g., chicken, pork, eggs). Converted to food and protein, beef has a 35:1 feed-to-food caloric ratio compared with a 10:1 ratio for other animal proteins and an 800:1 ratio for feed calories-to-protein ratio, which is almost 10 times lower for other animal protein sources (Eshel et al., 2014). Thus, eating less beef is becoming an important dietary message worldwide (FAO, 2016). However, there can be even greater reductions by lowering meat consumption in general (Eshel et al., 2014), and replacing meat, and especially ruminant meat, with plant-based alternatives, which reduces land, energy, and water use, while lowering GhG emissions and waste (Sabaté et al., 2014). While dairy is more efficient than beef, emitting less GhGs, dairy production exceeds egg, poultry, and pork production in land and water use (Eshel et al., 2014; Hoekstra, 2012; Westhoek et al., 2014). Thus, dairy production also contributes to the expansion of cropland and resource extraction which, together with beef production, eventually exceeds the Earth's safe operating space (Rockström et al., 2009).

Reducing beef consumption and replacing some with plant-based sources, chicken, pork, or eggs could decrease GhG emissions by up to 35% from the food sector (Macdiarmid et al., 2012); however, a moderate reduction and replacing beef with dairy has a negligible effect (Hallström et al., 2015). Replacing beef with fish may provide some benefit but this largely depends on the type of fish, its production system, and fish feed used in aquacultures (FAO, 2014). Eating less beef can reduce land use by 50% to 70% (see reviews by Hallström et al., 2015 and Aleksandrowicz et al., 2016). Thus, consuming less beef (and dairy) could slow land clearing for feed production and some of this land could be repurposed to grow food for human consumption (Westhoek et al., 2014).

Eating less animal and more plant protein in general is also in line with governmental dietary guidelines (FAO, 2016), since most developed nations exceed protein, and especially meat, recommendations (FAO, 2014). A recent article entitled "Protein production: planet, profit, plus people?" recommends people eat one third less protein overall, replace one further third of their protein intake by plants such as beans, nuts, and grains, and choose the final third from free-range animals (Aiking, 2014). Based on annual per capita intake data (USDA, 2003), if this rule were applied to meat intake, this would still give the average American 80–100 grams (3–4 ounces, oz) per day.

Considering dietary change that could contribute to climate change mitigation, shifting from a typical Western diet to a more environmentally sustainable diet with less meat and more plants would work (Aleksandrowicz et al., 2016). Being vegetarian or vegan would be better, with over 30% and up to 70% reduction potential in GhG emissions and land use (Aleksandrowicz et al., 2016; Sabaté et al., 2014; Scarborough et al., 2014) and 50% less water use (Aleksandrowicz et al., 2016). However, vegetarian or vegan lifestyles may not be preferred for many people (Macdiarmid, Douglas, & Campbell, 2016). In addition, recent advances also point toward beneficial roles of well-managed, sustainable grazing practices that promote carbon sequestration on rangelands (DeLonge, Owen, & Silver, 2014), and some areas in the world are less suited for crop production but still provide a great place for livestock, including ruminants. Adding more value to the consumption of meat is necessary (Aiking, 2014). Thus, in the above example by Aiking (2014), the last third of what used to make up a meat-based dish, should contain a source that can be traced back to its origin, showing a healthy environment where animals are part of an intact ecosystem, given a good life and an end with dignity (Aiking, 2014).

2. Dietary Guidelines and Sustainability

It is quite clear that eating less meat (especially less red and processed meat), besides eating less overall and more whole and plant-based foods (i.e., vegetables, fruit, nuts, beans, grains), would be one of the most important dietary strategies for both planet and people. These recommendations are also grounded in the dietary guidelines of many countries, some of which have integrated sustainability (FAO, 2016).

In recent years, governmental dietary recommendations from various countries have begun to integrate sustainability. According to a recent report by the Food and Agriculture Organization (FAO) (FAO, 2016), of 83 countries that have official dietary guidelines, there are 4 reported countries that reference environmental factors in their dietary guidelines. These include Sweden, Germany, Brazil, and Qatar. Table 3.2 highlights sustainability commitments beyond those generally targeted to health (e.g., increase plant foods).

TABLE 3.2
Sustainability commitments in Germany, Brazil, Sweden, and Qatar.

	GERMANY	BRAZIL	SWEDEN	QATAR
Sustainability Highlights	Eat meat in moderation. Use fresh ingredients. Take your time and enjoy eating. Eat fish once or twice a week.	Choose seasonally and locally grown produce. Try to restrict the amount of red meat. Limit the amount of processed foods. Eat in company. Develop, exercise and share cooking skills. Plan your time and make food and eating important in your life.	Eat less red and processed meat (no more than 500 g of cooked meat per week). Choose eco-labelled seafood. Try to maintain energy balance by eating just the right amount.	Limit red meat to 500 g per week. Avoid processed meat. Eat less fast foods and processed foods. Build and model healthy patterns for your family. Eat at least one meal together daily with family.

The first country world-wide to awaken awareness regarding sustainability and food consumption was Sweden in 2009, calling for a reduction in meat in consumers (Lagerberg Fogelberg, 2013), with a cohort of countries today advising to reduce overall meat consumption to 500 g per week (16–17 oz) (FAO, 2016). Current meat intake in the US is almost 4 kg (9 pounds, lbs) of trimmed, boneless meat per week, with an annual per capita consumption of almost 90 kg (195 lbs) (USDA, 2002). However, the US is not alone, as many European and South American countries, along with Australia are also high, but not quite as high. Calculating the yearly per capita consumption per sustainability guidelines, with 500 g per week or a total of 26 kg annually, this equates to about one third of the current US consumption pattern.

While inclusion of sustainability into the US Dietary Guidelines would have been highly significant, considering (1) the high calorie and meat consumption in the US and (2) the potential global impact of US dietary guidelines (USDA & US HHS, 2015), it remained invisible in the official guidelines (USDA, 2015). Although not part of national dietary advice, several countries have published scientific papers that focus on mathematical modeling to derive a regional, sustainable and healthy diet alternative to what is considered the norm. The New Nordic Diet and the Low Lands Diet are two such examples. Both studies focused on less meat, more (Nordic Diet) or less (Low Lands Diet) fish, and local, traditional foods, and both used the Mediterranean diet as benchmark to link health and sustainability (Saxe & Jensen, 2014; Corné van Dooren & Aiking, 2016). Further, there are several quasi-official guidelines, from government agencies or government-funded entities that also include sustainability (FAO, 2016). Most recently, the Netherlands published an update through the Netherlands Nutrition Centre, calling its citizens to action to reduce red meat intake to less than 300 g per week, while the UK's governmental agency, encompassing England, Wales, Scotland, and Ireland also added a 7% reduction of dairy products (Public Health England, Welsh Government, Scotland, & Food Standards Agency in Northen Ireland, 2016).

2.1. Are People Willing to Change Diets to Protect the Environment?

When dietary guidelines promote a change, press releases are often the next step, communicating the governmental messages to the public. However, it is well known that dietary guidelines are only marginally followed (Krebs-Smith, Guenther, Subar, Kirkpatrick, & Dodd, 2010) and that eating behaviors are difficult to change (Macdiarmid et al., 2016), especially if guidelines remain a verbal or written recommendation without the practical skill building required to put the guidelines into practice (Schösler, Boer, & Boersema, 2012). In addition, simply telling people what they should eat without communicating the reason behind this recommendation or focusing too much on diet and health may not work either. For example, Hekler and colleagues (2010) showed that a college course on society, ethics, and food changed eating practices more favorably than in students taking courses in health with a focus on biology, obesity, psychology, or community (Hekler, Gardner, & Robinson, 2010). However, what about sustainability and the environment? Do people (1) understand the link between eating less meat and climate change and (2) would they make the change if it were both good for health and good for the planet?

"Eat as if there is no tomorrow" (Macdiarmid et al., 2016) studied a sample of Scottish people living in rural and urban areas using focus groups and interviews. The purpose of the study was to examine the perceptions of people toward eating less meat. The authors identified the following common themes, using a qualitative analysis: there was (1) a general lack of awareness related to the link between climate change and meat consumption and (2) little understanding that personal choice regarding meat consumption had anything to do with climate change. Finally, the study also showed that those interviewed were generally resistant to reducing meat intake.

Meat is a traditional menu ingredient in many cultures meat is often the center piece of the plate. It should be apparent that dietary behavior change will only occur if people begin to understand how best to reduce meat intake. This requires innovative menu design, similar to what has been proposed by the Culinary Institute of America (CIA) and Harvard School of Public Health with the Menus of Change initiative (The culinary Institute of America & Harvard School of Public Health, n.d.), in addition to public campaigns such as Meatless Mondays. This was also the synthesis of a recent study (Schösler et al., 2012), proposing that besides policy change, innovative culinary training through reskilling to cook more balanced vegetarian meals would be necessary. In other words, food literacy training will be needed to bring these ideas closer to consumers.

Regardless of approach taken, promoting meat reduction for personal and planetary health, may continue to be challenging, as was shown by de Boer, de Witt, and Aiking, 2016. These authors studied people's perceptions as to the extent to which personal dietary change could mitigate climate change (de Boer et al., 2016). Few recognized eating less meat as an effective way to mitigate climate change, but those who did, showed greater willingness to eat less meat. When asked to rate personal preference of (1) eating less meat; (2) eating more organic food; and (3) eating more local/seasonal food as a vehicle to mitigate climate change, eating more locally/seasonally grown food appealed to more individuals than the other two, including the message of eating less meat (de Boer et al., 2016).

2.2. Duality of Sustainability and Health

As we begin to imagine how to integrate sustainability into healthy and athletic lifestyles through the food we chose, we must define what constitutes sustainable food. Sustainability means that "humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987) (p. 5). The three pillars of sustainability which include equity, environment, and economics often focus on what is currently unsustainable, for example in food production, but also tend not to challenge the consumer in moving to sustainable development. Sustainability is a moving target, dynamic and ever changing, as the planet is changing. Thus, adapting with the goal to mitigate climate change is needed in all sectors of production, distribution, consumption, and resource recovery, globally as well as locally. While there are numerous examples of sustainable agricultural advances, including organic production (Reganold & Wachter, 2016) and perennial polycultures (Batello et al., 2013), promoting greater social equity for farmers and welfare for animals and focusing on sustainable consumption patterns are also important. So, what is a sustainable diet?

"A sustainable diet is a diet with low environmental impacts which contributes to food and nutrition security and to a healthy life for present and future generations. A sustainable food system is protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and healthy, while optimizing natural and human resources" (FAO, 2010) (p. 111).

In 2014, Kjærgård and colleagues published a framework on how to link sustainability and health and by doing so, dual benefits could be observed (Kjærgård, Land, & Bransholm Pedersen, 2014). These authors referred to their concept as a duality between sustainability and health. Considering sustainable food choices, a sustainable diet would also be a healthy diet. To understand this duality concept a bit deeper, the example of meat shows the duality of sustainability and health quite well. In general, livestock production, especially beef production, is associated with resource depletion and pollution (FAO, 2006) and contributes significantly to GhG emissions, biodiversity loss, and high health care costs (Sutton & Dibb, 2013). Excessive red meat consumption has been associated with poor health outcomes, such as cardiovascular disease, obesity, diabetes, and cancer (Huang, Han, Xu, Zhu, & Li, 2013; IPPC, 2014; Micha, Wallace, & Mozaffarian, 2010; Pan et al., 2012). In addition, how animals are raised in some countries, in confined animal feeding operations (CAFOs), is also of concern regarding animal and worker welfare in the context of community prosperity, health, and quality of life near CAFOs, and human antibiotic resistance from non-therapeutic use of antibiotics in such production systems (Goldberg, 2016). The duality of health and sustainability shows that addressing the "eat less meat" message has co-benefits for both sustainability and health. From the consumer side, dietary approaches that promote high protein intakes, such as the westernized diets and those recently termed "the diets of the healthy and wealthy" (Garnett, 2016) fail to consider this duality approach, and thus, slow the shift urgently needed to promote both sustainable and healthful eating. There are other examples that provide insight into the intertwined synergies between sustainability and health, such as the ecosystem and health services arising from urban farms and community gardens (Egli, Oliver, & Tautolo, 2016) as well as reducing food waste (Pedersen, Land, & Kjaergard, 2015).

Taken together, the inclusion of sustainability in nutrition and health is critical for current and future generations. The science of nutrition must embrace environmental considerations similar to the time when public health nutrition emerged from the science of nutrition for individuals and expanded its reach to communities (Sabaté et al. 2016). "The nutrition of individuals and communities can only be maintained within an environmentally sustainable context, which is currently under serious threat." (Sabaté et al., 2016) (p. 817). Thus, we are in the center of a difficult reality a sustainable food system needs the support of an intact ecosystem, but the way we currently eat contributes directly to its degradation (Sabaté et al., 2016).

3. Eat As If You Could Save the Planet and Win!

Whether the intention is health, fitness, and/or sport performance, integrating environmental consciousness when making dietary choices, seems no longer an option but rather a necessity. And while global warming and climate change are often overwhelming topics, dreaming the alternative fires up the imagination of young people, as so beautifully described in the Future of Health by Hanlon and colleagues (Hanlon, Carlisle, Hannah, Lyon, & Reilly, 2012). Thus, to end a long discourse on the unsustainability of the current food system and its apparent lack to teach us anything about good food and healthy communities or environmental conservation, while the alternative does, the next section will focus on how to integrate these ideas into the daily eating practices of those who train to win.

3.1. Ecological Footprint: This Gets Us Thinking

To understand one's own impact on the environment, it is always a good exercise to calculate the ecological footprint (Personal Footprint, n.d.). This is especially true with respect to dietary choices, as most people do not make the connection between their own eating and climate change (Macdiarmid et al., 2016). However, there are also tradeoffs. Some might travel a lot by plane, which increases one's footprint significantly. A good tradeoff would be to make sustainable dietary choices to contribute to environmental protection.

3.2. Sustainability in Sport Nutrition?

The integration of environmental nutrition concepts might not be as intuitive in sport nutrition but there are many entry points. One might also argue that due to high energy intakes to meet energy demand, enormous use of packaged foods and bottled beverages, equipment, materials, and heavy travel schedules athletes and their teams should integrate sustainable practices whenever possible.

From a health perspective, athletes lead a more sustainable lifestyle than most of society. Athletes rarely burden the health care system due to chronic disease such as obesity and diabetes. And participating in sport should play a substantial role in making sustainable healthy lifestyle choices. Athletes are also great icons for kids to pick up sport. Athletes are role models for society at large and are generally represented by values of good sportsmanship (TrueSport: U.S. Anti-Doping Agency, n.d.). Athletes are also great spokespeople, sharing their lessons learned through sports (e.g., time management, discipline to work hard, the importance of rituals, discerning the meaning of failure or injuries). While still dormant, athletes could become a strong voice for planetary health, and begin to realize that success in sport depends, in part, on an intact food system. Athlete or non-athlete, all young people should receive sustainability literacy training, and a covert approach to nutrition education may work best, using experiential learning through taste education, farm visits, cooking and eating together. The conversation around the digital-free table can further the understanding of contemporary food topics and build knowledge surrounding the current issues of the food system and what the sustainable, tasty alternative is all about.

Finally, the sustainable diet is not only the athlete's responsibility. As we see with other big topics in sport nutrition such as eating disorders (Bratland-Sanda & Sundgot-Borgen, 2013; Sundgot-Borgen et al., 2013), if coaches, service providers, and administrators are supporting the underlying rationale of a refreshed approach to nutrition education, using sustainability principles, it will enable change. Athletes, coaches, service providers, and administrators all serve as role models for societal change, thus, the adoption of sustainability principles, while coming from the bottom up in our examples, are best diffused if top to bottom is committed and understands the rationale behind the effort. True sport needs true food!

Therefore, let's get athletes on board in saving the planet and winning! Because sport nutrition is often focused on quantity, quality, and timing of food intake relative to training and competition, below we list sustainability actions for these overall themes, add a section about food literacy and food citizenship for athletes, and consider some final thoughts regarding the integration of sustainable practices for teams, institutions, and international events, such as the Olympic Games.

We will focus on several areas that may apply to exercisers and fitness enthusiasts in general, but athletes in particular, making small steps toward a more sustainable diet as the overarching goal, and this begins with the work of the sport nutrition professional.

3.3. Quantity of Food

3.3.1. Eat Less and Better Meat

Athletes' diets are generally high enough in protein (Gillen et al., 2016; Parnell, Wiens, & Erdman, 2016), if not excessive (Juzwiak, Amancio, Vitalle, Pinheiro, & Szejnfeld, 2008; Spendlove et al., 2015). Current protein recommendations have increased for athletes (Thomas, Erdman, & Burke, 2016), ranging from 1.2–2 g/kg body mass (BM)/day, especially if the goal is muscle protein accretion (Churchward-Venne, Murphy, Longland, & Phillips, 2013). Recently, these recommendations were translated into practical strategies to help athletes maintain protein consumption at intervals throughout the day in the amounts of 0.25–0.3 g/kg BM (Moore et al., 2015) or about 20 g (Atherton et al., 2010) per meal, given several eating occasions (best every 4 h) (Areta et al., 2013) per day and before sleeping (Res et al., 2012). This has also been summarized in the recently released position paper on Nutrition and Athletic Performance (Thomas et al., 2016). That athletes follow guidelines for protein intake is shown in the most recent dietary study on a sample of well-trained Dutch athletes, with mean daily protein intakes of 108 ± 33 g (1.5 ± 04 g/kg BM/day) and 90 ± 24 g (1.4 ± 0.4 g/kg BM/day) in men and women, respectively (Gillen et al., 2016).

There have also been recent trends for even higher protein recommendations to promote health (Phillips, Chevalier, & Leidy, 2016), support weight loss strategies (Phillips, 2014), to preserve lean body mass (LBM) under hypocaloric situations (Helms, Zinn, Rowlands, & Brown, 2014), in resistance-type sports such as bodybuilding (Helms, Aragon, & Fitschen, 2014), and corporate sports performance programs (Arciero, Miller, & Ward, 2015). That athletes, especially in strength and power sports, accomplish higher protein intakes has also been shown (Pelly & Burkhart, 2014), with recent reports also highlighting the issue of extremely high protein intakes in some athletes (Della Guardia, Cavallaro, & Cena, 2015; Spendlove et al., 2015). Even though data are limited, practitioners should be well aware of excessive protein intakes in some athletes, aligning with current sport nutrition trends, including the paleo diet. Finally, practitioners may inadvertently promote high protein intakes, considering educational tools and strategies or athletes may simply get too much by eating a lot, since protein is a function of energy intake (Manore, Meyer, & Janice, 2009). However, what are the concerns besides the fact that some athletes may overdo it without proper guidance?

Because this paper is about sustainable diets, the question arises if current protein recommendations for athletes and actual intakes are going to align with global recommendations to reduce rather than increase protein intake in developed countries. Meeting protein recommendations in athletes per se may not necessarily be the issue. The issue is that the continued emphasis on higher protein needs will likely increase the demand for animal protein, including meat, dairy, and eggs. Considering the 50% rise in the world's population since 2000 and society's insatiable hunger for meat, the world meat and cheese demand will double by 2050, further burdening the planet (FAO, 2006). Animal proteins are already consumed in greater quantities than plant proteins, in both the general (Council for Agriculture Science & technology, 1999; USDA, 2002) and athletic population (Gillen et al., 2016), and the US considerably exceeds European countries in daily animal protein consumption (FAOSTAT, n.d.).

Table 3.3 shows hypothetical amounts of meat (in this case beef) in reference to the (1) non-athlete recommended daily allowance (RDA) for protein (Institute of Medicine, 2006), (2) current athlete protein recommendation (~1.5 g/kg BW/day (Thomas et al., 2016)), and (3) recently suggested athlete protein recommendations under energy restriction for weight loss (~2.5 g/kg BW/day (Helms, Zinn, et al., 2014; Phillips, 2014)). It is assumed under this example, that 50% of dietary protein is supplied by meat. This is a rather conservative estimate based on total animal protein intakes typically exceeding 65% in the general population (Council for Agriculture Science & technology, 1999).

TABLE 3.3
Daily protein recommendations using estimated daily meat contributions for athletes and non-athletes.

EXAMPLE	UNITS	NON-ATHLETE PRO RDA	ATHLETE'S STANDARD PRO	ATHLETE'S HYPOCALORIC PRO
60 kg female	PRO (g/day)	48	90	150
	Cooked Meat Contribution as 50% of total PRO (g/day) *	92	172	288
80 kg male	PRO (g/day)	64	120	200
	Cooked Meat Contribution as 50% of total PRO (g/day) *	123	230	387

* meat contribution at 50% of total protein recommendation, calculated for cooked ground lean beef (15% fat); 100 g edible portion equals 26 g of protein (similar for chicken, pork, lamb). Athlete's standard diet calculated at protein recommendation of 1.5 g/kg/day (Thomas et al., 2016). Athlete's hypocaloric diet calculated at protein recommendation of 2.5 g/kg/day (Helms, Zinn, et al., 2014; Phillips, 2014). PRO = Protein. Most sustainable and healthy dietary recommendations target 300 g of red meat or 500 g of total meat per week (FAO, 2016). RDA = Recommended Daily Allowance. Table shows how easily athletes may exceed these weekly meat recommendations if they ate 50% meat of the total protein recommended per day.

From Table 3.3, we can see that meat consumption may easily exceed what is currently considered sustainable, as a total of 500 grams (17.6 oz) of meat per week (~70 grams per day; 2.5 oz) and less or equal to 300 grams (10.6 oz) of red meat per week (~45 grams per day; 1.6 oz/day) would be the upper limit per person. These are also the upper limits for meat consumption of most countries' dietary guidelines (FAO, 2016), including those for Americans, to promote health (USDA, 2015).

If the recommendation by Aiking (2014) could be implemented it would mean to cut 1/3 of the protein (in this case we would focus on meat, especially red meat), replace 1/3 with plant protein (beans including soy, grain, nuts, seeds), and to choose grass-fed or pasture-raised animal protein sources to obtain higher quality meat with greater omega 3 fatty acids and antioxidants, (Daley, Abbott, Doyle, Nader, & Larson, 2010), not to mention less agricultural chemicals and antibiotic residues (Aiking, 2014).

Let's look at an example integrating the recommendation by Aiking (2014) from above (Aiking, 2014) but with focus on meat, especially red meat. If an 80-kg heavy male athlete eats 120 grams of protein of which 50% comes from meat, it equals approximately 240 grams of cooked meat per day. This is more than 3 times the 70-gram daily benchmark. Thus, if the athlete follows the recommendation for an environmentally friendly protein intake by Aiking (2014), they would first reduce this amount by 80 grams of meat which equals approximately 20 grams of protein (Aiking, 2014). Second, the athlete would creatively adapt protein intake, according to the Protein Flip Initiative (see Table 3.4), and replace another 80 grams (or 20 grams of protein) by plant sources (See Table 3.5). The question that will arise is whether the athlete should replace the first third of meat that was cut out, and if so, how would this be done within sustainable boundaries? The answer may be substituting red meat with chicken, pork, or eggs, or choosing a greater proportion of plant-based proteins (e.g., beans, peas, nuts, seeds, and/or grains). However, plant protein may lack essential amino acids (EAA), and thus, may be required in greater amounts to meet the RDA. A recent study compared the land use change and GhG emissions of various animal and plant sources in amounts corresponding to the RDA for EAA (Tessari, Lante, & Mosca, 2016). Interestingly, environmental impacts were no longer as discriminatory for animal versus plant proteins, with exception of soy, which showed the lowest

GhG emissions and land use. However, we should be cautious when interpreting these data, because people eat a variety of foods in variable amounts to meet daily protein and EAA needs. According to the American Academy of Nutrition and Dietetics Position Paper on Vegetarian Nutrition (Melina, Craig, & Levin, 2016), it is not necessary to get all EAA at one meal, and especially not from one plant or animal. Rather, EAA are accumulated over the course of a day from various foods, and it is not uncommon to find vegetarian meals enhanced with small amounts of animal protein (e.g., dairy, eggs), while vegan meals may include various protein-rich plant foods. Thus, the key message for omnivores is to reduce total amount of animal sources of protein, while for vegans, the message may be to ensure diets meet daily EAA needs by eating sufficient amounts of food, along with a combination of protein-rich, plant-based sources. Working toward a more balanced approach between animal and plant proteins should be the primary goal for both planetary and personal health. Considering the higher protein needs in athletes (Thomas et al., 2016), bugs may be the most suited protein to make up the difference from non-athletic controls, however, at substantially lower environmental cost.

3.3.2. Insects

Insects may well be the next protein source with which excessive meat may need to be replaced. Insects are nutritious, with similar amounts of protein compared to livestock and high levels of vitamins and minerals. Insects can also be a good source of essential fatty acids. Insects emit much lower GhG due to their highly efficient feed-to-protein conversion rates and insects have very low water requirement (van Huis et al., 2013). Insect powder may become a viable option for post-exercise recovery nutrition in liquid or solid food products, some of which are already on the market. In addition, plant-protein alternatives, such as pea (*pisum sativum*) protein powder, may also present a carbon-friendly source for athletes (Babault et al., 2015). Obviously, much more research is needed to compare various plant protein alternatives and insects to the well-researched and popularly used dairy proteins post-exercise. So, what about dairy?

3.3.3. Dairy

Milk, yogurt, Greek yogurt, and cheese all add up quickly, and most Americans, including athletes, may indeed meet the US dietary guidelines, recommending 700 mL of dairy products per day (USDA, 2003). While milk consumption has gradually decreased over the past decades, cheese, yogurt, and whey intakes have dramatically increased (USDA, 2003). It is estimated that milk production contributes 2.7% to total GhG emissions (FAO, 2010), although there is great variability based on farming systems (FAO, 2010), with industrial systems generally showing lower GhG emissions due to higher feed digestibility and milk productivity per unit of product, compared to extensive farming systems. However, if other components of environmental degradation (e.g., pollution of waterways and biodiversity), increased energy demand, and human and animal welfare—basically the sustainability of dairy production—are questioned (von Keyserlingk et al., 2013), the impact of intensification may well be greater (FAO, 2010).

TABLE 3.4
Examples for protein flip menus and burgers.

MEAL	ACTUAL	PRO g	PROTEIN FLIP	PRO g	COMMENTS
Grilled Beef with Quinoa and Veggies	4 oz beef	26	2 oz 100% grassfed beef	13	Rename to Southwest Anasazi Bean and Beef Bowl.
United States Olympic Committee	4 oz kale and quinoa	4	4 oz kale and quinoa	4	Launch educational campaign on protein flip.
Colorado Springs	4 oz broccoli	3	2 oz Anasazi beans	10	Add history of Colorado beans and quinoa.
	1/2 stuffed portobello	5	4 oz broccoli	4	
			1/2 stuffed portobello	5	
	total	38	total	36	
Pork loin with Poblano Chili and Rice	4 oz pork loin	26	2 oz organic pork loin	13	Rename to Ancient Grains with Poblano Chili Pork.
United States Olympic Committee	4 oz poblano chili	3	4 oz poblano chili	3	Launch educational campaign on protein flip.
Colorado Springs	4 oz white rice with veg	4	6 oz farro, beans, veggies	12	Integrate nutritional benefits of ancient grains.
					Add history of emmer and biodiversity of grains.
	total	33	total	30	
SWELL Burger	4 oz beef burger	22	2 oz 100% grassfed beef	10	This meal is served at UCCS Food Next Door.
University of Colorado	white bun	5	1.75 tsp black beans	2	SWELL Burger uses the protein flip approach.
Colorado Springs	1 cup dinner salad	1	1.75 tsp quinoa	1	Launch educational campaign on protein flip.
			1.75 tsp hemp	3	Integrate sustainable food literacy.
			1 T peppers, carrots, leeks, chard	1	Highlight nutritional benefits of grassfed beef.
			garlic, chili, cumin, chives		Include social justice issues regarding CAFO.
			1 slice socca (chick pea flatbread)	4	Highlight Slow Meat and Menus of Change ideas.
			SWELL kale salad with roasted veg	2	
			pumpkin seeds	2	
	total	28	total	25	

SWELL: Sustainability, Wellness, & Learning; UCCS: University of Colorado, Colorado Springs; PRO: Protein; CAFO: Confined Animal Feeding Operation; ounces (oz; 1 oz = 28.4 g); tsp: teaspoon; T: tablespoon.

TABLE 3.5

Cooked amounts of plant and animal-based foods delivering 20 g of protein

FOOD	GRAMS	OUNCES	CUPS	T	CALORIES	LIMITING AMINO ACIDS	LEUCINE (G)
Anasazi Beans	322	11.4	1.4	23	426	Sulfur containing AA	1.2
Black Beans	295	10.4	1.3	21	295	Sulfur containing AA	1.3
Chickpeas	284	10	1.3	20	336	Sulfur containing AA	1
Soybeans	204	7.2	1	14	268	Complete plant protein	2.3
Lentils	250	8.8	1.1	18	253	Sulfur containing AA	1.3
Tofu	284	10	1.3	20	189	Complete plant protein	1.3
Tempeh	306	10.8	1.4	22	265	Complete plant protein	2.4
Edamame	318	11.2	1.4	22	265	Complete plant protein	1.2
Seitan	408	14.4	1.8	29	270	Complete plant protein	no data
Buckwheat	755	26.6	3.3	53	516	Complete plant protein	0.4
Quinoa	567	20	2.5	40	555	Complete plant protein	0.5
Millet	748	26.4	3.3	53	683	Lysine, threonine	0.8
Amaranth	500	17.6	2.2	35	552	Complete plant protein	no data
Einkorn	145	5.1	0.6	10	218	no data	no data
Emmer	227	8	1	16	200	Lysine	0.3
Spelt	411	14.5	1.8	29	445	No data	no data
Kamut	411	14.5	1.8	29	454	Lysine	0.8
Almonds	227	8	1	16	575	Methionine, Cysteine	2.1
Peanut butter	68	2.4	0.3	5	470	Methionine, Cysteine	3.9
Hemp seeds	57	2	0.3	4	160	Lysine	0.7
Pumpkin seeds	132	4.6	0.6	9	433	Complete plant protein	3
Beef 15% fat	73	2.4	0.3	5	157	Complete protein	1.7
Chicken	91	3.2	0.4	6	100	Complete protein	3.3
Pork	73	2.4	0.3	5	152	Complete protein	1.9
Milk 2% fat	567	20.0	2.5	40	284	Complete protein	0.8
Eggs	188	6.4	0.8	13	291	Complete protein	2
Fish (tuna)	141	4.8	0.6	10	179	Complete protein	3.2

T: tablespoon

Combining protein-rich, plant-based foods will be the best strategy in obtaining all amino acids if partially or fully replacing animal-based foods.

Globally, about 45%, 20%, and 35% of milk is processed into cheese, milk powders, and fresh or fermented dairy products, respectively (FAO, 2010). In the US, 50% of raw milk is generally processed into cheese (IDF/FIL, 2010). Milk production generates about 1 kg of CO_2 eq/kg of milk (or 2.4 CO_2 eq/kg ready to consume milk) at farm gate (FAO, 2010). Additional processing, transport, and distribution for dairy products, such as cheese, whey and yogurt increase GhG emissions (FAO, 2010). Finished products, such as cheese and yogurt, show greater emissions due to the fact they need more milk per unit produced (see Table 3.1).

Depending on current dairy intake, a climate friendly start could be to reduce dairy products in general, and cheese in particular, due to greater GhG emissions (Macdiarmid et al., 2012). The UK (Buttriss, 2016) currently suggests a 7% decrease in dairy, among reductions in meat, for all citizens to participate in consumer-driven climate change mitigation. This is world-wide the only guideline that targets reductions in dairy. Athletes may want to focus on milk, rich in whey, in the recovery period after an important workout, since this is an effective protocol to promote post-exercise protein synthesis (Thomas et al., 2016) and is palatable. Whether environmental differences exist among milk-derived protein depends on what functional unit is used to express GhG emissions. A Canadian study shows that per gram of protein, GhG emissions are similar or slightly less for cheese and yogurt compared with milk. However, per kg product, milk ranks significantly lower in GhG emissions than cheese and yogurt (Vergé et al., 2013). Should an athlete need to focus on extra weight/muscle gain, casein-rich Greek yogurts appear popular before going to bed to promote protein synthesis at night (Res et al., 2012); however, Greek yogurt emits more GhGs than regular yogurt, because its production requires more milk (Bulletin of the International Dairy Federation (IDF/FIL, 2010).

While sweetened yogurts are often loaded with sugar and unrecognizable ingredients, a good choice is the least processed type that contains naturally occurring beneficial bacteria from fermentation. These bacteria are generally known as probiotics and are thought to boost gut health (McFarland, 2015). Thus, for both the environment and health, less processing in yogurts may be the way to go. Because most of the sport nutrition research has been conducted using dairy products, future studies are needed on more environmentally conscious plant protein alternatives and insect protein. This is especially important for athletes who, by default, likely exceed animal protein recommendations from meat and dairy (including whey), currently deemed unsuitable to protect the environment.

3.3.4. Reinventing the Athlete's Plate

To make the message of meat (and dairy) reduction palatable, practically engaging initiatives are needed. Choosing less and better meat is Slow Food's global strategy (Slow Food USA, n.d.) for developed nations, where meat intake is generally very high. Flipping protein on the plate and making meat the topping or side dish is a strategy promoted through the Culinary Institute of America's Protein Flip initiative (Culinary Institute of America & Harvard School of Public Health, 2016; which originated from the Menus of Change collaborative between the CIA and Harvard School of Public Health. Recreating the plate using meat as a garnish and complementing this dish with whole grain pasta, potatoes, vegetables, and protein-rich grain, legumes, nuts, and seeds is also an easy and creative way to rebuild an athlete's plate. This is the current topic of ongoing research at the United States Olympic Committee's (USOC) Food and Nutrition Services, as the Athlete's Plate (Team USA, n.d.) was shown to promote more protein than recommended for easy, moderate, and hard training days (Reguant-Closa, Harris, & Meyer, 2016). Further analysis indicates that the protein dished up on the plates by trained professionals was mostly of animal origin (more than 70%) with marginal amounts of plant protein (Reguant-closa, Judson, Harris, Moreman, & Meyer, 2016). It is expected, as was previously shown (Schösler et al., 2012), that food service organization and restaurants may lack the experience with meat-reduced, vegan and vegetarian cuisine. Thus, while flipping proteins of animal-based plates is becoming more popular, taking a closer look at vegan and vegetarian menus and their composition will also help promote plant-based meals for omnivores. Once culinary professionals, students, and nutrition professionals tackle such menus, calculating nutrient profiles could be helpful (Drewnowski & Fulgoni, 2011; Lobstein & Davies, 2009), as the outcome of a protein flip menu should not compromise nutrient density—in fact, it should improve it. Most athletes consume sufficient calories to meet micronutrient needs and the majority also takes dietary supplements (Knapik et al., 2016) and eats fortified foods (e.g., cereals, bars), which makes the integration of plant-based eating less concerning. Our preliminary work with the USOC Food and Nutrition Services shows hypothetically that (1) protein flip menus (with less meat) and (2) improved vegetarian menus, increase rather than compromise nutrients, while protein remains at moderate yet recommended levels for athletes. The University of Colorado, Colorado Springs, having transitioned from a corporate to a self-operated dining and hospitality system, recently adopted the CIA's Menus of Change initiative and serves a very popular protein flip burger at its local food station called "Food Next Door" (UCCS Dining and Hospitality Services: Food Next Door) (see Table 3.4 for examples).

Protein flip and vegetarian menus provide greater amounts of carbohydrate and fiber (Melina et al., 2016). While extra carbohydrates are performance-enhancing, there may be concerns that phytates from fiber may inhibit iron absorption, thus, making the iron from meat less available. One strategy to assist with improving bioavailability of these changed menus is through iron enhancers, including fermented foods. Lactic fermentation is one of the oldest methods for food preservation (Scheers, Rossander-Hulthen, Torsdottir, & Sandberg, 2016). Research shows that lactic fermentation of vegetables, corn, and soybeans can drastically reduce phytate content (Bering et al., 2006), thereby reducing its effect on nutrient absorption. For iron absorption, the mechanism is thought to be through the increase in ferric iron (Fe^{3+}), enhancing iron bioavailability (Scheers et al., 2016). It has also been shown that fermented sauerkraut improves iron absorption (Hallberg & Rossander, 1982) and that fermented foods contribute to enhanced nutrient bioavailability in Asian cultures (Kwak, Lee, Oh, & Park, 2010).

3.3.5. An Omnivore's Choice to Eat Vegan

While vegan diets may need more caution to ensure protein quantity, quality, and complementarity as well as achieving athletes' energy availability, it is generally accepted that these diets do not present with adverse health (Melina et al., 2016) or performance effects (Barr & Rideout, 2004; Dinu, Abbate, Gensini, Casini, & Sofi, 2016; Nieman, 1999; Venderley & Campbell, 2006). In fact, most data show that plant-based diets are not only great for the environment (Hallström et al., 2015; Tilman & Clark, 2014), but also human health (Dinu et al., 2016; Melina et al., 2016; Tilman & Clark, 2014), and they may promote performance enhancement (Craddock, Probst, & Peoples, 2016; Vergé et al., 2013). While some athletes may use vegan diets to mask an eating disorder, there is no evidence that vegan or vegetarian diets cause eating disorders (Fisak, Peterson, Tantleff-Dunn, & Molnar, 2006). Considering that a reduction in meat, using more plant-based approaches, is effective in decreasing environmental impact does not mean that athletes must turn vegan. However, integrating meat-less meals and days in omnivorous athletes is not only fun and healthful but it is also educational. Making tasty and nutritionally-balanced vegan meals can also mean a new challenge for those in the kitchen. If proper screening and assessment of individual athlete risk precedes the introduction of plant-based dietary approaches, and education is provided about the rationale for such an approach, there should be no concern.

The best start into an environmentally friendlier diet for athletes is to start right here. As sport nutrition professionals, we need to understand the impact diet has on the environment. Athletes can simply consider the total animal and plant protein contributions in their diet and aim to reduce (not eliminate) red meat first, followed by integration of more plant-based protein choices. A closer look at dairy protein may also be warranted. If everyone in the United States ate no meat just one day per week, it would account for the carbon equivalents of driving 91 billion miles less or taking 7.6 million cars off the road (Hamerschlag, 2011). Reducing meat consumption, in general, can have significant savings overall in food-related GhG emissions and land-use change, exceeding what can be achieved from the transportation sector (Hallström et al., 2015). Recent research also highlights the individuality of diets and that reductions in environmental impact can be achieved using various approaches, not necessarily compromising personal, cultural, or economic factors (Horgan, Perrin, Whybrow, & Macdiarmid, 2016). While animal protein reductions in athletes should be of primary importance considering environmental conservation, overall protein intake, nutritional status and the athlete's cultural background will determine if this is the best approach to take. However, we should not forget to highlight athletes who have been using vegan and vegetarian approaches and athletes who stand up for a healthier environment and restorative farming practices (Athlete's for Farming).

3.4. Quality of Food

3.4.1. Plant Biodiversity—Diet Diversity

In the last 100 years, three quarters of plant and animal species globally have been lost, and the majority of the world's food supply comes from a dozen plant and a handful of animal species (FAO, 2010). At the same time, food processing has increased in a way that creates an artificial diversity and a false sense of food security, when browsing through endless aisles in a grocery store. Perhaps it is this level of agricultural simplification that has made the broad field of nutrition oblivious to the topic of biodiversity. Balanced nutrition depends not only on a variety of foods in the diet. The human diet also depends on the diversity within a food crop (Mouillé, Charrondière, Burlingame, & Lutaladio, 2009). While largely understudied and under-documented, fragmented data show vast differences in nutrients within the same species; for example, in potatoes, rice, mangoes, bananas (Burlingame, Charrondiere, & Mouille, 2009; Burlingame, Mouillé, & Charrondière, 2009), and tomatoes (Pinela, Barros, Carvalho, & Ferreira, 2012), but also indigenous corn grown in the American Southwest (Dickerson, 2003). Perhaps one of the most striking results in nutrient density comes from the potato, a staple of many countries, and often marginalized as a processed fast food not tolerated on healthy plates. Potato biodiversity is still broad, with over 5000 known varieties remaining and vastly differing nutrient content (Burlingame, Mouillé, et al., 2009), particularly for sugar, protein, potassium and vitamin C. Similarly, wild plants, still contributing significantly to the health-promoting properties of the Mediterranean regions, have higher amounts of vitamins A, C, and those of the B-complex compared to their cultivated counterparts (Rivera et al., 2006). Interestingly, wild and local foods are increasingly being recognized as an integral part of contemporary nutrition, as countries are redefining their dietary guidelines, linking sustainable and healthful eating in a traditional context (Saxe, Larsen, & Mogensen, 2013; C. Van Dooren, Marinussen, Blonk, Aiking, & Vellinga, 2014). Unfortunately, crop biodiversity and its role in nutrition is generally neglected and this may be due to the field's professionals (Burlingame, Charrondiere, et al., 2009). Perhaps a visual comparison as shown in a recent New York Times article (Marsh & Curtius, 2013) brings the message home. We simply assume that a tomato is a tomato and that nutrient density will remain the same despite significant differences (Pinela et al., 2012). It is true that nutrition education appears to be almost blind to biodiversity (FAO, 2010), although resources are available (FAO, n.d.). Diet biodiversity is becoming a rapidly emerging field but has remained understudied, especially in the nutrition sciences. However, with the return to the farm, scientists are recognizing that agricultural biodiversity can support food and diet diversity, thereby improving nutrition and health (Bioversity International, 2014). Research is also emerging that agricultural intensification, characteristic of high yield outputs, is associated with the loss of rare plant species (Storkey, Meyer, Still, & Leuschner, 2012), but shifting to more sustainable systems, biodiversity may be conserved and ecological functions secured (Rockström et al., 2017). Losing biodiversity means loss of diet quality, which can lead to micronutrient deficiencies, food insecurity, more pests on farms, fragile ecosystems, and the loss of culture and tradition. Thus, biodiversity should not only be recognized as an important player in sustainable agriculture, but also as a necessary contributor to a healthy diet (Fanzo, Hünter, Borelli, & Mattei, 2013).

3.4.2. Nutrient Composition and Nutrient Density

Dietary choice from the farm or factory gate produces variable foods with variable consequences. Meat and dairy from cows grazing on pastures all their lives provide a nutritionally superior (Daley et al., 2010), healthier, and safer product (Fantke & Jolliet, 2016; Friel et al., 2009; Goldberg, 2016), especially considering antibiotic use in CAFOs (CDC, n.d.; Broom, Galindo, & Murgueitio, 2013). However, grassfed beef is generally more expensive and considered less sustainable because more land is needed for animals to graze, with greater GhG emissions per kg of beef produced (Ripple et al., 2014). Unfortunately, animal welfare is not yet part of LCA studies, thus, intensive, as opposed to extensive farming systems, usually fare better in both GhG emissions and land use (Ripple et al., 2014).

Considering the topic of fish, omega-3 fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) found variably in fish, wild and farmed, have significant health benefits (Calder, 2012) recognized by health organizations world-wide (FAO & WHO, 2011). Fish oils are also popular in athletes (Mickleborough, 2013). However, fish has been a topic of much debate, not only because of variable omega 3 fatty acid content but also environmental contaminants. Whether farmed fish contains lower, comparable, or greater amounts of EPA and DHA than a wild-caught counterpart continues to be an equivocal topic (Jakob et al., 2015; Lundebye et al., 2017; Nichols, Glencross, Petrie, & Singh, 2014; Usydus & Szlinder-Richert, 2012). The type of feed (plant vs fish-based) used in farmed fish is one important consideration (Seierstad et al., 2005). Recent trends of vegetable oils in salmon feed have shown to increase the proportion of omega 6 fatty acids, while omega 3 fatty acids decrease (Sprague, Dick, & Tocher, 2016), potentially impacting negatively on both fish and human health (Rosenlund, Torstensen, Stubhaug, Usman, & Sissener, 2016). Although wild fish supply is diminishing fast, if people were to eat the wild fish that are seasonally available rather than the wild fish they desire (e.g., salmon), there would continue to be some level of access—at least for a little while (NOAA Fisheries, 2016). However, wild fish supplies will not be able to meet the rising demand of a growing world population (FAO, 2014), nor will wild fish necessarily be free of pollutants (Lundebye et al., 2017). Already to date, more than 50% of all fish consumed globally come from aquacultures (FAO, 2014). Aquacultures generally emit lower GhG compared to wild fisheries, although concerns exist about the feed used in aquacultures (Ripple et al., 2014). While disconnecting marine resources from fish farming is recognized as an invaluable progress for protecting marine ecosystems, it does not come without increasing challenges about the feed used in aquacultures, especially if produced terrestrially (Fry et al., 2016). Perhaps plant alternatives (e.g., microalgae) will be able to provide sustainable solutions in the future, so humans can continue to benefit from fish-derived EPA and DHA.

What about conventional versus organic production? Organic milk provides a superior nutritional profile than conventional milk, with organic milk containing more protein and omega 3 fatty acids (Palupi, Jayanegara, Ploeger, & Kahl, 2012), and raw milk may provide potential protection against allergies, although there is a greater risk of pathogens (Lucey, 2015; van Neerven, Knol, Heck, & Savelkoul, 2012). On a crop-level, nutrient composition in food has suffered in the last sixty years, with nutrient losses of up to 30%, most likely due to depletion of soil nutrient quality (Worthington, 2001). Conventional agriculture may produce food more economically and in higher quantities. However, research is gradually emerging, showing ecological and human health repercussions of such systems (Eshel et al., 2014; Fantke & Jolliet, 2016; Guyton et al., 2015; Nemecek et al., 2011; Sabaté et al., 2014; Samsel & Seneff, 2013b). Organically grown soybeans show significantly higher nutrient composition, including amino acids, total protein and several micronutrients, compared to conventional and genetically modified (GM) soybeans. While the debate continues whether organic vs. conventional produce is superior in nutrients (Barański et al., 2014; Reganold & Wachter, 2016), organic foods contain significantly less herbicides, pesticides, toxins, and antibiotic residues (Barański et al., 2014; Di Renzo et al., 2007) compared with conventionally produced food. Organic systems can also be more energy-efficient, may thrive in drought conditions, tend not to pollute waterways with synthetic pesticides and nitrate, and typically protect ecosystem services, such as biodiversity (see Reganold and Wachter, 2016, for an excellent review. Finally, while largely understudied considering nutrient content, local food systems provide the most direct pathway from farm to table, with potential for greater nutrient density due to seasonality and reduced transit time from farm to consumer (Wunderlich, Feldman, Kane, & Hazhin, 2008).

Taken together, from animals to plants, we must begin to pay attention to the quality of food. In addition, people must understand that dietary choices have the power to either protect or degrade ecosystem and health services. This knowledge may be difficult to teach in a classroom, and it is not nearly as fun as going to the farm. Farm field trips may be especially health-promoting for young, active children, as recent studies show the immune benefit of growing up on the farm (Stein et al., 2016).

3.4.3. The Grain Chain

The discourse on better food for health of both planet and people, however, is not complete without a discussion on grains. In addition, grains remain the world's most important staple (FAO, 2010) and may be a key strategy of the Menus of Change initiative. And yet, there has not been more controversy regarding issues of modern wheat (Jabr, 2015), including its higher amounts of triggering gluten proteins (van den Broeck et al., 2010). Gluten-free eating has seen a tremendous popularity. In athletes, studies show that over 40% of athletes adhere to a gluten-free diet even if they do not have to (Lis, Stellingwerff, Shing, Ahuja K, & Fell, 2014), and despite the fact such diets do not improve performance (Dana Lis, Stellingwerff, Kitic, Ahuja, & Fell, 2015). However, are all grains as evil as they sound?

First, whole grains are packed with fiber, protein, carbohydrate, and B-vitamins and studies show whole grains reduce all-cause mortality and morbidity, with lower risk for cardiovascular disease, cancer, and diabetes (Aune et al., 2016). When wheat is grown organically it has been shown to contain superior nutritional profiles compared to conventional wheat (Vaher, Matso, Levandi, Helmja, & Kaljurand, 2010).

Wheat's nutritional profile has significantly decreased since the 1960s (Dinelli et al., 2011; Fan, Zhao, Fairweather-Tait, et al., 2008; Fan, Zhao, Poulton, & McGrath, 2008), while the number of new gluten proteins has increased (De Lorgeril & Salen, 2014), and this is reportedly not due to changes in soil, but changes in wheat hybridization. On the other hand, ancient wheat such as einkorn, emmer, kamut, durum, and spelt, celebrating a recent comeback, exceed nutrient composition (e.g., protein, lipids, minerals and elements, antioxidants such as lutein) compared to modern wheat (Dinelli et al., 2011; Hidalgo, Brandolini, Pompei, & Piscozzi, 2006; Hussain, Larsson, Kuktaite, & Johansson, 2010; Lachman, Orsák, Pivec, & Jírů, 2012). A recent study on khorosan, also known by the name Kamut, shows greater anti-inflammatory effects through antioxidants, blood minerals, and reduced metabolic (e.g., lipids, glucose) and oxidative stress markers in healthy subjects consuming khorosan in bread, pasta, and crackers for 8 weeks, compared to consuming these products made with a semi whole-wheat product (Sofi et al., 2013). Thus, these older cultivars may contribute significantly to nutrient dense diets (Hussain et al., 2010) and health promotion (Sofi et al., 2013).

Such ancient wheat varieties are not only more nutritious and promote antioxidant protection, but some also lack the highly immuno-suppressive —gliadin peptides— the major component of gluten that provokes gluten intolerance. These are encoded by the D-genome of wheat. Thus, species that lack the D-genome of wheat, such as einkorn, emmer, and durum, show lower reactivity compared to common wheat (Molberg et al., 2005). Work in Italy is currently focused on einkorn, the oldest form of wild wheat first domesticated 12,000 years ago by hunter-gatherers in Mesopotamia. Along with wild emmer, also known as the mother of all wheats, "einkorn is considered a catalyst of agriculture and the initiation of wheat's vast biodiversity" (Rogosa, 2016) (p.22). Einkorn appears to either pose no (Pizzuti et al., 2006) or fewer adverse reactions in Celiac patients compared to modern wheat (Zanini et al., 2013). Athletes who have been diagnosed with Celiac's disease, should consult their sport dietitian before trying einkorn since it may still have the potential to induce the Celiac's disease syndrome (Vaccino, Becker, Brandolini, Salamini, & Kilian, 2009). For a great review see Kucek, Veenstra, Amnuaycheewa & Sorrells, (2015) (Kucek, Veenstra, Amnuaycheewa, & Sorrell).

Understanding nutritional differences among grain varieties also opens the dialogue on bread. While the choice of grain permits greater nutrient intake, fermentation using a sourdough starter has also been shown to increase bioavailability of nutrients such as iron. This is most likely due to a reduction in phytates (Scheers et al., 2016). Fermented bread decreases post-prandial glycemic response through organic acids that delay gastric emptying (Björck & Elmståhl, 2003). This, therefore, is a great low glycemic alternative to processed white bread for active individuals, especially at breakfast. Finally, sourdough fermented bread also appears to retain antioxidants better due to lower pH levels (Lindenmeier & Hofmann, 2004), which if baked with an antioxidant and protein-rich grain, such as einkorn or emmer (Hidalgo et al., 2006), by far exceeds the nutrient density compared to bread made with modern wheat.

Studies also show that both germination (sprouting) and fermentation (e.g., sourdough baking) can break down gliadin, one of the gluten proteins known to increase reactivity. While still not safe for Celiac patients (Stenman et al., 2009), there are fewer immunoreactive peptides in sprouted products (Kucek et al., 2015). As for fermentation, lactic acid bacteria degrade some of the gliadins but multiple microbes appear to be needed to effectively degrade the majority of gliadin (Gallo, De Angelis, McSweeney, Corbo, & Gobbetti, 2005). In a study by Greco et al., (2011), 97% of gluten was degraded by fermentation (Greco et al., 2011). However, there were still a few Celiac patients in the study who showed measurable villi atrophy compared to non-gluten control treatments. Thus, wheat sourdough fermentation, as compared to non-fermented flour, does not degrade gluten enough to prevent adverse responses in Celiac patients (Engström, Sandberg, & Scheers, 2015).

Taken together, there does not seem a clear relief for Celiac patients, from ancient or heritage wheat, whether sprouted, fermented, or not. However, research suggests that there may be wide variability among reactivity to gluten, depending on the type of grain and level of processing. In addition, Celiac's disease expression, while triggered by gliadin-induced antibodies, can also be quite variable. While Celiac's disease has become more prevalent, with about 1% of the general population being affected, only 10%–20% of people appear to be aware of their condition and follow a strictly gluten-free diet (Kurppa et al., 2009). Mild forms of Celiac's disease, however, have the potential to worsen with age, thus, management through a gluten-free diet is necessary to decrease severe complications, such as osteoporotic fractures and intestinal cancers (Kurppa et al., 2009).

Interestingly, there are also other clinical presentations that do not fully correspond with Celiac's disease but rather consist of new clinical syndromes, typically termed non-celiac gluten and/or non-celiac wheat sensitivity. Though controversial and under-studied, it is generally accepted that these syndromes exist, but in the absence of gluten-ingested, celiac-specific antibodies (Catassi et al., 2013) or wheat allergies (De Lorgeril & Salen, 2014). What ultimately triggers these syndromes is unclear, as it may not need to be gluten but could include other components of wheat, such as the low fermentable, poorly absorbed, short-chain carbohydrates (FODMAPs) (Biesiekierski et al., 2013), other proteins (Junker et al., 2012), or insecticides such as glyphosate (Samsel & Seneff, 2013b, 2013a).

Regardless of exact mechanism, variability in clinical symptoms from grain or wheat ingestion pose new opportunities for nutrition professionals, considering both, the recent changes in clinical presentations and the modernization of many plants, including wheat (De Lorgeril & Salen, 2014). While challenging, this should provide new avenues for dietary management of those who prefer a gluten-free diet for performance enhancement or health promotion, in the absence of Celiac's disease, to trial various approaches (De Lorgeril & Salen, 2014; Greco et al., 2011; D Lis, Ahuja, Stellingwerff, Kitic, & Fell, 2016; McKenzie et al., 2016), as opposed to eating a strictly gluten-free diet. A gluten-free diet per se, with a high amount of processed gluten-free foods, may not meet nutritional recommendations, and a gluten-free, vegan diet could pose serious negative health and performance effects (e.g., B-vitamin deficiency). It has also been suggested that individuals should choose grains and their processing wisely, as this may reduce the risk of developing Celiac's disease in those who may have hereditary risk (Kucek et al., 2015). As ancient and heritage grain production is sweeping through the United States as a long-awaited player in the local food movement, the grain chain, from farmer to baker to table, is filled with food literacy opportunities for athletes such as making bread together. After all, bread has been a staple around the world with thousands of traditional uses. Bread is also one of the primary carbohydrate choices for athletes in training and competition, and carbohydrate is the major source of calories for most humans (Institute of Medicine, 2006), including athletes (Burke, Hawley, Wong, & Jeukendrup, 2011).

While ancient and heritage grains are making their way back to the grocery stores, their production remains relatively small. However, these grains are known to be more drought tolerant (Rogosa, 2016) and using grains in crop rotation or as cover crop can meaningfully contribute to farm diversification and sustainable agriculture (Reganold & Wachter, 2016). Grain production may soon take a turn for the better and become more sustainable as scientists at the Land Institute in Salina, Kansas (The Land Institute, n.d.) will likely announce that perennial grains (long roots capture carbon, enhance soil quality, and help reduce erosion) may replace modern wheat, not only on the field but also in people's bread baskets.

3.5. Food Literacy and Food Citizenship in Sport and Exercise

There is much to relearn when it comes to food. Perhaps we have moved away too far from field, farm, and the kitchen to know where food comes from and when it is in season. We also have lost important life skills such as cooking. We have to relearn and teach these simple skills to rebuild the knowledge needed to establish a healthy relationship with food. This brings us to the topic of food literacy. Recently, Vidgen and Gallegos, 2014 defined food literacy as the following:

"Food literacy is the scaffolding that empowers individuals, households, communities or nations to protect diet quality through change and strengthen dietary resilience over time. It is composed of a collection of inter-related knowledge, skills and behaviors required to plan, manage, select, prepare and eat food to meet needs and determine intake. This can simply be translated as the tools needed for a healthy lifelong relationship with food" (Vidgen & Gallegos, 2014) (p. 54).

Academic programs that promote food literacy, through curricula that meet joint goals of health promotion and sustainable development, especially in the health professions, may allow for transformative experiences (Hekler et al., 2010). Such food literacy discourse has the ability to diffuse, with outcomes that promote food citizenship in young people, and therefore, future generations (Gill & Stott, 2009; Wiek, Withycombe, & Redman, 2011). Food citizenship is the practice of engaging in food-related behaviors (defined narrowly and broadly) that support, rather than threaten, the democratic, socially and economically just, and environmentally sustainable food systems (Wilkins, 2005) (p. 271).

Athletes and their support staff should be introduced to the link between daily food choices, health, and sustainability. It is most likely the sport dietitian who will bring this topic to the table, and the best and least confrontational approach, may be through a sustainably sourced meal cooked together such as a "Team Dinner" or a fun food literacy event with multiple stations, competitive team work, and food-related prizes. Shopping at local food outlets, including the farmer's market, and cooking together might be other options to open the dialogue pertaining to sustainable quantity and quality of food, as discussed above. Eating practices and fueling strategies are a performance-determining factor; however, becoming a food citizen (O'Kane, 2016) with knowledge and skill to navigate through an ever more complex food web opens the narrow sport-performance focus of a young athlete and introduces areas such as environmental conservation. Thus, sport nutrition education should begin to integrate sustainable food topics and promote food citizenship and food literacy by an enabling, participatory approach when the timing is right and where opportunities arise.

3.5.1. Athletes to Farm

While sport nutrition is a broad field and athlete performance and health issues take precedent over sustainability efforts, the sport dietitian will need to find a good balance that allows for sustainability integration, without feeling constrained but rather enabled in promoting awareness, building knowledge, and enhancing skills around food, ultimately improving dietary habits of young people. Thus, going to a local farm and/or market to buy food is only the first stop in this refreshed sport nutrition curriculum. While athletes often crave for the latest in exotic products from far away (e.g., Acai berries), eating some of the unfamiliar and wild foods grown close to home, may not only be more nutritious, but will also come with a plethora of learning opportunities. To allow athletes to make a connection with their home environment through the farmers who grow their food, training plans may need to be flexible to allow for Community Supported Agriculture (CSA) share pick up, a farmer's market visit, or a farm-field training day, as this may offer invaluable experiential nutrition education. The opportunity for athletes to experience "local life" is short but is increasingly meaningful, as sport teams and elite athletes are in the spotlight at home. Engaging with the local community may bring personal and team-related benefits for farm-fresh food support that has the potential to strengthen athletes' community involvement and build a sense of place. Finally, investing in the community, through food procurement from local farms, may also set the precedent for a supportive environment should athletes get injured or to facilitate the transition from athletic to normalized life after the career is concluded.

Eating locally grown and raised food has many benefits, but it may not automatically be more environmentally sustainable. Nevertheless, the local food movement might ignite people's desire for better taste, connection to place and to the people in their community. Local food seems to attract people also because of its economic benefit to the community, and there is a general sense, despite the fact that local food often costs more, that it is more affordable (Feldmann & Hamm, 2015). Regardless, those having worked and experienced the local food movement cannot let it go, and while the urgency to become more food secure in this changing world calls for revolutionary action through more sustainable food production (Rockström et al., 2017), engaging in local food mobilizes people on a deeply emotional level, often difficult to express for those who are in it (Brownlee, 2016), but likely the reason why people may identify it as a realistic way to change eating behavior (de Boer et al., 2016). Recent research also shows that those buying direct from the farmer think and act around food very differently, compared to those going to a chain grocery store to procure their food (O'Kane, 2016). Thus, the local food system is engaging inter-personally and economically within a community and it also teaches about food, the seasons, biodiversity, flavors, nutrition, cooking, culture and tradition.

While not always the most sustainable, the local food system may be a vehicle that could direct people to healthier and more mindful eating. A recent study illustrates how the awareness of dietary choices and eating can meet joint goals of individual health, environmental sustainability, and food security (Fung, Long, Hung, & Cheung, 2016). Thus, the many facets of a local food system can act as living learning laboratory to practice mindfulness training, even in athletes and their teams, as they cultivate both eating for sport and eating for planet Earth.

Local food systems are defined as "collaborative effort in a particular place to build more locally based, self-reliant food systems and economics—one in which sustainable food production, processing, distribution and consumption is integrated to enhance the economic, environmental and social health of a particular place." (Feenstra, 2002) (p. 100).

If athletes receive food money, a resource factsheet with local food procurement options could begin the collaboration with local business. A factsheet could also promote best choices when shopping at grocery stores, how to identify what's locally produced, what's seasonal, which labels to observe (e.g., USDA Organic; Buy Local; Marine Stewardship Council, MSC or Aquaculture Stewardship Council, ASC; GMO Free Project; Humanely Raised, American Grassfed, Direct or Fair Trade), the list of the dirty dozen (Environmental Working Group, n.d.), and how to order in bulk online, including heritage/ancient grains. Identifying farm-team partnerships requires farm visits and direct communication with the farmers (Local Harvest, n.d.). In addition, providing some community service at the farm with 1 or 2 workouts held at the farm per year, supporting planting, weeding, or harvesting, will facilitate access to local, farm-fresh food because a connection is built much to the delight of the small-scale farmer who feels supported by the local sports team. Teams may also obtain group discounts if ordering in bulk through local buying clubs, food hubs, or food cooperatives. With CSA shares, there is great flexibility should shares get temporarily suspended when athletes travel. It is also possible to obtain surplus food and getting parents involved to preserve this food for later. Preservation, including fermentation, will not only support nutrition programming, but could be applied at times of increased team stress when athletes' immune function is more susceptible to illness. Locally, seasonally, and organically grown produce is more nutritious (Barański et al., 2014; Bøhn et al., 2014; Di Renzo et al., 2007; Palupi et al., 2012; Vaher et al., 2010) and fermentation (e.g., pre- and probiotics) may add immune (Martinez, Bedani, & Saad, 2015; Shokryazdan, Faseleh Jahromi, Navidshad, & Liang, 2017) support in times when athletes need it. Check with local University Extension offices for safe guidelines on canning and fermentation.

3.5.2. Taste Education and Cooking

Taste education with athletes can be integrated at any time, combined with a general team talk (locally grown fruit, vegetables, or grains as tasters), fueling or recovery workshops (integrating seasonal fruit, yogurt, and honey), or even during a travel nutrition talk (cultural food tasting of the travel destination). Nutrition should no longer be taught without hands-on learning from farm to kitchen. Written or visual materials (e.g., posters) or recipes that integrate local producers, topics of food citizenship (e.g., farmer's market shopping), or health benefits of diet diversity (e.g., biodiversity of greens) will keep building awareness and return home economics to young people's lives. Edible nutrition education is not only fun, inspiring, and tasty but it also teaches young people important skills and it builds a lifelong healthy relationship with food—and that is food literacy (Vidgen & Gallegos, 2014). In addition, working with a farm-to-training table curriculum in sports also provides an opportunity to highlight local producers, dairies, farmers, or bakers, the history of the place, and this brings meaning and relational values (Chan et al., 2016). If time is tight, University nutrition programs may partner to support a revisited curriculum that integrates agriculture and culinary training. One such example is the Flying Carrot Food Literacy Truck (Meyer, 2015). This program has been led by graduate students in sport nutrition at UCCS for the past 5 years (UCCS: Dining and Hospitality Services: The Flying Carrot, n.d.). After initial inception, several food-related courses, internships, and service learning experiences within the Southern Colorado regional food system, including a campus farm with its farm-to-table café, Food Next Door (UCCS Dining and Hospitality Services: Food Next Door, n.d.), and local food literacy farmhouse, are now serving a vigorous on-farm and in-kitchen curriculum for undergraduate and graduate students at UCCS, some of whom are in sport nutrition.

3.5.3. Budgets, Planning, and Food Waste

Food literacy should also integrate the full circle of engaged eaters' choices, including the discussion of food waste. Athletes and their families may tap into rescued food programs if budgets are tight. Most cities today have food rescue programs and some cities and programs, such as the one known as P.O.W.W.O.W. by the Borderland Foodbank in Southern Arizona (Borderlands Food Bank, n.d.), have made it possible to access fresh food, at affordable price, that otherwise would go to landfill. Food waste at the consumer level originates especially due to consumers' aesthetic preferences and arbitrary sell-by dates (Gustavsson et al., 2011) as well as simply by purchasing, cooking, preparing and serving too much (Parfitt et al., 2010). Teaching athletes to purchase what they can eat, cook what they purchase and promoting safe preservation and freezing techniques, are all part of food literacy training. The sport dietitian can help with weekly planning, providing input with shopping and cooking, so that athletes learn when, what, and how much to cook and to plan their dietary strategies, as much as the coach plans their training schedule. Cooking and planning ahead has been identified as a critical strategy to reducing food waste on the consumer level (Parfitt et al., 2010). When traveling, a little bit of research ahead of time will pay off. Food cooperatives often have restaurants and there are many "Pay-What-You-Can" non-profit community restaurants in the US that serve local and organic food, often rescued from what would have otherwise been wasted, and sold at very low price (or what the team can pay (One World Cafe, n.d.)). These types of food outlets, including food "waste" supermarkets, are becoming more available everywhere. Obviously, each such stop will add to nutrition education and athletes learn they can eat this way everywhere they go. For good restaurant, market, and café guides that serve local, sustainable, and organic food, see Slow Food USA or Edible Communities (Edible Communities, n.d.; "Slow Food USA," n.d.-a).

3.6. Timing of Sustainability Integration in Exercise and Sports

In this paper, we addressed the environmental impact of food choices, easy changes that can be made (e.g., eating less meat), and paying attention to the food value chain to obtain high quality food with zero waste strategies. We have also integrated the local food system as a great entry way to connect sustainability and health, leveraging co-benefits for both planet and people. Posing the question on when to integrate sustainability principles in sports nutrition may sound as if athletes and sport teams have a special status concerning the food of the future. The answer is, nobody does, and shifting to a low-carbon consumer culture is a necessity rather than a choice. However, there needs to be careful consideration when to launch or what to initiate within the economic boundaries of grass-root sports, where parents are the coaches and kids are running from A to Z with plastic wrappers in their hands, squeezing out their pre-game meal. Likewise, timing considerations on the elite level must involve everyone because the budgets will have to, at least in part, account for increased food costs, cooking and team dinners, and time to pick up fresh food at farmers' markets, farm stands or neighborhood stores.

The best timing to plan any new programs within the world of sports is usually as the season is coming to an end and early before the start of the next training cycle. This is especially true should extra resources be needed to support the program. Farm CSA shares cost between $500–$600 for 6–8 months or about $20–$30 weekly, with each share providing food for about 4 people. Team talks with edible tasters will either require planning and connecting with local producers for samples or more expensive transactions at the store or market. Thus, the more time is invested to form farm-to-sport partnerships, the better and more economical the outcome.

All athletes spend time training at home. This is the best time to teach shopping and cooking. Depending on the season, it is also the best time to introduce local food with farm and market visits. Even though athletes are still on the go every day while in training, there is the potential for community connections through the local food system. Thus, providing a platform for this to occur may create a new sense of purpose, external to the identity of being an athlete. Participating in the community may balance the lives of the elite and new friendships may arise with those who work the land, which may create awareness of earth stewardship and food citizenship.

Once a program launches it is difficult to hold it back and it will evolve on its own. This is especially true for the local food movement. It needs ignition, but once the web is being explored and experiences are made, there is no going back. It is a paradigm shift. It's a local food revolution (Brownlee, 2016).

Should sustainability be a topic while traveling? The answer is yes, because in many countries, sustainable food systems are still the norm. Thus, traveling to European and Eastern European countries is often an eye-opener. Taking athletes into the grocery stores or through a local market is food literacy away from home, and sport dietitians also increase their knowledge and skills when exploring foods abroad. While most travels abroad are hectic with little time, surprisingly, the Olympics may be the perfect place for food literacy. The local volunteers are a great resource for information and they provide access to local markets to purchase fresh food. Thus, even when traveling, there are multiple opportunities to broaden food experiences and teach important cultural food differences.

Finally, introducing sustainability in sport nutrition may also be timely for those who are injured. These athletes may have more time and interest to learn about whole, nutritious food and cooking that could enhance healing. In addition, introducing athletes to other areas outside of sport, such as agriculture or cooking, may distract the overly occupied mind, and help maintain a positive attitude during the recovery and return-to-play period.

Taken together, while the timing of sustainability integration must be carefully considered to bring change to nutrition programming for athletes, small steps can fit everywhere and they bring with them deliciousness, beauty, and inspiration to participate in the food chain from farm to kitchen and table. There should be no doubt that this is the future of how nutrition should be taught, also in sports.

3.7. Integration of Sustainability Practices as Collective Commitment in Sports

3.7.1. Team Sustainability

Integrating sustainability in the sport nutrition program benefits first the athlete. However, coaches and other members of the sport science team, including athletic trainer, sport medicine doctor, and psychologist all benefit. Because of the performance enhancing team approach and multi-disciplinary strategies, sustainability and food will also open the dialogue of sustainable practices in general. This may mean that the team develops a vision or even a policy for sustainable development, especially considering training venues at home, where more influence is possible. Starting with food and drink, this may mean the team implements a recycling, re-using, and composting strategy. It may mean the team bans bottled water and throw-away, take-out containers. And it may mean preferred vendors for training tables or team meetings come from local businesses, using sustainably and locally sourced food. Catering may be enhanced through the-less-but-better meat initiative in combination with highly nutritious grains and beans, seasonal vegetables and fresh fruit. Team commitments may also include coach and support staff's eating practices that are coherent with the underlying philosophy of eating for performance and health. Finally, taking on a team vision for a sustainable future may also inspire parents and families and this could be supported by social media and website resources. A great example of how sustainability can be part of every sporting venue is the Green Sports Alliance ("Green Sports Alliance," n.d.).

3.7.2. Institutional Sustainability

Whether it is at a high school, university, or national/regional/local sport center level, integrating sustainable food procurement into food service starts to open many opportunities. It allows for a new seasonal menu. Reducing meat through the protein flip and boosting vegetarian offerings, sparks creativity in chefs and curiosity in athletes. Sourcing locally brings in the story of the farmer, unknown diet diversity, and awareness related to the link between fresh food and health on an individual, community, and environmental level. If institutions have gardens or farms, there is potential to integrate edible education linked to the menu served, in addition to the invaluable seed- -to-plate menu. However, change is always more challenging than we think. Thus, to initiate a new menu, it is crucial that athletes and coaches understand the rationale behind the change. If resistance develops, athletes could be integrated in various educational activities that incorporate their own food preferences, cooking competitions, or recipe contests. It is helpful for athletes to see protein numbers of a meal and over a day to reduce fear of not getting enough. From a health perspective, there are many opportunities when food service commits to a more sustainable menu, with procurement gradually shifting to seasonal, organic, local, pasture-fed, free-range, and sustainably produced, fished or farmed food.

3.7.3. Event Sustainability

Integrating sustainable food into sporting events is being done on many levels. Some examples include London 2012 (*Food vision for the London 2012 Olympic Games and Paralympic Games*, 2009) and Rio 2016 (Rio Food Vision, 2014). Both local organizing committees published their sustainable food visions and made procurement with sustainable agricultural standards a priority. Especially the Rio Games were impressive as to the portrayed commitment to environmental consciousness through sustainable sourcing, improving supply chains, managing packaging, and reducing waste. As previously discussed, Brazil is one of the few countries whose governmental guidelines have embraced sustainability (FAO, 2016). Whether visions and guidelines are ultimately implemented at the international events is difficult to tell, as there has been no labeling that details sustainable sourcing. This has previously been noted and published by Pelly et al. 2014 based on a survey conducted by sport dietitians, representing various countries at the 2012 London Olympic Games (Pelly, Meyer, Pearce, Burkhart, & Burke, 2014). While the international sport nutrition organization, Professionals in Nutrition for Exercise and Sport (PINES) (Professionals in Nutrition for Exercise and Sport, n.d.) reviews the menus for each Olympic cycle, an on-site implementation phase could help improve both menu and labeling, with inclusion of sustainable sourcing. In addition, the athlete dining hall and the Olympic village present an enormous challenge to sustain environmental commitments, considering food waste, bottled beverages, and to-go meals. In the future, food service at the Olympic Games should promote sustainability more visibly, highlighting a country's food culture and offering athletes experiential learning opportunities that showcase regional food traditions, seasonality, world heritage, and the story of farmers. Tokyo 2020 would be an excellent host city to bring change to the athlete dining hall with greater transparency for sourcing, local food literacy, and hands-on learning (e.g., how to make tofu or soba). The Olympics are long and many athletes have downtime. Why not learn something about the host country's food culture, sustainability efforts, seasonality of food, and how traditional foods are produced? While currently implemented at the Youth Olympic Games, integrating the host country's food traditions could augment the cultural experience of athletes visiting the Olympic village dining hall.

4. Conclusions

Environmental impact of food production is high, especially when considering the GhG emissions, land, and water use of animal agriculture. Many governmental organizations are beginning to integrate sustainability into their dietary guidelines and are calling on consumers to eat less animal and more plant-based foods. Integrating health and sustainability creates co-benefits, as for the most part, sustainable eating also means healthful eating. Nutrition recommendations, for active and athletic individuals should also begin to integrate sustainability. Using innovative approaches, including experiential learning from farm to table, renews the relationship of food by rediscovering the broad meaning of food, building knowledge and skills in the kitchen, and sharing food around the table. Initiating sustainable practices in sport, including sustainable food procurement, opens many opportunities for athletes and their entourage to engage in local and regional food systems, and by curbing the appetite for meat, individuals, teams, institutions and organizers begin to contribute to a reduction in global warming from the food sector.

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References

Aiking, H. (2014). Protein production: Planet, profit, plus people? *American Journal of Clinical Nutrition*, *100*(SUP-PL. 1), 483–489. https://doi.org/10.3945/ajcn.113.071209

Aleksandrowicz, L., Green, R., Joy, E. J. M., Smith, P., & Haines, A. (2016). The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: A systematic review. *PLoS ONE*, *11*(11), 1–16. https://doi.org/10.1371/journal.pone.0165797

Antibiotic / Antimicrobial Resistance | CDC. (n.d.). Retrieved December 30, 2016, from https://www.cdc.gov/drugresistance/

Arciero, P. J., Miller, V. J., & Ward, E. (2015). Performance Enhancing Diets and the PRISE Protocol to Optimize Athletic Performance. *Journal of Nutrition and Metabolism*, *2015*, 715859. https://doi.org/10.1155/2015/715859

Areta, J. L., Burke, L. M., Ross, M. L., Camera, D. M., West, D. W. D., Broad, E. M., ... Coffey, V. G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *The Journal of Physiology*, *591*(9), 2319–2331. https://doi.org/10.1113/jphysiol.2012.244897

Atherton, P. J., Etheridge, T., Watt, P. W., Wilkinson, D., Selby, A., Rankin, D., ... Rennie, M. J. (2010). Muscle full effect after oral protein: time-dependent concordance and discordance between human muscle protein synthesis and mTORC1 signaling. *The American Journal of Clinical Nutrition*, *92*(5), 1080–1088. https://doi.org/10.3945/ajcn.2010.29819

Athlete's for Farming. (n.d.). Retrieved January 1, 2016, from https://athletesforfarming.com

Auestad, N., & Fulgoni, V. L. (2015). What current literature tells us about sustainable diets: emerging research linking dietary patterns, environmental sustainability, and economics. *Advances in Nutrition (Bethesda, Md.)*, *6*(1), 19–36. https://doi.org/10.3945/an.114.005694

Aune, D., Keum, N., Giovannucci, E., Fadnes, L. T., Boffetta, P., Greenwood, D. C., ... Norat, T. (2016). Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. *BMJ (Clinical Research Ed.)*, *353*, i2716. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/27301975

Babault, N., Païzis, C., Deley, G., Guérin-Deremaux, L., Saniez, M.-H., Lefranc-Millot, C., & Allaert, F. A. (2015). Pea proteins oral supplementation promotes muscle thickness gains during resistance training: a double-blind, randomized, Placebo-controlled clinical trial vs. Whey protein. *Journal of the International Society of Sports Nutrition*, *12*(1), 3. https://doi.org/10.1186/s12970-014-0064-5

Bajželj, B., Richards, K. S., Allwood, J. M., Smith, P., Dennis, J. S., Curmi, E., & Gilligan, C. A. (2014). Importance of food-demand management for climate mitigation. *Nature Climate Change*, 4(10), 924–929. https://doi.org/10.1038/nclimate2353

Barański, M., Średnicka-Tober, D., Volakakis, N., Seal, C., Sanderson, R., Stewart, G. B., ... Leifert, C. (2014). Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. *British Journal of Nutrition*, *112*(05), 794–811. https://doi.org/10.1017/S0007114514001366

Barr, S. I., & Rideout, C. A. (2004). Nutritional considerations for vegetarian athletes. *Nutrition*. https://doi.org/10.1016/j.nut.2004.04.015

Bassett, A., Gunther, A., & Mundy, P. (2013). *A Breath of Fresh Air: The truth about pasture-based livestock production and environmental sustainability*. Retrieved from http://animalwelfareapproved.org/wp-content/uploads/2013/01/A-Breath-of-Fresh-Air-v1.pdf

Batello, C., Wade, L., Cox, S., Pogna, N., Bozzini, A., & Choptiany, J. (2013). *Perennial Crops for Food Security: Proceedings of the FAO Expert Workshop. Proceedings of the Perennial crops for food security Proceedings of the FAO expert workshop.*

Bering, S., Suchdev, S., Sjøltov, L., Berggren, A., Tetens, I., & Bukhave, K. (2006). A lactic acid-fermented oat gruel increases non-haem iron absorption from a phytate-rich meal in healthy women of childbearing age. *The British Journal of Nutrition*, *96*(1), 80–85. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16869994

Biesiekierski, J., Peters, S., Newnham, E., Rosella, O., Muir, J., & Gibson, P. (2013). No effects of gluten in patients with self-reported non-celiac gluten sensitivity after dietary reduction of fermentable, poorly absorbed, short-chain carbohydartes. *Gastroenterology*, *145*(2), 320–328. https://doi.org/10.1053/j.gastro.2013.04.051

Bioversity International. (2014). *Annual Report, 2013*. Rome, Italy. Retrieved from http://www.bioversityinternational.org/e-library/publications/detail/bioversity-international-annual-report-2013/

Björck, I., & Elmståhl, H. L. (2003). The glycaemic index: importance of dietary fibre and other food properties. *The Proceedings of the Nutrition Society*, *62*(1), 201–206. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12749347

Bøhn, T., Cuhra, M., Traavik, T., Sanden, M., Fagan, J., & Primicerio, R. (2014). Compositional differences in soybeans on the market: Glyphosate accumulates in Roundup Ready GM soybeans. *Food Chemistry*, *153*, 207–215. https://doi.org/10.1016/j.foodchem.2013.12.054

Borderlands Food Bank. (n.d.). Retrieved June 10, 2016, from http://www.borderlandfoodbank.org

Bratland-Sanda, S., & Sundgot-Borgen, J. (2013). Eating disorders in athletes: Overview of prevalence, risk factors and recommendations for prevention and treatment. *European Journal of Sport Science*, *13*(5), 499–508. https://doi.org/10.1080/17461391.2012.740504

Broom, D. M., Galindo, F. A., & Murgueitio, E. (2013). Sustainable, efficient livestock production with high biodiversity and good welfare for animals. *Proceedings of the Royal Society B: Biological Sciences*, *280*(1771), 20132025–20132025. https://doi.org/10.1098/rspb.2013.2025

Brownlee, M. (2016). *The Local Food Revolution: how humanity will feed itself in uncertain times*. Berkley, CA: North Atlantic Books.

Brundtland, G. (1987). Report of the World Commision on Environement and Development: Our Common Future. *Oxford Paperbacks*, 400. https://doi.org/10.2307/2621529

Bulletin of the International Dairy Federation (IDF/FIL). (2010). *The World Dairy Situation 446/2010*.

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences*, *29 Suppl 1*, S17-27. https://doi.org/10.1080/02640414.2011.585473

Burlingame, B., Charrondiere, R., & Mouille, B. (2009). Food composition is fundamental to the cross-cutting initiative on biodiversity for food and nutrition. *Journal of Food Composition and Analysis*, *22*(5), 361–365. https://doi.org/10.1016/j.jfca.2009.05.003

Burlingame, B., Mouillé, B., & Charrondière, R. (2009). Nutrients, bioactive non-nutrients and anti-nutrients in potatoes. *Journal of Food Composition and Analysis*, *22*(6), 494–502. https://doi.org/10.1016/j.jfca.2009.09.001

Buttriss, J. L. (2016). The Eatwell Guide refreshed. *Nutrition Bulletin*, *41*(2), 135–141. https://doi.org/10.1111/nbu.12211

Calder, P. C. (2012). Omega-3 polyunsaturated fatty acids and inflammatory processes : nutrition or pharmacology ? https://doi.org/10.1111/j.1365-2125.2012.04374.x

Carlsson-Kanyama, A., & González, A. D. (2009). Potential contributions of food consumption patterns to climate change. *The American Journal of Clinical Nutrition*, *89*(5), 1704S-1709S. https://doi.org/10.3945/ajcn.2009.26736AA

Catassi, C., Bai, C., Bonaz, B., Bouma, G., Calabrò, A., Carroccio, A., … Holtmeier, W. (2013). Non-Celiac Gluten Sensitivity: The New Frontier of Gluten related Disorders. *Nutrients*, *5*(10), 3839–3853. https://doi.org/10.3390/nu5103839

Chan, K. M. A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., … Turner, N. (2016). Opinion: Why protect nature? Rethinking values and the environment. *Proceedings of the National Academy of Sciences*, *113*(6), 1462–1465. https://doi.org/10.1073/pnas.1525002113

Charles, H., Godfray, J., & Garnett, T. (2014). Food security and sustainable intensification. *Philos Trans R Soc B*, *369*. https://doi.org/10.1098/rstb.2012.0273

Churchward-Venne, T. A., Murphy, C. H., Longland, T. M., & Phillips, S. M. (2013). Role of protein and amino acids in promoting lean mass accretion with resistance exercise and attenuating lean mass loss during energy deficit in humans. *Amino Acids*, *45*(2), 231–240. https://doi.org/10.1007/s00726-013-1506-0

Council for Agriculture Science & technology. (1999). *Animal Agriculture and Global Food Supply. 1999. Task Force Report* (Vol. 135). Ames, Iowa, USA.

Craddock, J. C., Probst, Y. C., & Peoples, G. E. (2016). Vegetarian and Omnivorous Nutrition - Comparing Physical Performance. *International Journal of Sport Nutrition and Exercise Metabolism*, *26*(3), 212–220. https://doi.org/10.1123/ijsnem.2015-0231

Culinary Institute of America, & Harvard School of Public Health. (2016). *Protein Plays: Foodservice strategies for our future*. Retrieved from www.menusofchange.org

Daley, C. A., Abbott, A., Doyle, P. S., Nader, G. A., & Larson, S. (2010). A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. *Nutrition Journal*, *9*, 10. https://doi.org/10.1186/1475-2891-9-10

de Boer, J., de Witt, A., & Aiking, H. (2016). Help the climate, change your diet: A cross-sectional study on how to involve consumers in a transition to a low-carbon society. *Appetite*, *98*, 19–27. https://doi.org/10.1016/j.appet.2015.12.001

De Lorgeril, M., & Salen, P. (2014). Gluten and wheat intolerance today: are modern wheat strains involved? *Int J Food Sci Nutr*, *65*(5), 963–7486. https://doi.org/10.3109/09637486.2014.886185

Della Guardia, L., Cavallaro, M., & Cena, H. (2015). The risks of self-made diets: the case of an amateur bodybuilder. *Journal of the International Society of Sports Nutrition*, *12*(1), 16. https://doi.org/10.1186/s12970-015-0077-8

DeLonge, M. S., Owen, J. J., & Silver, W. L. (2014). *Greenhouse Gas Mitigation Opportunities in California Agriculture: Review of California Rangeland Emissions and Mitigation Potential.. NI GGMOCA R* 4. Durham, NC.

Di Renzo, L., Di Pierro, D., Bigioni, M., Sodi, V., Galvano, F., Cianci, R., … De Lorenzo, A. (2007). Is antioxidant plasma status in humans a consequence of the antioxidant food content influence? *European Review for Medical and Pharmacological Sciences*, *11*(3), 185–192.

Dickerson, G. (2003). Nutritional analysis of New Mexico blue corn and dent corn kernels Guide H-233. *Cooperative Extension Service, New Mexico State University*, (H-223), 1–2. Retrieved from http://agris.fao.org/agris-search/search.do?recordID=US9509600

Dinelli, G., Segura-Carretero, A., Di Silvestro, R., Marotti, I., Arráez-Román, D., Benedettelli, S., … Fernadez-Gutierrez, A. (2011). Profiles of phenolic compounds in modern and old common wheat varieties determined by liquid chromatography coupled with time-of-flight mass spectrometry. *Journal of Chromatography A*, *1218*(42), 7670–7681. https://doi.org/10.1016/j.chroma.2011.05.065

Dinu, M., Abbate, R., Gensini, G. F., Casini, A., & Sofi, F. (2016). Vegetarian, vegan diets and multiple health outcomes: a systematic review with meta-analysis of observational studies. *Critical Reviews in Food Science and Nutrition*, 0. https://doi.org/10.1080/10408398.2016.1138447

Drewnowski, A., & Fulgoni, V. (2011). Comparing the Nutrient Rich Foods Index with "Go," "Slow," and "Whoa" Foods. *Journal of the American Dietetic Association*, *111*(2), 280–284. https://doi.org/10.1016/j.jada.2010.10.045

Edible Communities. (n.d.). Retrieved October 10, 2016, from http://www.ediblecommunities.com/

Egli, V., Oliver, M., & Tautolo, E. S. (2016). The development of a model of community garden benefits to wellbeing. *Preventive Medicine Reports*, *3*, 348–352. https://doi.org/10.1016/j.pmedr.2016.04.005

Engström, N., Sandberg, A. S., & Scheers, N. (2015). Sourdough fermentation of wheat flour does not prevent the interaction of transglutaminase 2 with 2-gliadin or gluten. *Nutrients*, *7*(4), 2134–2144. https://doi.org/10.3390/nu7042134

Environmental Working Group. (2016). WEG's 2016 Shopper's Guide to Pesticides in Produce. Retrieved August 16, 2016, from https://www.ewg.org/foodnews/dirty_dozen_list.php

Eshel, G., Shepon, A., Makov, T., & Milo, R. (2014). Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States. *Proceedings of the National Academy of Sciences*, 1402183111-. https://doi.org/10.1073/pnas.1402183111

Fan, M. S., Zhao, F. J., Fairweather-Tait, S. J., Poulton, P. R., Dunham, S. J., & McGrath, S. P. (2008). Evidence of decreasing mineral density in wheat grain over the last 160 years. *Journal of Trace Elements in Medicine and Biology*, *22*(4), 315–324. https://doi.org/10.1016/j.jtemb.2008.07.002

Fan, M. S., Zhao, F. J., Poulton, P. R., & McGrath, S. P. (2008). Historical changes in the concentrations of selenium in soil and wheat grain from the Broadbalk experiment over the last 160??years. *Science of the Total Environment*, *389*(2–3), 532–538. https://doi.org/10.1016/j.scitotenv.2007.08.024

Fantke, P., & Jolliet, O. (2016). Life cycle human health impacts of 875 pesticides, *21*(5), 722–733. https://doi.org/10.1007/s11367-015-0910-y

Fanzo, J., Hünter, D., Borelli, T., & Mattei, F. (2013). *Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health (Issues in Agricultural Biodiversity)*. (Routledge, Ed.) (Halewood,).

FAO. Animal Production and Health Division. (2010). *Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment*. Rome, Italy. https://doi.org/10.1016/S0301-4215(01)00105-7

FAO. International Network of Food Data Systems (INFOODS): Nutrition and Biodiversity. Retrieved August 9, 2016, from www.fao.org/infoods/infoods/food-biodiversity/en/

FAO. (2010). *Sustainable diets and biodiversity*. Rome: Food and Agriculture Organisation of the United Nations (FAO). https://doi.org/10.1017/S002081830000607X

FAO. (2013). *Food wastage footprint Summary Report*. Rome, Italy.

FAO. (2014). *The state of world fisheries and aquaculture. Food and Agriculture Oraganization of the United Nations* (Vol. 2014). https://doi.org/92-5-105177-1

FAO. (2016). *Plates, pyramids, planets. Developments in national healthy and sustainable dietary guidelines: a state of play assessment*. Food and Agriculture Organisation of the United Nations (FAO) and the Food Climate Research Network at The University of Oxford (FCRN).

FAO. (2006). *Livestock's long shadow - environmental issues and options. Food and Agriculture Organization of the United Nations* (Vol. 3). Rome, Italy. https://doi.org/10.1007/s10666-008-9149-3

The Food and Agriculture Organization/World Health Organization. (2011). Report of the joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption; FAO: Rome, Italy; World Health Organization: Geneva, Switzerland, 2011; p. 50.

FAOSTAT. (n.d.). Retrieved August 29, 2016, from http://www.fao.org/faostat/en/#home

Feenstra, G. (2002). Creating space for sustainable food systems: Lessons from the field. *Agriculture and Human Values*, *19*, 99–106. https://doi.org/DOI: 10.1023/A:1016095421310

Feldmann, C., & Hamm, U. (2015). Consumers' perceptions and preferences for local food: A review. *Food Quality and Preference*, *40*(PA), 152–164. https://doi.org/10.1016/j.foodqual.2014.09.014

Fisak, B., Peterson, R. D., Tantleff-Dunn, S., & Molnar, J. M. (2006). Challenging previous conceptions of vegetarianism and eating disorders. *Eating and Weight Disorders : EWD*, *11*(4), 195–200. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17272949

Food vision for the London 2012 Olympic Games and Paralympic Games. (2009). London. Retrieved from http://learninglegacy.independent.gov.uk/documents/pdfs/sustainability/cp-london-2012-food-vision.pdf

Friel, S., Dangour, A. D., Garnett, T., Lock, K., Chalabi, Z., Roberts, I., … Haines, A. (2009). Public health benefits of strategies to reduce greenhouse-gas emissions: food and agriculture. *The Lancet*, *374*(9706), 2016–2025. https://doi.org/10.1016/S0140-6736(09)61753-0

Fry, J. P., Love, D. C., MacDonald, G. K., West, P. C., Engstrom, P. M., Nachman, K. E., & Lawrence, R. S. (2016). Environmental health impacts of feeding crops to farmed fish. *Environment International*, *91*, 201–214. https://doi.org/10.1016/j.envint.2016.02.022

Fung, T. T., Long, M. W., Hung, P., & Cheung, L. W. Y. (2016). An Expanded Model for Mindful Eating for Health Promotion and Sustainability: Issues and Challenges for Dietetics Practice. *Journal of the Academy of Nutrition and Dietetics*, *116*(7), 1081–1086. https://doi.org/10.1016/j.jand.2016.03.013

Gallo, G., De Angelis, M., McSweeney, P. L. H., Corbo, M. R., & Gobbetti, M. (2005). Partial purification and characterization of an X-prolyl dipeptidyl aminopeptidase from Lactobacillus sanfranciscensis CB1. *Food Chemistry*, *91*(3), 535–544.

Garnett, T. (2016). Plating up solutions, *353*(6305).

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., … Tempio, G. (2013). *Tackling Climate Change Through Livestock-A global assessment of emissions and mitigation opportunities*. *FAO, Rome*. Rome.

Gill, M., & Stott, R. (2009). Health professionals must act to tackle climate change. *The Lancet*, *374*(9706), 1953–1955. https://doi.org/10.1016/S0140-6736(09)61830-4

Gillen, J. B., Trommelen, J., Wardenaar, F. C., Brinkmans, N. Y. J., Versteegen, J. J., Jonvik, K. L., … van Loon, L. J. C. (2016). Dietary Protein Intake and Distribution Patterns of Well-Trained Dutch Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, 1–23. https://doi.org/10.1123/ijsnem.2016-0154

Goldberg, A. M. (2016). Farm Animal Welfare and Human Health. *Current Environmental Health Reports*, 313–321. https://doi.org/10.1007/s40572-016-0097-9

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., & Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Philos Trans R Soc Lond B Biol Sci*, *365*(1554), 2973–2989. https://doi.org/10.1098/rstb.2010.0158

Greco, L., Gobbetti, M., Auricchio, R., Di Mase, R., Landolfo, F., Paparo, F., … Auricchio, S. (2011). Safety for Patients With Celiac Disease of Baked Goods Made of Wheat Flour Hydrolyzed During Food Processing. *Clinical Gastroenterology and Hepatology*, *9*(1), 24–29. https://doi.org/10.1016/j.cgh.2010.09.025

Green Sports Alliance. (n.d.). Retrieved August 18, 2016, from http://greensportsalliance.org/

Gunders, D. (2012). Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill. *NRDC Issue Paper*, (August), 1–26. https://doi.org/12-06-B

Gustavsson, J., Cederberg, C., & Sonesson, U. (2011). *Global food losses and food waste - Extent, causes and prevention*. *FAO*. Rome, Italy.

Guyton, K. Z., Loomis, D., Grosse, Y., El Ghissassi, F., Benbrahim-Tallaa, L., Guha, N., … Zeise, L. (2015). Carcinogenicity of tetrachlorvinphos, parathion, malathion, diazinon, and glyphosate. *The Lancet Oncology*, *16*(5), 490–491. https://doi.org/10.1016/S1470-2045(15)70134-8

Hall, K. D., Guo, J., Dore, M., & Chow, C. C. (2009). The Progressive Increase of Food Waste in America and Its Environmental Impact, 4(11), 9–14. https://doi.org/10.1371/journal.pone.0007940

Hallberg, L., & Rossander, L. (1982). Absorption of iron from Western-type lunch and dinner meals. *The American Journal of Clinical Nutrition*, *35*(3), 502–509. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7064901

Hallström, E., Carlsson-Kanyama, A., & Börjesson, P. (2015). Environmental impact of dietary change: a systematic review. *Journal of Cleaner Production*, *91*, 1–11. https://doi.org/10.1016/j.jclepro.2014.12.008

Hamerschlag, K. (2011). *Meat Eaters Guide to climate Change and Health*. *Environmental Networking Group* (Vol. 115). https://doi.org/10.1097/ALN.0b013e3182318466

Hanlon, P., Carlisle, S., Hannah, M., Lyon, A., & Reilly, D. (2012). A perspective on the future public health practitioner. *Perspectives in Public Health*, *132*(5), 235–239. https://doi.org/10.1177/1757913911412217

Hansen, J., Sato, M., Hearty, P., Ruedy, R., Kelley, M., Masson-Delmotte, V., … Bauer, M. (2016). Ice melt, sea level rise and superstorms: Evidence from paleoclimate data, climate modeling, and modern observations that 2 ??c global warming could be dangerous. *Atmospheric Chemistry and Physics*, *16*(6), 3761–3812. https://doi.org/10.5194/acp-16-3761-2016

Hekler, E. B., Gardner, C. D., & Robinson, T. N. (2010). Effects of a College Course About Food and Society on Students' Eating Behaviors. *AMEPRE*, *38*(5), 543–547. https://doi.org/10.1016/j.amepre.2010.01.026

Helms, E. R., Aragon, A. A., & Fitschen, P. J. (2014). Evidence-based recommendations for natural bodybuilding contest preparation: nutrition and supplementation. *Journal of the International Society of Sports Nutrition*, *11*(1), 20. https://doi.org/10.1186/1550-2783-11-20

Helms, E. R., Zinn, C., Rowlands, D. S., & Brown, S. R. (2014). A systematic review of dietary protein during caloric restriction in resistance trained lean athletes: a case for higher intakes. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(2), 127–138. https://doi.org/10.1123/ijsnem.2013-0054

Herrero, M., Havlík, P., Valin, H., Notenbaert, A., Rufino, M. C., Thornton, P. K., ... Obersteiner, M. (2013). Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(52), 20888–20893. https://doi.org/10.1073/pnas.1308149110

Hidalgo, A., Brandolini, A., Pompei, C., & Piscozzi, R. (2006). Carotenoids and tocols of einkorn wheat (Triticum monococcum ssp. monococcum L.). *Journal of Cereal Science*, *44*(2), 182–193. https://doi.org/10.1016/j.jcs.2006.06.002

Hoekstra, A. Y. (2012). The hidden water resource use behind meat and dairy. *Animal Frontiers*, *2*(2), 3–8. https://doi.org/10.2527/af.2012-0038

Horgan, G. W., Perrin, A., Whybrow, S., & Macdiarmid, J. I. (2016). Achieving dietary recommendations and reducing greenhouse gas emissions: modelling diets to minimise the change from current intakes. *International Journal of Behavioral Nutrition and Physical Activity*, *13*(1), 46. https://doi.org/10.1186/s12966-016-0370-1

Huang, W., Han, Y., Xu, J., Zhu, W., & Li, Z. (2013). Red and processed meat intake and risk of esophageal adenocarcinoma: a meta-analysis of observational studies. *Cancer Causes & Control*, *24*(1), 193–201. https://doi.org/10.1007/s10552-012-0105-9

Hussain, A., Larsson, H., Kuktaite, R., & Johansson, E. (2010). Mineral composition of organically grown wheat genotypes: Contribution to daily minerals intake. *International Journal of Environmental Research and Public Health*, *7*(9), 3442–3456. https://doi.org/10.3390/ijerph7093442

Institute of Medicine. (2006). *Dietary reference intakes: the essential guide to nutrient requirements*. *Dietary Reference Intakes*. Retrieved from www.iom.edu.

IPPC. (2014). *IPCC, 2014: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. *Cambridge University Press*. Cambridge, United Kingdom and New York, NY, USA. https://doi.org/10.1017/CBO9781107415416

ISO 14040:2006. Environmental management - Life Cycle Assessment - Principles and Framework. (2006).

Jabr, F. (2015, October 29). Bread is Broken. *The New York Times Magazine*. Retrieved from http://www.nytimes.com/2015/11/01/magazine/bread-is-broken.html

Jakob, O., Hove, H. T., Duinker, A., Lundebye, A., Berntssen, M. H. G., Hannisdal, R., ... Julshamn, K. (2015). Contaminant levels in Norwegian farmed Atlantic salmon (Salmo salar) in the 13-year period from 1999 to 2011. *Environment International*, *74*, 274–280. https://doi.org/10.1016/j.envint.2014.10.008

Jones, T. W. (2004). *Using Contemporary Archaeology and Applied Anthropology to Understand Food Loss in the American Food System*.

Junker, Y., Zeissig, S., Kim, S.-J., Barisani, D., Wieser, H., Leffler, D. a, ... Schuppan, D. (2012). Wheat amylase trypsin inhibitors drive intestinal inflammation via activation of toll-like receptor 4. *The Journal of Experimental Medicine*, *209*(13), 2395–2408. https://doi.org/10.1084/jem.20102660

Juzwiak, C. R., Amancio, O. M. S., Vitalle, M. S. S., Pinheiro, M. M., & Szejnfeld, V. L. (2008). Body composition and nutritional profile of male adolescent tennis players. *Journal of Sports Sciences*, *26*(11), 1209–1217. https://doi.org/10.1080/02640410801930192

Kibria, G., Yousuf Haroon, A., Nugegoda, D., & Rose, G. (2010). *Climate change and chemicals: Environmental and biological aspects*. New Delhi, India: New Indial Publishing.

Kjærgård, B., Land, B., & Bransholm Pedersen, K. (2014). Health and sustainability. *Health Promotion International*, *29*(3), 558–568. https://doi.org/10.1093/heapro/das071

Knapik, J. J., Steelman, R. A., Hoedebecke, S. S., Austin, K. G., Farina, E. K., & Lieberman, H. R. (2016). Prevalence of Dietary Supplement Use by Athletes: Systematic Review and Meta-Analysis. *Sports Medicine (Auckland, N.Z.)*, *46*(1), 103–123. https://doi.org/10.1007/s40279-015-0387-7

Konikow, L. F. (2013). Groundwater Depletion in the United States (1900 – 2008). *Scientific Investigations Report 2013 – 5079*, 75. https://doi.org/10.1111/gwat.12306

Krebs-Smith, S. M., Guenther, P. M., Subar, A. F., Kirkpatrick, S. I., & Dodd, K. W. (2010). Americans do not meet federal dietary recommendations. *The Journal of Nutrition*, *140*(10), 1832–1838. https://doi.org/10.3945/jn.110.124826

Kucek, L. K., Veenstra, L. D., Amnuaycheewa, P., & Sorrells, M. E. (2015). A grounded guide to gluten how modern genotypes and processing impact wheat sensitivity. *Comprehensive Reviews in Food Science and Food Safety*, *14*(3), 285–302. https://doi.org/10.1111/1541-4337.12129

Kurppa, K., Collin, P., Viljamaa, M., Haimila, K., Saavalainen, P., Partanen, J., … Kaukinen, K. (2009). Diagnosing mild enteropathy celiac disease: a randomized, controlled clinical study. *Gastroenterology*, *136*(3), 816–823. https://doi.org/10.1053/j.gastro.2008.11.040. Epub 2008 Nov2014

Kwak, C. S., Lee, M. S., Oh, S. I., & Park, S. C. (2010). Discovery of Novel Sources of Vitamin B 12 in Traditional Korean Foods from Nutritional Surveys of Centenarians. *Current Gerontology and Geriatrics Research*, *2010*, 1–11. https://doi.org/10.1155/2010/374897

Lachman, J., Orsák, M., Pivec, V., & Jírů, K. (2012). Antioxidant activity of grain of einkorn (Triticum mono-coccum l.), emmer (Triticum dicoccum schuebl [schrank]) and spring wheat (Triticum aestivum l.) varieties. *Plant, Soil and Environment*, *58*(1), 15–21.

Lagerberg Fogelberg, C. (2013). *Towards environmentally sound dietary guidelines*. Retrieved from https://www.livsmedelsverket.se/globalassets/rapporter/2008/2008_nfa_report_9_towards_environmentally_sound_dietary_guidelines.pdf

Lindenmeier, M., & Hofmann, T. (2004). Influence of Baking Conditions and Precursor Supplementation on the Amounts of the Antioxidant Pronyl- l -lysine in Bakery Products. *Journal of Agricultural and Food Chemistry*, *52*(2), 350–354. https://doi.org/10.1021/jf0346657

Lis, D, Ahuja, K. D. K., Stellingwerff, T., Kitic, C. M., & Fell, J. (2016). Case Study: Utilizing a low FODMAP Diet to Combat Exercise-Induced Gastrointestinal Symptoms. *International Journal of Sports Nutrition and Exercise Metabolism*, *26*(5), 481–487. https://doi.org/10.1123/ijsnem.2015-0293

Lis, Dana, Stellingwerff, T., Kitic, C. M., Ahuja, K. D. K., & Fell, J. (2015). No Effects of a Short-Term Gluten-free Diet on Performance in Nonceliac Athletes. *Medicine and Science in Sports and Exercise*, *47*(12), 2563–2570. https://doi.org/10.1249/MSS.0000000000000699

Lis, Dana, Stellingwerff, T., Shing, C. M., Ahuja K, D. K., & Fell, J. (2014). Exploring the Popularity, Experiences and Beliefs Surrounding Gluten-Free Diets in Non-Coeliac Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*. https://doi.org/10.1123/ijsnem.2013-0247

Lobstein, T., & Davies, S. (2009). Defining and labelling “healthy” and “unhealthy” food. *Public Health Nutrition*, *12*(3), 331–340. https://doi.org/10.1017/S1368980008002541

Local Harvest. (n.d.). Retrieved May 10, 2016, from http://www.localharvest.org

Lucey, J. A. (2015). Raw Milk Consumption: Risks and Benefits. *Nutrition Today*, *50*(4), 189–193. https://doi.org/10.1097/NT.0000000000000108

Lundebye, A., Lock, E., Rasinger, J. D., Jakob, O., Hannisdal, R., Karlsbakk, E., … Ørnsrud, R. (2017). Lower levels of Persistent Organic Pollutants, metals and the marine omega 3-fatty acid DHA in farmed compared to wild Atlantic salmon (Salmo salar), *155*(January), 49–59. https://doi.org/10.1016/j.envres.2017.01.026

Macdiarmid, J. I. (2013). Is a healthy diet an environmentally sustainable diet? *The Proceedings of the Nutrition Society*, *72*(1), 13–20. https://doi.org/10.1017/S0029665112002893

Macdiarmid, J. I., Douglas, F., & Campbell, J. (2016). Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. *Appetite*, *96*, 487–493. https://doi.org/10.1016/j.appet.2015.10.011

Macdiarmid, J. I., Kyle, J., Horgan, G. W., Loe, J., Fyfe, C., Johnstone, A., & McNeill, G. (2012). Clean fuel for the future: Can we contribute to reducing greenhouse gas emissions by eating a healthy diet? *The American Journal of Clinical Nutrition*, *96*(2), 632–639. https://doi.org/10.3945/ajcn.112.038729.

Manore, M. M., Meyer, N. L., & Janice, T. (2009). *Sport Nutrition for Health and Performance* (2nd ed.). Champaign IL: Human Kinetics.

Marsh, B., & Curtius, M. (2013, May 25). Nutritional Weaklings in the Supermarket. *The New York Times*. Retrieved from http://www.nytimes.com/interactive/2013/05/26/sunday-review/26corn-ch.html?ref=sunday&_r=0

Martinez, R. C. R., Bedani, R., & Saad, S. M. I. (2015). Scientific evidence for health effects attributed to the consumption of probiotics and prebiotics: an update for current perspectives and future challenges. *British Journal of Nutrition*, *114*(12), 1993–2015. https://doi.org/10.1017/S0007114515003864

Masset, G., Vieux, F., Verger, E. O., Soler, L. G., Touazi, D., & Darmon, N. (2014). Reducing energy intake and energy density for a sustainable diet: A study based on self-selected diets in French adults. *American Journal of Clinical Nutrition*, *99*(6), 1460–1469. https://doi.org/10.3945/ajcn.113.077958

McFarland, L. V. (2015). From Yaks to Yogurt: The History, Development, and Current Use of Probiotics. *Clinical Infectious Diseases*, *60*(suppl 2), S85–S90. https://doi.org/10.1093/cid/civ054

McKenzie, Y., Bowyer, R., Leach, H., Guila, P., Horobin, J., O'Sullivan, N., ... Lomer, M. (2016). British Dietetic Association systematic review and evidence-based practice guidelines for the dietary management of irritable bowel syndrome in adults (2016 update). *J Hum Nutr Diet*, *29*(5), 549–575. https://doi.org/0.1111/jhn.12385

Meatless Mondays. (n.d.). Retrieved August 10, 2016, from (www.meatlessmonday.com)

Mekonnen, M. M., & Hoekstra, A. Y. (2012). A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems*, *15*(3), 401–415. https://doi.org/10.1007/s10021-011-9517-8

Melina, V., Craig, W., & Levin, S. (2016). Position of the Academy of Nutrition and Dietetics: Vegetarian Diets. *Journal of the Academy of Nutrition and Dietetics*, *116*(12), 1970–1980. https://doi.org/10.1016/j.jand.2016.09.025

Meyer, N. L. (2015). The Meaning of Local Food in Education. *Local Food Shift*. Retrieved from http://www.localfoodshift.pub/the-meaning-of-local-food-in-education/

Micha, R., Wallace, S. K., & Mozaffarian, D. (2010). Red and Processed Meat Consumption and Risk of Incident Coronary Heart Disease, Stroke, and Diabetes Mellitus: A Systematic Review and Meta-Analysis. *Circulation*, *121*(21), 2271–2283. https://doi.org/10.1161/CIRCULATIONAHA.109.924977

Mickleborough, T. D. (2013). Omega-3 polyunsaturated fatty acids in physical performance optimization. *International Journal of Sport Nutrition and Exercise Metabolism*, *23*(1), 83–96. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23400626

Miranda, N. D., Tuomisto, H. L., & McCulloch, M. D. (2015). Meta-analysis of greenhouse gas emissions from anaerobic digestion processes in dairy farms. *Environmental Science and Technology*, *49*(8), 5211–5219. https://doi.org/10.1021/acs.est.5b00018

Molberg, O., Uhlen, A. K., Jensen, T., Flaete, N. S., Fleckenstein, B., Arentz-Hansen, H., ... Sollid, L. M. (2005). Mapping of gluten T-cell epitopes in the bread wheat ancestors: implications for celiac disease. *Gastroenterology*, *128*(2), 393–401. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15685550

Moore, D. R., Churchward-Venne, T. A., Witard, O., Breen, L., Burd, N. A., Tipton, K. D., & Phillips, S. M. (2015). Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *70*(1), 57–62. https://doi.org/10.1093/gerona/glu103

Mouillé, B., Charrondière, U. R., Burlingame, B., & Lutaladio, N. (2009). Nutrient composition of the potato Interesting varieties from human nutrition perspective, *22*(6), 2009.

Naylor, R. L., Battisti, D. S., Vimont, D. J., Falcon, W. P., & Burke, M. B. (n.d.). Assessing risks of climate variability and climate change for Indonesian rice agriculture.

Nemecek, T., Dubois, D., Huguenin-Elie, O., & Gaillard, G. (2011). Life cycle assessment of Swiss farming systems: I. Integrated and organic farming. *Agricultural Systems*, *104*(3), 217–232. https://doi.org/10.1016/j.agsy.2010.10.002

Nemecek, T., Jungbluth, N., Canals, L. M., & Schenck, R. (2016). Environmental impacts of food consumption and nutrition: where are we and what is next? *The International Journal of Life Cycle Assessment*, 607–620. https://doi.org/10.1007/s11367-016-1071-3

Nichols, P. D., Glencross, B., Petrie, J. R., & Singh, S. P. (2014). Readily Available Sources of Long-Chain Omega-3 Oils: Is Farmed Australian Seafood a Better Source of the Good Oil than Wild-Caught Seafood?, 1063–1079. https://doi.org/10.3390/nu6031063

Nieman, D. C. (1999). Physical fitness and vegetarian diets: is there a relation? *The American Journal of Clinical Nutrition*, *70*(3 Suppl), 570S-575S. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10479233

NOAA Fisheries. (2016). *Status of Stocks 2015. Annual Report to Congress on the Status of U.S. Fisheries*.

O'Kane, G. (2012). What is the real cost of our food? Implications for the environment, society and public health nutrition. *Public Health Nutrition*, *15*(02), 268–276. https://doi.org/10.1017/S136898001100142X

O'Kane, G. (2016). A moveable feast: Exploring barriers and enablers to food citizenship. *Appetite*, *105*, 674–687. https://doi.org/10.1016/j.appet.2016.07.002

One World Cafe. (n.d.). Retrieved September 28, 2016, from http://oneworld-cafe.com/

Palupi, E., Jayanegara, A., Ploeger, A., & Kahl, J. (2012). Comparison of nutritional quality between conventional and organic dairy products: a meta-analysis. *Journal of the Science of Food and Agriculture*, *92*(14), 2774–2781. https://doi.org/10.1002/jsfa.5639

Pan, A., Sun, Q., Bernstein, A. M., Schulze, M. B., Manson, J. E., Stampfer, M. J., ... Hu, F. B. (2012). Red Meat Consumption and Mortality. *Archives of Internal Medicine*, *172*(7), 555. https://doi.org/10.1001/archinternmed.2011.2287

Parfitt, J., Barthel, M., & Macnaughton, S. (2010). Food waste within food supply chains : quantification and potential for change to 2050, 3065–3081. https://doi.org/10.1098/rstb.2010.0126

Parnell, J. A., Wiens, K. P., & Erdman, K. A. (2016). Dietary intakes and supplement use in pre-adolescent and adolescent Canadian athletes. *Nutrients*, *8*(9), 1–13. https://doi.org/10.3390/nu8090526

Pedersen, K., Land, B., & Kjaergard, B. (2015). Duality of Health Promotion and Sustainable Development:-perspectives on food waste reduction strategies. *The Journal of Transdisciplinary ...*, *14*(2). Retrieved from http://forskningsbasen.deff.dk/Share.external?sp=S932e1a32-2c67-4aba-8d6b-f631cfab0e6c&sp=Sruc

Pelly, F. E., & Burkhart, S. J. (2014). Dietary regimens of athletes competing at the Delhi 2010 Commonwealth Games. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(1), 28–36. https://doi.org/10.1123/ijsnem.2013-0023

Pelly, F., Meyer, N. L., Pearce, J., Burkhart, S. J., & Burke, L. M. (2014). Evaluation of Food Provision and Nutrition Support at the London 2012 Olympic Games: The Opinion of Sports Nutrition Experts. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(6), 674–683. https://doi.org/10.1123/ijsnem.2013-0218

Personal Footprint. (n.d.). Retrieved October 31, 2016, from http://www.footprintnetwork.org/en/index.php/GFN/page/personal_footprint

Phillips, S. M. (2014). A Brief Review of Higher Dietary Protein Diets in Weight Loss: A Focus on Athletes. *Sports Medicine*, *44*, 149–153. https://doi.org/10.1007/s40279-014-0254-y

Phillips, S. M., Chevalier, S., & Leidy, H. J. (2016). Protein "requirements" beyond the RDA: implications for optimizing health. *Applied Physiology, Nutrition, and Metabolism*, *572*(February), 1–8. https://doi.org/10.1139/apnm-2015-0550

Pinela, J., Barros, L., Carvalho, A. M., & Ferreira, I. C. F. R. (2012). Nutritional composition and antioxidant activity of four tomato (Lycopersicon esculentum L.) farmer' varieties in Northeastern Portugal homegardens. *Food and Chemical Toxicology : An International Journal Published for the British Industrial Biological Research Association*, *50*(3–4), 829–834. https://doi.org/10.1016/j.fct.2011.11.045

Pizzuti, D., Buda, A., D'Odorico, A., D'Incà, R., Chiarelli, S., Curioni, A., & Martines, D. (2006). Lack of intestinal mucosal toxicity of *Triticum monococcum* in celiac disease patients. *Scandinavian Journal of Gastroenterology*, *41*(11), 1305–1311. https://doi.org/10.1080/00365520600699983

Professionals in Nutrition for Exercise and Sport. (n.d.). Retrieved March 7, 2016, from www.pinesnutrition.org

Public Health England, Welsh Government, Scotland, F. S., & Food Standards Agency in Northen Ireland. (2016). *Eat Well Guide*. Retrieved from https://www.gov.uk/government/publications/the-eatwell-guide

Raanan, R., Harley, K. G., Balmes, J. R., Bradman, A., Lipsett, M., & Eskenazi, B. (2015). Early-life exposure to organophosphate pesticides and pediatric respiratory symptoms in the CHAMACOS cohort. *Environmental Health Perspectives*, *123*(2), 179–185. https://doi.org/10.1289/ehp.1408235

Reganold, J. P., & Wachter, J. M. (2016). Organic agriculture in the twenty-first century. *Nature Plants*, *2*(February), 15221. https://doi.org/10.1038/NPLANTS.2015.221

Reguant-Closa, A., Harris, M., & Meyer, N. (2016). Validation of the Athlete's Plate Quantitative Analysis (Phase 1). In *International Journal of Sport Nutrition and Metabolism* (Vol. 26:S1-S15, pp. S1–S15).

Reguant-Closa, A., Judson, A., Harris, M., Moreman, T., & Meyer, N. L. (2016). Including sustainability principles into the Athlete's Plate Nutritional Educational Tool. In *Oral Communication presented at the International Confederation of Dietetics 17th Conference in September 2016, Granada, Spain*.

Res, P. T., Groen, B., Pennings, B., Beelen, M., Wallis, G. A., Gijsen, A. P., … VAN Loon, L. J. C. (2012). Protein ingestion before sleep improves postexercise overnight recovery. *Medicine and Science in Sports and Exercise*, *44*(8), 1560–1569. https://doi.org/10.1249/MSS.0b013e31824cc363

Reynolds, L. P., Wulster-Radcliffe, M. C., Aaron, D. K., & Davis, T. A. (2015). Importance of animals in agricultural sustainability and food security. *Journal of Nutrition*, *145*(7), 1377–1379. https://doi.org/10.3945/jn.115.212217

Richman, E. L., Stampfer, M. J., Paciorek, A., Broering, J. M., Carroll, P. R., & Chan, J. M. (2010). Intakes of meat, fish, poultry, and eggs and risk of prostate cancer progression1,2. *American Journal of Clinical Nutrition*, *91*(3), 712–721. https://doi.org/10.3945/ajcn.2009.28474

Rio Food Vision. (2014). *Diagnostic Analysis for the Supply of Healthy and Sustainable Food for the 2016 Rio Olympic and Paralympic Games*. Rio de Janeiro. Retrieved from www.riofoodvision.org

Ripple, W. J., Smith, P., Haberl, H., Montzka, S. A., McAlpine, C., & Boucher, D. H. (2014). Ruminants, climate change and climate policy. *Nature Climate Change*, *4*(1), 2–5. https://doi.org/10.1038/nclimate2081

Rivera, D., Obón, C., Heinrich, M., Inocencio, C., Verde, A., & Fajardo, J. (2006). Gathered Mediterranean Food Plants – Ethnobotanical Investigations and Historical Development. In *Local Mediterranean Food Plants and Nutraceuticals* (pp. 18–74). Basel: KARGER. https://doi.org/10.1159/000095207

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., … Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., … Sibanda, L. (2017). Sustainable intensification of agriculture for human prosperity and global sustainability, 4–17. https://doi.org/10.1007/s13280-016-0793-6

Rogosa, E. (2016). *Restoring Heritage grains*. White River Junction, VT: Chelsea Green Publishing.

Rosenlund, G., Torstensen, B. E., Stubhaug, I., Usman, N., & Sissener, N. H. (2016). Atlantic salmon require long-chain n-3 fatty acids for optimal growth throughout the seawater period. *Journal of Nutritional Science*, *5*, e19. https://doi.org/10.1017/jns.2016.10

Sabaté, J., Harwatt, H., & Soret, S. (2016). Environmental nutrition: A new frontier for public health. *American Journal of Public Health*, *106*(5), 815–821. https://doi.org/10.2105/AJPH.2016.303046

Sabaté, J., Sranacharoenpong, K., Harwatt, H., Wien, M., & Soret, S. (2014). The environmental cost of protein food choices. *Public Health Nutrition*, *18*(11), 1–7. https://doi.org/10.1017/S1368980014002377

Samsel, A., & Seneff, S. (2013a). Glyphosate, pathways to modern diseases II: Celiac sprue and gluten intolerance. *Interdisciplinary Toxicology*, *6*(4), 159–184. https://doi.org/10.2478/intox-2013-0026

Samsel, A., & Seneff, S. (2013b). Glyphosate's Suppression of Cytochrome P450 Enzymes and Amino Acid Biosynthesis by the Gut Microbiome: Pathways to Modern Diseases. *Entropy*, *15*(4), 1416–1463. https://doi.org/10.3390/e15041416

Saxe, H., & Jensen, J. D. (2014). Does the environmental gain of switching to the healthy New Nordic Diet outweigh the increased consumer cost ? In *9th International Conference LCA of Food*.

Saxe, H., Larsen, T. M., & Mogensen, L. (2013). The global warming potential of two healthy Nordic diets compared with the average Danish diet. *Climatic Change*, *116*(2). https://doi.org/10.1007/s10584-012-0495-4

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Climatic Change*, *125*(2), 179–192. https://doi.org/10.1007/s10584-014-1169-1

Scheers, N., Rossander-Hulthen, L., Torsdottir, I., & Sandberg, A.-S. (2016). Increased iron bioavailability from lactic-fermented vegetables is likely an effect of promoting the formation of ferric iron (Fe(3+)). *European Journal of Nutrition*, *55*(1), 373–382. https://doi.org/10.1007/s00394-015-0857-6

Schösler, H., Boer, J. de, & Boersema, J. J. (2012). Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. *Appetite*, *58*(1), 39–47. https://doi.org/10.1016/j.appet.2011.09.009

Seierstad, S. L., Seljeflot, I., Johansen, O., Hansen, R., Haugen, M., Rosenlund, G., … Arnesen, H. (2005). Dietary intake of differently fed salmon; the influence on markers of human atherosclerosis. *European Journal of Clinical Investigation*, *35*(1), 52–59. https://doi.org/10.1111/j.1365-2362.2005.01443.x

Shokryazdan, P., Faseleh Jahromi, M., Navidshad, B., & Liang, J. B. (2017). Effects of prebiotics on immune system and cytokine expression. *Medical Microbiology and Immunology*, *206*(1), 1–9. https://doi.org/10.1007/s00430-016-0481-y

Slow Food USA. (n.d.-a). Retrieved July 3, 2016, from www.slowfoodusa.com;

Slow Food USA. (n.d.-b). Slow Meat. Retrieved July 6, 2016, from https://www.slowfoodusa.org/slow-meat

Smil, V. (2000). *Feeding the world: A challenge for the 21st century* (1st ed.). Cambridge, Massachusetts: MIT Press.

Sofi, F., Whittaker, A., Cesari, F., Gori, A. M., Fiorillo, C., Becatti, M., … Benedettelli, S. (2013). Characterization of Khorasan wheat (Kamut) and impact of a replacement diet on cardiovascular risk factors: cross-over dietary intervention study. *European Journal of Clinical Nutrition*, *67*(2), 190–195. https://doi.org/10.1038/ejcn.2012.206

Spendlove, J., Mitchell, L., Gifford, J., Hackett, D., Slater, G., Cobley, S., & O'Connor, H. (2015). Dietary Intake of Competitive Bodybuilders. *Sports Medicine (Auckland, N.Z.)*, *45*(7), 1041–1063. https://doi.org/10.1007/s40279-015-0329-4

Sprague, M., Dick, J. R., & Tocher, D. R. (2016). Impact of sustainable feeds on omega-3 long-chain fatty acid levels in farmed Atlantic salmon, 2006-2015. *Scientific Reports*, *6*(November 2015), 21892. https://doi.org/10.1038/srep21892

Springmann, M., Godfray, H. C. J., Rayner, M., & Scarborough, P. (2016). Analysis and valuation of the health and climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(15), 4146–4151. https://doi.org/10.1073/pnas.1523119113

Stein, L. J., Gunier, R. B., Harley, K., Kogut, K., Bradman, A., & Eskenazi, B. (2016). Early childhood adversity potentiates the adverse association between prenatal organophosphate pesticide exposure and child IQ: The CHAMACOS cohort. *Neurotoxicology*, *56*, 180–187. https://doi.org/10.1016/j.neuro.2016.07.010

Stein, M. M., Hrusch, C. L., Gozdz, J., Igartua, C., Pivniouk, V., Murray, E. S., … Sperling, A. I. (2016). Innate Immunity and Asthma Risk in Amish and Hutterite Farm Children. *New England Journal of Medicine*, *375*(5), 411–421. https://doi.org/10.1056/NEJMoa1508749

Stenman, S. M., Venäläinen, J. I., Lindfors, K., Auriola, S., Mauriala, T., Kaukovirta-Norja, A., … Mäki, M. (2009). Enzymatic detoxification of gluten by germinating wheat proteases: Implications for new treatment of celiac disease. *Annals of Medicine*, *41*(5), 390–400. https://doi.org/10.1080/07853890902878138

Storkey, J., Meyer, S., Still, K. S., & Leuschner, C. (2012). The impact of agricultural intensification and land-use change on the European arable flora. *Proceedings of the Royal Society of London B: Biological Sciences*, *279*(1732), 1421–1429. https://doi.org/10.1098/rspb.2011.1686

Sundgot-Borgen, J., Meyer, N. L., Lohman, T. G., Ackland, T. R., Maughan, R. J., Stewart, A. D., & Müller, W. (2013). How to minimise the health risks to athletes who compete in weight-sensitive sports review and position statement on behalf of the Ad Hoc Research Working Group on Body Composition, Health and Performance, under the auspices of the IOC Medical Commission. *British Journal of Sports Medicine*, *47*(16), 1012–1022. https://doi.org/10.1136/bjsports-2013-092966

Sutton, C., & Dibb, S. (2013). *Prime cuts, Valuing the meat we eat*. Godalming, UK.

Team USA. (n.d.). Team USA, Nutrition. Retrieved February 20, 2016, from http://www.teamusa.org/nutrition

Tessari, P., Lante, A., & Mosca, G. (2016). Essential amino acids: master regulators of nutrition and environmental footprint? *Scientific Reports*, *6*(April), 26074. https://doi.org/10.1038/srep26074

The culinary Institute of America, & Harvard School of Public Health. (n.d.). The Protein Flip. Retrieved October 10, 2016, from http://www.menusofchange.org/images/uploads/pdf/CIA_The_Protein_Flip_C_FINAL_6-17-15.pdf

The Land Institute. (n.d.). The Land Insitute: Kernza Grain: Toward a Perennial Agriculture. Retrieved September 10, 2016, from https://landinstitute.org/our-work/perennial-crops/kernza/

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Medicine and Science in Sports and Exercise*, *48*(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

Tilman, D. (1999). Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. *Pnas*, *96*(11), 5995–6000. https://doi.org/10.1073/pnas.96.11.5995

Tilman, David, & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518–522. https://doi.org/10.1038/nature13959

TrueSport: U.S. Anti-Doping Agency. (n.d.). Retrieved July 28, 2016, from http://www.usada.org/truesport/

UCCS: Dining and Hospitality Services: The Flying Carrot. (n.d.). Retrieved October 20, 2016, from http://www.uccs.edu/diningservices/swell/the-flying-carrot.html

UCCS Dining and Hospitality Services: Food Next Door. (n.d.). Retrieved October 1, 2016, from http://www.uccs.edu/diningservices/swell/food-next-door.html

USDA. (2002). *Agriculture Fact Book 2001-2002*. Retrieved from http://www.usda.gov/documents/usda-factbook-2001-2002.pdf

USDA. (2003). Profiling Food Consumption in America, 13–22. Retrieved from http://www.usda.gov/factbook/

USDA. (2015). 2015 – 2020 Dietary Guidelines for Americans. *U.S. Department of Health and Human Services and U.S. Department of Agriculture*, 18. https://doi.org/10.1097/NT.0b013e31826c50af

USDA, & US HHS. (2015). *Scientific Report of the 2015 Dietary Guidelines Advisory Committee. USDA and US Department of Health and Human Services* (Vol. 53). Washington (DC). https://doi.org/10.1017/CBO9781107415324.004

Usydus, Z., & Szlinder-Richert, J. (2012). Functional Properties of Fish and Fish Products: A Review. *International Journal of Food Properties*, *15*(4), 823–846. https://doi.org/10.1080/10942912.2010.503356

Vaccino, P., Becker, H.-A., Brandolini, A., Salamini, F., & Kilian, B. (2009). A catalogue of Triticum monococcum genes encoding toxic and immunogenic peptides for celiac disease patients. *Molecular Genetics and Genomics*, *281*(3), 289–300. https://doi.org/10.1007/s00438-008-0412-8

Vaher, M., Matso, K., Levandi, T., Helmja, K., & Kaljurand, M. (2010). Phenolic compounds and the antioxidant activity of the bran, flour and whole grain of different wheat varieties. *Procedia Chemistry*, *2*(1), 76–82. https://doi.org/10.1016/j.proche.2009.12.013

van den Broeck, H., de Jong, H. C., Salentijn, E. M., Dekking, L., Bosch, D., Hamer, R. J., … Smulders, M. J. (2010). Presence of celiac disease epitopes in modern and old hexaploid wheat varieties: wheat breeding may have contributed to increased prevalence of celiac disease. *Theory Applied Genetics*, *121*, 1527–1539. https://doi.org/10.1007/s00122-010-1408-4

Van Dooren, C., Marinussen, M., Blonk, H., Aiking, H., & Vellinga, P. (2014). Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns. *Food Policy*, *44*, 36–46. https://doi.org/10.1016/j.foodpol.2013.11.002

van Dooren, Corné, & Aiking, H. (2016). Defining a nutritionally healthy, environmentally friendly, and culturally acceptable Low Lands Diet. *International Journal of Life Cycle Assessment*, *21*(5), 688–700. https://doi.org/10.1007/s11367-015-1007-3

van Huis, A., Itterbeeck, J. Van, Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). *Edible insects. Future prospects for food and feed security*. *Food and Agriculture Organization of the United Nations* (Vol. 171). https://doi.org/10.1017/CBO9781107415324.004

van Neerven, R. J. J., Knol, E. F., Heck, J. M. L., & Savelkoul, H. F. J. (2012). Which factors in raw cow's milk contribute to protection against allergies? *Journal of Allergy and Clinical Immunology*, *130*(4), 853–858. https://doi.org/10.1016/j.jaci.2012.06.050

Venderley, A. M., & Campbell, W. W. (2006). Vegetarian diets : nutritional considerations for athletes. *Sports Medicine (Auckland, N.Z.)*, *36*(4), 293–305. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/16573356

Vergé, X. P. C., Maxime, D., Dyer, J. A., Desjardins, R. L., Arcand, Y., & Vanderzaag, A. (2013). Carbon footprint of Canadian dairy products: Calculations and issues. *Journal of Dairy Science*, *96*(9), 6091–6104. https://doi.org/10.3168/jds.2013-6563

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate Change and Food Systems. *Annual Review of Environment and Resources*, *37*(1), 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

Vidgen, H. A., & Gallegos, D. (2014). Defining food literacy and its components. *Appetite*, *76*, 50–59. https://doi.org/10.1016/j.appet.2014.01.010

Viel, J.-F., Warembourg, C., Le Maner-Idrissi, G., Lacroix, A., Limon, G., Rouget, F., … Chevrier, C. (2015). Pyrethroid insecticide exposure and cognitive developmental disabilities in children: The PELAGIE mother-child cohort. *Environment International*, *82*, 69–75. https://doi.org/10.1016/j.envint.2015.05.009

von Keyserlingk, M. a G., Martin, N. P., Kebreab, E., Knowlton, K. F., Grant, R. J., Stephenson, M., … Smith, S. I. (2013). Invited review: Sustainability of the US dairy industry. *Journal of Dairy Science*, *96*(9), 5405–5425. https://doi.org/10.3168/jds.2012-6354

Westhoek, H., Lesschen, J. P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., … Oenema, O. (2014). Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Global Environmental Change*, *26*, 196–205. https://doi.org/10.1016/j.gloenvcha.2014.02.004

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, *6*(2), 203–218. https://doi.org/10.1007/s11625-011-0132-6

Wilkins, J. (2005). Eating right here: Moving from consumer to food citizen. Agriculture and Human values. *Agriculture and Human Values*, 22–269. https://doi.org/doi:10.1007/s10460-005-6042-4

Worthington, V. (2001). Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, *7*(2), 161–173. https://doi.org/10.1089/107628001300303691

Wunderlich, S. M., Feldman, C., Kane, S., & Hazhin, T. (2008). Nutritional quality of organic, conventional, and seasonally grown broccoli using vitamin C as a marker. *International Journal of Food Sciences and Nutrition*, *59*(1), 34–45. https://doi.org/10.1080/09637480701453637

Zanini, B., Petroboni, B., Not, T., Di Toro, N., Villanacci, V., Lanzarotto, F., … Lanzini, A. (2013). Search for atoxic cereals: a single blind, cross-over study on the safety of a single dose of Triticum monococcum, in patients with celiac disease. *BMC Gastroenterology*, *13*, 92. https://doi.org/10.1186/1471-230X-13-92

CONTRIBUTION II:

Validation of the Athlete's Plate Nutrition Educational Tool: Phase I

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Abstract

Nutrition education visual tools are designed to help the general population translate science into practice. The purpose of this study was to validate the Athlete's Plate (AP) to ensure that it meets current sport nutrition recommendations for athletes. Twelve Registered Dietitians (RD, 10 female, 2 male), volunteered for the study. Each RD was asked to create 3 real and virtual plates at three different times corresponding to breakfast, lunch and dinner and the three different AP training intensities: Easy (E), Moderate (M) and Hard (H), divided into two weight categories (male: 75kg; female: 60kg). Data of real and virtual plates were evaluated using Computrition Software (Hospitality Suite, v. 18.1, Chatsworth, California). Statistical analyses were conducted by SPSS (V.23) to compare the difference between each training load category (E, M, H) and the recommendations. No statistically significant differences were found among the created plates and the recommendations for energy, carbohydrates, fat, and fiber for E, M, and H. Protein relative to body mass (BM) was higher than recommended for E ($1.9 \pm 0.3 g \cdot kg^{-1} BM \cdot day^{-1}$; $p \leq 0.05$); M ($2.3 \pm 0.3 g \cdot kg^{-1} BM \cdot day^{-1}$; $p \leq 0.001$) and H ($2.9 \pm 0.5 g \cdot kg^{-1} BM \cdot day^{-1}$; $p \leq 0.001$). No differences were found for macronutrient distribution by gender when correcting for kg of BM. We conclude that the AP meets the nutrition recommendations for athletes at different training intensities for energy, carbohydrate, fat and fiber, but exceeds recommendations for protein. Further research should consider this protein discrepancy and develop an AP model that meets, besides health and performance goals, contemporary guidelines for sustainability.

KEYWORDS: Sport Nutrition, protein, nutrition/training periodization, education

1. Introduction

There are several educational tools developed for the general population to promote healthy eating. Food pyramids and plate models have been widely used to demonstrate different eating paradigms (Bach-Faig et al., 2011; Forman, Colby, Gellar, Kavanagh, & Spence, 2015; Ruini et al., 2015; U.S Department of Health & U.S Department of Agriculture, 2015). These tools are designed for the user to help meet dietary recommendations. Tools have also been developed to target more specific populations, for example children, elderly or pregnant women (U.S Department of Health & U.S Department of Agriculture, 2015). Some tools also have integrated other messages, such as sustainability, to reduce the environmental impact of food choices (FAO, 2016). However, there are few valid tools specifically designed for athletes (Mettler et al., 2009). Athletes are a population with specific nutritional requirements to optimize health and performance (Thomas et al., 2016). One of the more relevant studies is the validation of the Food Pyramid for Swiss Athletes (FPSA) by Mettler et al. (2009). The aim of the validation was to ensure that the FPSA met the recommended energy and nutrient amounts for athletes training up to 4 hrs per day at moderate intensity. The FPSA validation is an important step forward to provide adequate educational tools for athletes that also reflect accuracy.

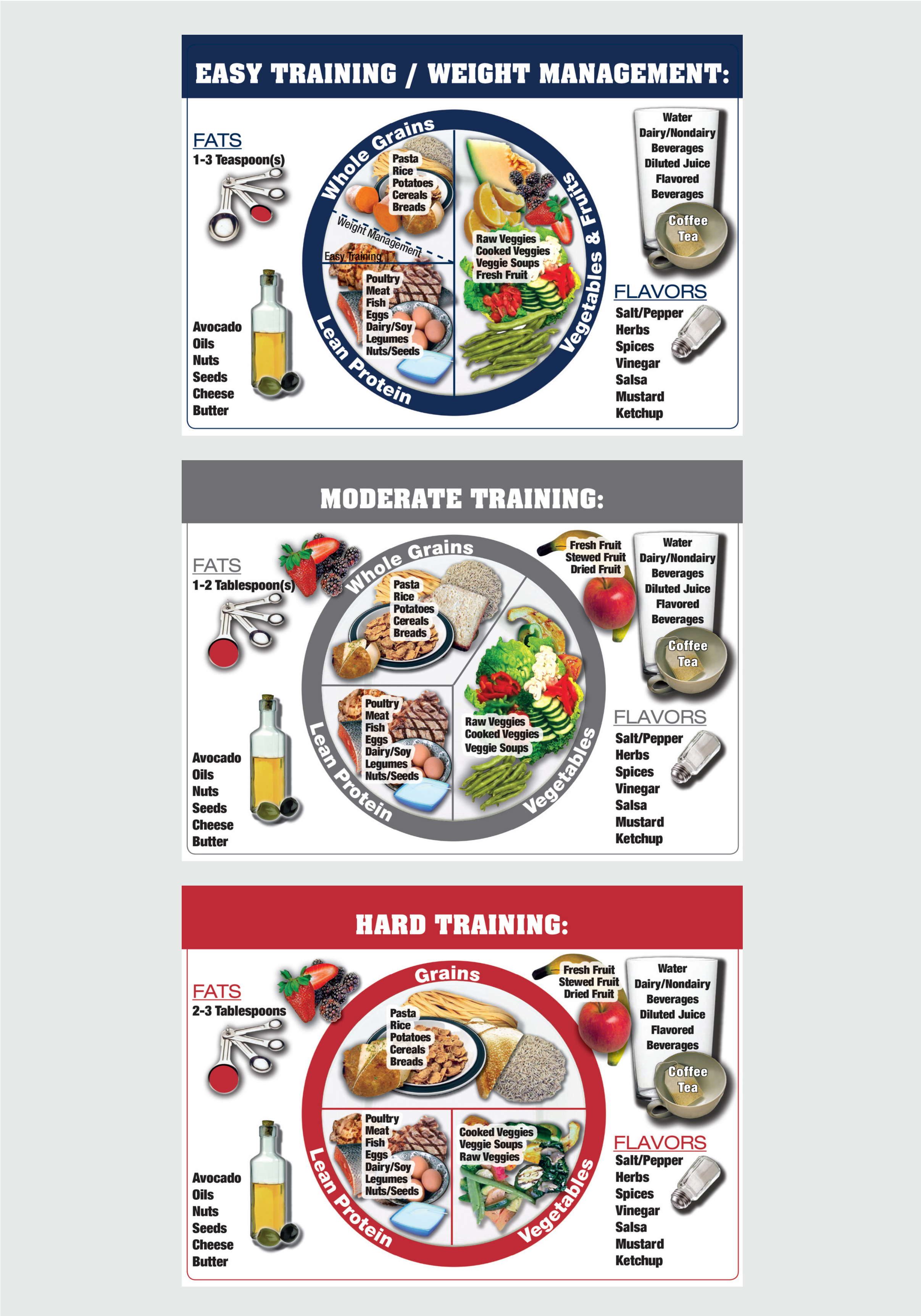

FIGURE 3.1

The Athlete's Plate nutrition education tool

The Athlete's Plates (AP) were designed by Dr. Nanna Meyer and the Sport Nutrition Graduate Program at the University of Colorado, Colorado Springs (UCCS) in collaboration with the United States Olympic Committee (USOC) (Figure 3.1). The aim of the AP is to help sport dietitians working with athletes and athletes themselves adjust food intake according to changes in training volume and intensity (e.g. load) using a practical, visual way. Because athletes have different requirements, depending on the periodization of training and competition, three plates were designed: Easy (E), Moderate (M) and Hard (H) training. The AP was never meant to be a daily nutrition guideline that fits all, but a visual a tool for teaching and learning. The AP can be applied to variable training and competition scenarios (e.g. pre or post event/training nutrition) or training phases within the periodized training plan. In addition the AP can be adapted to food cultures, and their specific ways of eating, adjusting food intake according to training load, without confinement to the plate per se (or bowls, cups etc.). However, even if adjusting the AP to diverse serving vessels or specific food cultures, the philosophy of the periodized nutrition recommendations of the AP can be maintained. In fact, some countries have adopted the AP system, integrating their cultural foods (e.g. Costa Rica and Mexico; https://www.gob.mx/conade/prensa/platos-nutricionales-herramienta-para-revitalizar-la-alimentacion-en-mexico).

The AP was launched during the 2012 London Olympics and has been in use since then by the USOC sport dietitians and internationally, as it is available for free download at www.uccs.edu/swell/athletes-plate. To date, the AP has not been validated. The validation was needed to ensure that the plates meet the recommended amounts of energy and nutrients depending on training load. We started with the validation of the plates through sport dietitians making plates for athletes, as they are the experts on the topic. We hypothesized that the three plates meet current sport nutrition recommendations for energy and macronutrient recommendations.

2. Methods

Two male and ten female Registered Dietitians (RD) (18-50 years) participated. Six were practicing sport dietitians and six graduate students in sport nutrition. As in the validation of the FPSA, RDs were selected as subjects, as they are the experts in sport nutrition (Mettler et al., 2009) and likely the professionals to guide athletes using tools such as the AP. RDs were asked to report to the USOC Training Center in Colorado Springs (CS-OTC) dining hall at separate times without prior knowledge of the menu and create 3 plates for training load (E, M and H) following the AP visual tool. They repeated this protocol 3 times to ensure each RD made plates for all meals (breakfast, lunch, and dinner), for E, M and H training. To adjust energy and macronutrients to body mass (BM), weight categories were defined by gender (60 kg, females (f); 75 kg males (m)). Each sport dietitian created 18 plates. To avoid food waste, half of the plates were created "virtually" on paper, while the other half were created with food. For the virtual plates, dietitians had to inspect the menu and the food available at the dining hall and annotate the content of the plate, detailing the food, recipe, portion size and/or household measures. The main researcher reviewed the food content of each virtual plate to ensure accuracy. For the real food plates, dietitians were asked to modify the food content of the plates following the proportions as defined by the AP. While adjusting their plate to the hypothetical athlete assigned, dietitians were not confined to a plate or dish portion size; they could use all dishes available at the dining hall or add more food to the same plate. They could use a plate, a side bowl, add more food to the same plate, a dressing or shake on the side, a bowl of soup, a piece of fruit or a glass of milk. Moreover, different kinds of dishes could be used for different meals (e.g., breakfast vs dinner).

The food content of each plate was weighed to obtain the grams of each dish and respective food contents. For the analysis, breakfast, lunch and dinner plate content of each RD were summed by gender (m/f) and training load (E, M and H), accounting for 77% of daily energy intake (EI). An additional 23% of EI, with the same nutritional composition of breakfast, lunch and dinner combined was calculated for each RD, again by gender and training load, to account for snacks (Burke et al., 2003; Erdman, Tunnicliffe et al., 2013). This process was chosen to maintain variability in energy and macronutrient distribution for each RD's set of plates. The snack portion (23%) was added, to sum up to 100% of daily EI to be able to test the AP against daily sport nutrition recommendations. Thus, the data shown in this study represent a daily average by gender (m/f), training load (E, M, H) and meals (B, L, D).

Data were analyzed by Computrition (Computrition, Hospitality Suite, v.18.1, Chatsworth, California) and expressed in g·kg-1BM·day-1. The study was approved by the University of Colorado, Colorado Springs (UCCS) Institutional Review Board, with all RDs signing an approved written informed consent.

The following macronutrient intakes were considered:

Carbohydrates

The IOC consensus statement by Burke et al. (2011), was used for carbohydrates, considering exercise intensities: light (3-5g·kg^{-1}BM·day^{1}), moderate (5-7g·kg^{-1}BM·day^{-1}), high (6-10g·kg^{-1}BM·day^{-1}) and very high (8-12g·kg^{-1}BM·day^{-1}). Because we only had three categories (E, M and H) in this study, the hard and very hard categories were combined (H). Therefore, the recommendations for carbohydrate intake were defined as: E(4g·kg^{-1}BM·day^{-1}), M(6g·kg^{-1}BM·day^{-1}) and H(8g·kg^{-1}BM·day^{-1}).

Protein

The IOC consensus statement by Phillips & Van Loon, (2011) was used for protein intake to optimize protein synthesis and training adaptation. The authors recommend a range of daily protein intake of 1.3g·kg^{-1}BM·day^{-1} to 1.8g·kg^{-1}BM·day^{-1}, with Thomas et al., 2016 a recommending between 1.2g·kg^{-1}BM·day^{-1} and 2g·kg^{-1}BM·day^{-1}. Thus, the current study adopted a protein amount of 1.6g·kg^{-1}BM·day^{-1} for E, M and H.

Fat

Recommendations for fat intake are generally based on the Dietary Reference Intake (DRI) and are not relative to BM (Institute of Medicine, 2005). However, a frequently used range is 0.8g·kg^{-1}BM·day^{-1} to 2.0g·kg^{-1}BM·day^{-1}, corresponding to 20-25% of total daily EI (Lowery, 2004; Stellingwerff et al., 2011; Thomas et al., 2016). Fat is added as flavor and represents an important energy source, hence, fat requirements were set at E(1g·kg^{-1}BM·day^{-1}), M(1.5g·kg^{-1}BM·day^{-1}) and H(2g·kg^{-1}BM·day^{-1}), respectively.

Energy

It is difficult to give general recommendations for energy intakes in athletes due to individual variability and differential nature of the sport. Also, a minimum energy availability (EA) is needed in athletes at 30 $kcal \cdot kg^{-1} FFM \cdot day^{-1}$, specially for female athletes to maintain normal menstrual function (Loucks, 2004). The AP was designed with the idea of adjusting carbohydrate and fat intake to increased training loads. For example, total energy from carbohydrate will vary depending on BM of the athlete at different intensity levels, and consequently, energy content of the plates will be influenced. Thus, energy content was calculated backwards from the macronutrient content for E, M, H days, considering the macronutrient values as defined above. Consequently, energy content resulted in the following values: E(31$kcal \cdot kg^{-1} BM \cdot day^{-1}$), M(44$kcal \cdot kg^{-1} BM \cdot day^{-1}$) and H(56$kcal \cdot kg^{-1} BM \cdot day^{-1}$).

Fiber

There are no general recommendations for fiber in athletes. However, dietary fiber is critical to build and maintain a healthy gut and microbiota important for athletic performance (Clark & Mach, 2016). Thus, for the AP validation 14g of fiber per 1000kcal was used (Institute of Medicine, 2005). However, the E and M plates are designed to increase fiber intake, while the H plate attempts to moderate fiber intake to facilitate nutrient digestion and assimilation (de Oliveira et al., 2014; Jeukendrup, 2017).

Statistical Analysis

The food content of each plate was entered into Computrition Software (Computrition, Hospitality Suite, v.18.1, Chatsworth, California) to obtain the macronutrient and energy content and distribution. For each RD, meals (B, L, D) were summed by training load (E, M and D) and gender (m/f) to account for 77% of daily EI before adding 23% in snacks for each case. Mean daily energy and nutrient contents were calculated by training load and gender and are expressed in means±SD.

Statistical analyses were performed using SPSS (IBM, version v.23.0, Armonk, NY). After testing assumptions, a one sample t-test was used to compare mean daily energy and nutrient content with current sport nutrition recommendations. An independent sample t-test was used to compare by gender.

To study interactions among training load (E, M, H), meal (B, L, D) and gender (m/f), a 3x3x2 factorial treatment plan with a repeated measures for training load, meal, and gender was performed. Prior to the Analysis of Variance (ANOVA) of the factorial treatment plan, a multiple regression analysis was carried out on each nutrient to account for unequal assignment of graduate students RD vs sport dietitians RD to virtual vs real plates. Each nutrient was adjusted for the main effect of sport dietitians' RD status and their interaction with virtual and real plates.

3. Results

Easy, Moderate and Hard training plates met energy, carbohydrate, fat and fiber recommendations. Protein exceeded the recommendations, especially for M and H plates (Table 3.6). The plates did not differ in energy and macronutrients relative to BM between females and males for E, M and H ($p>0.05$).

TABLE 3.6
Athlete's Plate vs Reference Values

	EASY			MODERATE			HARD		
	Mean ± SD	Reference value	p	Mean ± SD	Reference value	p	Mean ± SD	Reference value	p
Energy ($Kcal \cdot kg^{-1} BM \cdot day^{-1}$)	31 ± 6.7	31	0.314	41.5 ± 7.2	44	0.255	57.4 ± 11.7	56	0.686
Carbohydrate ($g \cdot kg^{-1} BM \cdot day^{-1}$)	3.8 ± 0.8	4	0.376	5.3 ± 1.1	6	0.052	8.2 ± 1.9	8	0.688
Protein ($g \cdot kg^{-1} BM \cdot day^{-1}$)	1.9 ± 0.3	1.6	0.007*	2.3 ± 0.3	1.6	0.000*	2.9 ± 0.5	1.6	0.000*
Fat ($g \cdot kg^{-1} BM \cdot day^{-1}$)	1 ± 0.4	1	0.803	1.4 ± 0.3	1.5	0.500	1.7 ± 0.5	2	0.089
Fiber ($g \cdot 1000\ kcal^{-1}$)	19.7 ± 6.8	14	0.013*	15.2 ± 2.9	14	0.837	16.4 ± 6.5	14	0.237

* Statistically significant compared with reference value at $p<0.05$

When analyzing carbohydrates, the main effect of training load was significant for linear ($p \leq 0.001$) and quadratic ($p=0.013$), with a larger difference between M($1.441 \pm 0.083 g \cdot kg^{-1} BM \cdot meal^{-1}$) and H($2.218 \pm 0.133 g \cdot kg^{-1} BM \cdot meal^{-1}$) training than between M and E($1.046 \pm 0.067 g \cdot kg^{-1} BM \cdot meal^{-1}$).

When analyzing fat, the main effect of training load was significant for linear ($p \leq 0.001$) but not quadratic ($p=0.623$), increasing from E($0.280 \pm 0.033 g \cdot kg^{-1} BM \cdot meal^{-1}$) to M($0.390 \pm 0.024 g \cdot kg^{-1} BM \cdot meal^{-1}$) to H($0.468 \pm 0.040 g \cdot kg^{-1} BM \cdot meal^{-1}$).

When analyzing energy, the main effect of training load from E to M to H was significant for linear ($p \leq 0.001$) but not quadratic ($p=0.251$) and there was a difference among the training load intervals from E($8.586 \pm 0.530 kcal \cdot kg^{-1} BM \cdot meal^{-1}$) to M($11.480 \pm 0.422 kcal \cdot kg^{-1} BM \cdot meal^{-1}$) and H($15.746 \pm 0.814 kcal \cdot kg^{-1} BM \cdot meal^{-1}$).

Figures 3.2 and 3.3 portray the 3-way interaction for protein as indicated by the two-way interaction for training load and meal, which varied with gender. The effect of training load was significant for linear ($p \leq 0.001$) but not quadratic ($p=0.596$). The effect of the meal from breakfast to lunch to dinner was significant for linear ($p=0.011$) and quadratic ($p=0.027$). While protein increased similarly for males and females with training load for lunch and dinner, it changed more from breakfast to lunch in females than in males with training load (Table 3.7). Figure 3.4 shows protein distribution on the plates being 70% from animal sources.

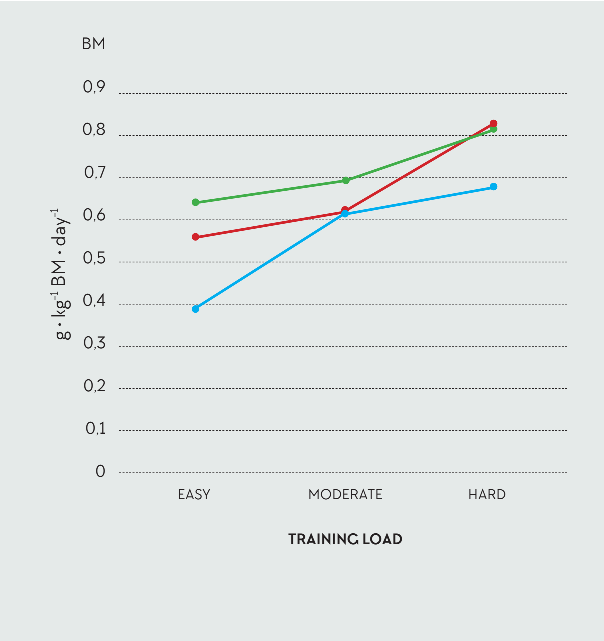

FIGURE 3.2

Female two-way interaction (meal x training load) for protein

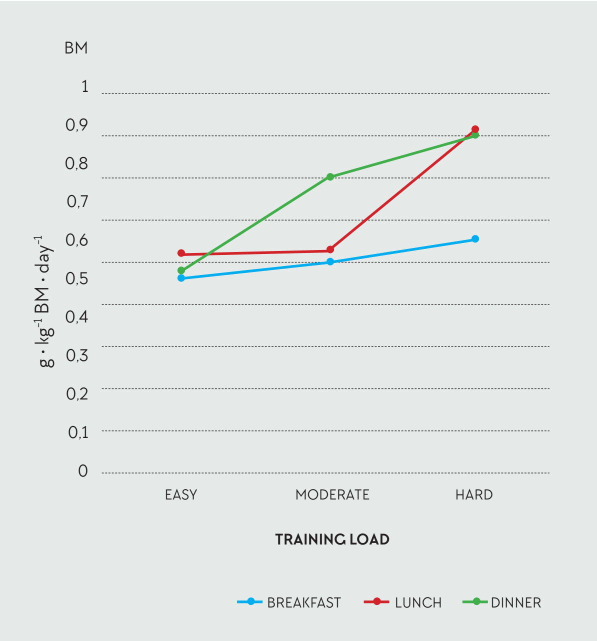

FIGURE 3.3

Male two-way interaction (meal x training load) for protein

TABLE 3.7

Gender x meal x training load, three-way interaction for protein

GENDER	MEAL	TRAINING LOAD	MEAN ± SEM (g · kg^{-1} BM · meal^{-1})
Female	Breakfast	Easy	0.388 ± 0.038
		Moderate	0.611 ± 0.061
		Hard	0.673 ± 0.070
	Lunch	Easy	0.639 ± 0.057
		Moderate	0.693 ± 0.055
		Hard	0.810 ± 0.070
	Dinner	Easy	0.556 ± 0.055
		Moderate	0.618 ± 0.043
		Hard	0.826 ± 0.052
Male	Breakfast	Easy	0.502 ± 0.039
		Moderate	0.548 ± 0.049
		Hard	0.603 ± 0.045
	Lunch	Easy	0.518 ± 0.053
		Moderate	0.771 ± 0.075
		Hard	0.879 ± 0.069
	Dinner	Easy	0.564 ± 0.042
		Moderate	0.576 ± 0.047
		Hard	0.890 ± 0.072

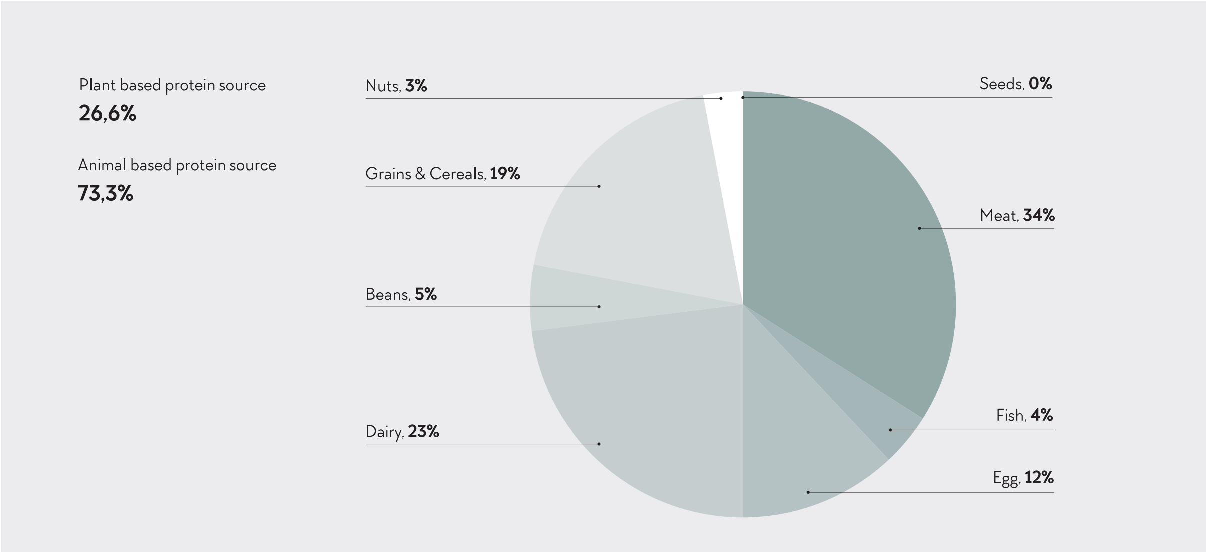

FIGURE 3.4

Contribution of plant and animal food sources to total daily protein intake

4. Discussion

The purpose of this study was to validate the AP against international sport nutritional recommendations starting with sport dietitians making meals for athletes. The results show that the AP is a valid educational tool to guide athletes in building their plates according to training load. In fact, training load is the main factor that drives increases in energy and macronutrients in the E, M, and H. Conversely, fiber content of the plates was significantly higher for E compared to M and H, which was expected. In contrast, protein content for E, M, and H exceeded recommendations when considering the midpoint of 1.6g·kg-1BM·day-1, but was within the recommended range of 1.2-2g·kg-1BM·day-1 for E (Thomas et al., 2016), but above for M and H. This increase was more pronounced at lunch and dinner versus breakfast. It appears that the 2-way interaction of meal and training load is mainly due to low protein content at breakfast, especially in females.

It has been reported that athletes have difficulties when modifying energy and macronutrient intakes according to training loads. Drenowatz et al. (2012) found no significant differences in dietary intake in endurance athletes in response to variable training periods. Moreover, it has been reported that endurance athletes, and specifically females, have difficulties meeting recommended energy and carbohydrate intakes for optimal performance (Manore et al., 2017; Noll et al., 2017). This is likely due to the high training loads and an inadvertent low EA and/or energy restriction (Melin et al., 2016; Viner et al., 2015). Viner at al. (2015) found mean carbohydrate intakes of 3.9g·kg^{-1}BM·day^{-1} and low EA across the season in female and male cyclists. This low EA and carbohydrate intake could be reversed with educational approaches that help athletes periodize nutrition according to training load. For that reason, the AP could be a good visual guide for sport dietitians to help athletes increase energy and carbohydrate intake.

The AP was designed to help athletes increase energy, carbohydrate, and fat intake with increased training loads, however, leaving protein constant. This is due to the fact that protein intake is a function of energy and carbohydrate intakes (Gillen et al., 2017), keeping relative proportions unchanged while still meeting protein recommendations for sports. However, the results of this study found higher than recommended amounts for protein, especially for M and H training loads (Table 3.7). This increase mostly occurred at lunch and dinner for both M and H. For females, protein was high for most conditions, but especially at lunch and dinner for H (Figure 3.2). For males, excess protein was especially apparent for lunch at both M and H training loads and for dinner for H (Figure 3.3). This excess of protein is statistically significant, and thus, an important factor to consider when interpreting the results of this study. It is well known that protein recommendations are higher for athletes compared with the general population (Thomas et al., 2016). However, recent trends show even higher intakes of protein than recommended in many sports (Gillen et al., 2017; Parnell et al., 2016), with some studies showing excessive intakes as high as $4.3 g \cdot kg^{-1} BM \cdot day^{-1}$ (Juzwiak, et al., 2008; Spendlove et al., 2015).

The reason why the AP tool resulted in higher than recommended protein contents, as directed by RDs, is difficult to explain but multiple discussion points seem relevant. First, the AP design may cause a high protein intake. For example, some of the designed plates had a dairy beverage or a Greek yogurt as dessert, which adds protein to the total protein content (Kanda et al., 2016; Phillips, et al., 2009). Second, the menus of the CS-USOC dining hall, where the data collection occurred, is buffet style with a wide range and variety of foods offered to athletes, including a salad bar along with a full range of starters, main dishes and a recovery station. This design gives the sport dietitian and athletes different choices of proteins but also risks inflation of total protein intake. Nutrition education, including how athletes should use the plate, along with menu labeling with nutrition facts, highlighting protein, could avoid this issue. Third, recent rising trends in protein requirements for athletes (Hector & Phillips, 2017; Phillips et al., 2016; Phillips & Van Loon, 2011) may have influenced the RDs who built the plates in this study.

One of the limitations of this study is the inability to account for snacks ingested throughout the day. The snack portion of an athlete varies depending on the training session, the goal of the session, travel constrains, and recovery strategies, to name a few. Several studies have shown that snacking in athletes makes up between 23-25% of daily EI (Burke et al., 2003; Erdman, Tunnicliffe et al., 2013). The purpose of this study was to validate the AP against daily sport nutrition recommendations but without the inclusion of snacks. Thus, 23% of EI was added to the three meals (B, L, D) by training load (E, M, H) and gender (m/f) with the same macronutrient distribution to maintain variability. While this is an approximation to daily intake that needs consideration when interpreting the results, this strategy should have not affected the outcome of this study. Considering protein intake in athletes, recent focus has not only been on quantity but also timing of ingestion relative to exercise (Areta et al., 2013; Macnaughton et al., 2016; Res et al., 2012) to optimize recovery and muscle anabolism. The current recommendation for athletes is to consume $0.3 g \cdot kg^{-1} BM \cdot day^{-1}$ or 20-25g of protein per meal 4-5 times per day (Moore et al., 2009; Phillips & Van Loon, 2011), some of which is likely to be consumed post-exercise in the form of a snack (Abbey et al., 2017; Parnell et al., 2016; Whitehouse & Lawlis, 2017). Thus, if anything, this study likely underestimates protein content. Some studies have reported a suboptimal distribution of protein intake through the day especially at breakfast (Gillen et al., 2017). Similar results have been observed in this study, with higher protein content observed at lunch and dinner versus breakfast. This suggests that more efforts have to be directed at educating athletes on how to distribute protein throughout the day, considering timing of training sessions and digestibility of different protein sources.

Another factor to consider is protein quality (Pennings et al., 2011; Phillips & Van Loon, 2011; Res et al., 2012). It has been demonstrated that a good quality protein with high leucine content will help with recovery and training adaptation (Macnaughton et al., 2016; Pennings et al., 2011; Phillips & Van Loon, 2011; Rowlands et al., 2014). Though most studies have focused on dairy and meat as a source to increase protein intake, especially post-exercise (Burd et al., 2015; Pennings et al., 2011), very few studies have examined plant-based sources of protein (Babault et al., 2015; van Vliet et al., 2015). Some authors suggest that well-balanced, plant-based protein could have the same effect as animal-based protein regarding muscle adaptation, but more studies are needed (van Vliet et al., 2015).

Western diets are typically higher in animal versus plant protein, and this is also true for most athletes, although results are not always conclusive. For example, Gillen et al., (2017), found 57% animal vs 43% plant-based sources of protein in Dutch athletes. In contrast, the current US study showed 73.3% of total protein content originating from animal sources (Figure 3.4). While most international dietary recommendations propose to reduce red meat consumption for disease prevention, some countries have also adopted such considerations for environmental protection (Kromhout et al., 2016). Animal protein, specially red meat and dairy, have a higher environmental impact, compared with plant-based alternatives (Sabaté et al. 2014). While it seems that plant-based options are highly accessible in the US and also promoted (U.S Department of Health & U.S Department of Agriculture, 2015), in sport nutrition such guidance is typically associated with a word of caution, likely due to the potential negative consequences, including compromised energy and nutrient intakes (Cialdella-Kam et al., 2016). New research, however, shows adequacy in both omnivorous and vegetarian diet patterns for athletes when well planned (Boldt et al., 2018). Thus, sport nutrition recommendations, including associated educational tools, should integrate plant-based and plant-forward considerations to promote sustainable practices and environmental protection, as recently highlighted by the Lancet EAT-Commission on Healthy Diets from Sustainable Food Systems (Willett et al., 2019). Specifically, when working with and using the AP, the following recommendations apply: 1. Reduce animal protein on the plates (especially beef and dairy); 2. Include more plant-based protein sources on the plates; 3. Balance high protein foods from plants and animal sources on the same plate (eg., avoid quinoa+lentils+beef+milk shake); 4. Re-design the plates using the protein flip (http://www.menusofchange.org/), moving meat to the periphery or making it a topping and not the centerpiece of the plate; 5. More protein is not better. Distribute protein intake equally throughout the day according to sport nutrition guidelines (Phillips & Van Loon, 2011).

A limitation of this study includes the few weight categories considered. These weight categories were chosen by the CS-OTC RDs to fit the average athlete at their training center. However, weight categories do not include all athletes and weights might differ depending on the sport, level of competition, and country. In addition, one plate might not be enough to fit the heavier athlete. Therefore, an adaption or a different approach might be considered for higher weight categories. Another limitation is that this study took place at the dining hall of the CS-USOTC, where a broad range of food is provided to a broad range of athletes. The menu complies with the food culture of the United States. For this reason, this validation might only be applicable in this setting, although westernized food cultures may vary little, especially in sport nutrition because guidelines are provided by an international governing body.

In summary, the findings of this study show that the AP is a valid tool to educate athletes regarding the needed increase in energy, carbohydrate, and fat with higher training loads, from E to M to H. However, the AP exceeds protein recommendations especially for M and H. To meet guidelines for performance, health, and sustainability sport nutrition professionals, including the authors of this study, should integrate environmental impacts when making recommendations, while maintaining the health and performance of the athlete as the highest priority.

5. Acknowledgments

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6. References

Abbey, E. L., Wright, C. J., & Kirkpatrick, C. M. (2017). Nutrition practices and knowledge among NCAA Division III football players. *Journal of the International Society of Sports Nutrition*, *14*, 13. http://doi.org/10.1186/s12970-017-0170-2

Areta, J. L., Burke, L. M., Ross, M. L., Camera, D. M., West, D. W. D., Broad, E. M., … Coffey, V. G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *The Journal of Physiology*, *591*(9), 2319–31. http://doi.org/10.1113/jphysiol.2012.244897

Babault, N., Païzis, C., Deley, G., Guérin-Deremaux, L., Saniez, M.-H., Lefranc-Millot, C., & Allaert, F. A. (2015). Pea proteins oral supplementation promotes muscle thickness gains during resistance training: a double-blind, randomized, Placebo-controlled clinical trial vs. Whey protein. *Journal of the International Society of Sports Nutrition*, *12*(1), 3. http://doi.org/10.1186/s12970-014-0064-5

Bach-Faig, A., Berry, E. M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., … Serra-Majem, L. (2011). Mediterranean diet pyramid today. Science and cultural updates. *Public Health Nutrition*, *14*(12A), 2274–2284. http://doi.org/10.1017/S1368980011002515

Boldt, P., Knechtle, B., Nikolaidis, P., Lechleitner, C., Wirnitzer, G., Leitzmann, C., … Wirnitzer, K. (2018). Quality of life of female and male vegetarian and vegan endurance runners compared to omnivores – results from the NURMI study (step 2). *Journal of the International Society of Sports Nutrition*, *15*(1), 33. http://doi.org/10.1186/s12970-018-0237-8

Burd, N. A., Gorissen, S. H., van Vliet, S., Snijders, T., & van Loon, L. J. (2015). Differences in postprandial protein handling after beef compared with milk ingestion during postexercise recovery: a randomized controlled trial. *American Journal of Clinical Nutrition*, *102*(4), 828–836. http://doi.org/10.3945/ajcn.114.103184

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences*, *29 Suppl 1*, S17-27. http://doi.org/10.1080/02640414.2011.585473

Burke, L. M., Slater, G., Broad, E. M., Haukka, J., Modulon, S., & Hopkins, W. G. (2003). Eating patterns and meal frequency of elite Australian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*(4), 521–38. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14967874

Chatsworth California. (n.d.). Hospitality Suite Computrition (v 18.1).

Cialdella-Kam, L., Kulpins, D., & Manore, M. (2016). Vegetarian, Gluten-Free, and Energy Restricted Diets in Female Athletes. *Sports*, *4*(4), 50. http://doi.org/10.3390/sports4040050

Clark, A., & Mach, N. (2016). Exercise-induced stress behavior, gut-microbiota-brain axis and diet: A systematic review for athletes. *Journal of the International Society of Sports Nutrition*, *13*(1), 1–21. http://doi.org/10.1186/s12970-016-0155-6

de Oliveira, E. P., Burini, R. C., & Jeukendrup, A. (2014). Gastrointestinal complaints during exercise: prevalence, etiology, and nutritional recommendations. *Sports Medicine (Auckland, N.Z.)*, *44 Suppl 1*, S79-85. http://doi.org/10.1007/s40279-014-0153-2

Drenowatz, C., Eisenmann, J. C., Carlson, J. J., Pfeiffer, K. A., & Pivarnik, J. M. (2012). Energy expenditure and dietary intake during high-volume and low-volume training periods among male endurance athletes. *Applied Physiology, Nutrition, and Metabolism*, *37*(2), 199–205. http://doi.org/10.1139/h11-155

Erdman, K. A., Tunnicliffe, J., Lun, V. M., & Reimer, R. A. (2013). Eating patterns and composition of meals and snacks in elite Canadian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *23*(3), 210–9. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23114732

FAO. (2016). *Plates, pyramids, planets. Developments in national healthy and sustainable dietary guidelines: a state of play assessment*. Food and Agriculture Organisation of the United Nations (FAO) and the Food Climate Research Network at The University of Oxford (FCRN).

Forman, A., Colby, S. E., Gellar, L., Kavanagh, K., & Spence, M. (2015). My Painted Plate: Art Enhances Nutrition Education with Children. *Journal of Nutrition Education and Behavior*, *47*(4), S57. http://doi.org/10.1016/j.jneb.2015.04.152

Hector, A., & Phillips, S. M. (2017). Protein Recommendations for Weight Loss in Elite Athletes: A Focus on Body Composition and Performance. *International Journal of Sport Nutrition and Exercise Metabolism*, *32*, 1–26. http://doi.org/10.1123/ijsnem.2017-0273

IBM Corp Released. (2015). SPSS v 23. NY.

Institute of Medicine. (2005). *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients)*. (The National Academies Presss, Ed.). Washington, DC. http://doi.org/10.17226/10490

J.Gillen, J.Trommelen, F. Wardenaar, et al. (2017). Dietary protein intake and distribution patterns of well-trained Dutch athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*(2), 105–114. http://doi.org/10.1123/ijsnem.2016-0154

Jeukendrup, A. E. (2017). Training the Gut for Athletes. *Sports Medicine*, *47*(s1), 101–110. http://doi.org/10.1007/s40279-017-0690-6

Juzwiak, C. R., Amancio, O. M. S., Vitalle, M. S. S., Pinheiro, M. M., & Szejnfeld, V. L. (2008). Body composition and nutritional profile of male adolescent tennis players. *Journal of Sports Sciences*, *26*(11), 1209–17. http://doi.org/10.1080/02640410801930192

Kanda, A., Nakayama, K., Sanbongi, C., Nagata, M., Ikegami, S., & Itoh, H. (2016). Effects of Whey, Caseinate, or Milk Protein Ingestion on Muscle Protein Synthesis after Exercise. *Nutrients*, *8*(6), 339. http://doi.org/10.3390/nu8060339

Kromhout, D., Spaaij, C. J. K., de Goede, J., & Weggemans, R. M. (2016). The 2015 Dutch food-based dietary guidelines. *European Journal of Clinical Nutrition*, (February), 1–10. http://doi.org/10.1038/ejcn.2016.52

Loucks, A. B. (2004). Energy balance and body composition in sports and exercise. *Journal of Sports Sciences*, *22*(1), 1–14. http://doi.org/10.1080/0264041031000140518

Lowery, L. M. (2004). Dietary fat and sports nutrition: A primer. *Journal of Sports Science and Medicine*, *3*(3), 106–117.

Macnaughton, L. S., Wardle, S. L., Witard, O. C., McGlory, C., Hamilton, D. L., Jeromson, S., … Tipton, K. D. (2016). The response of muscle protein synthesis following whole-body resistance exercise is greater following 40 g than 20 g of ingested whey protein. *Physiological Reports*, 4(15), 1102–1106. http://doi.org/10.14814/phy2.12893

Manore, M. M., Patton-Lopez, M. M., Meng, Y., & Sung Wong, S. (2017). Sport Nutrition Knowledge, Behaviors and Beliefs of High School Soccer Players. *Nutrients*, *9*(350), 1–14. http://doi.org/10.3390/nu9040350

Melin, A., Tornberg, Å. B., Skouby, S., Møller, S. S., Faber, J., Sundgot-Borgen, J., & Sjödin, A. (2016). Low-energy density and high fiber intake are dietary concerns in female endurance athletes. *Scandinavian Journal of Medicine & Science in Sports*, *26*(9), 1060–1071. http://doi.org/10.1111/sms.12516

Mettler, S., Mannhart, C., & Colombani, P. C. (2009). Development and validation of a food pyramid for Swiss athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *19*(5), 504–18. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19910652

Moore, D. R., Robinson, M. J., Fry, J. L., Tang, J. E., Glover, E. I., Wilkinson, S. B., … Phillips, S. M. (2009). Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. *The American Journal of Clinical Nutrition*, *89*(1), 161–168. http://doi.org/10.3945/ajcn.2008.26401

Noll, M., de Mendonça, C. R., de Souza Rosa, L. P., & Silveira, E. A. (2017). Determinants of eating patterns and nutrient intake among adolescent athletes: a systematic review. *Nutrition Journal*, *16*(1), 46. http://doi.org/10.1186/s12937-017-0267-0

Parnell, J. A., Wiens, K. P., & Erdman, K. A. (2016). Dietary intakes and supplement use in pre-adolescent and adolescent Canadian athletes. *Nutrients*, *8*(9), 1–13. http://doi.org/10.3390/nu8090526

Pennings, B., Boirie, Y., Senden, J. M., Gijsen, A. P., Kuipers, H., & van Loon, L. J. (2011). Whey protein stimulates postprandial muscle protein accretion more effectively than do casein and casein hydrolysate in older men. *American Journal of Clinical Nutrition*, *93*(5), 997–1005. http://doi.org/10.3945/ajcn.110.008102

Phillips, S. M., Chevalier, S., & Leidy, H. J. (2016). Protein "requirements" beyond the RDA: implications for optimizing health. *Applied Physiology, Nutrition, and Metabolism*, *572*(February), 1–8. http://doi.org/10.1139/apnm-2015-0550

Phillips, S. M., Tang, J. E., & Moore, D. R. (2009). The role of milk- and soy-based protein in support of muscle protein synthesis and muscle protein accretion in young and elderly persons. *Journal of the American College of Nutrition*, *28*(4), 343–54. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20368372

Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. *Journal of Sports Sciences*, *29*(sup1), S29–S38. http://doi.org/10.1080/02640414.2011.619204

Res, P. T., Groen, B., Pennings, B., Beelen, M., Wallis, G. A., Gijsen, A. P., ... VAN Loon, L. J. C. (2012). Protein ingestion before sleep improves postexercise overnight recovery. *Medicine and Science in Sports and Exercise*, 44(8), 1560–9. http://doi.org/10.1249/MSS.0b013e31824cc363

Rowlands, D. S., Nelson, A. R., Phillips, S. M., Faulkner, J. A., Clarke, J., Burd, N. A., ... Stellingwerff, T. (2014). *Protein-leucine fed dose effects on muscle protein synthesis after endurance exercise*. *Medicine and Science in Sports and Exercise* (Vol. 47). http://doi.org/10.1249/MSS.0000000000000447

Ruini, L. F., Ciati, R., Pratesi, C. A., Marino, M., Principato, L., & Vannuzzi, E. (2015). Working toward Healthy and Sustainable Diets: The "Double Pyramid Model" Developed by the Barilla Center for Food and Nutrition to Raise Awareness about the Environmental and Nutritional Impact of Foods. *Frontiers in Nutrition*, *2*, 9. http://doi.org/10.3389/fnut.2015.00009

Sabaté, J., Sranacharoenpong, K., Harwatt, H., Wien, M., & Soret, S. (2014). The environmental cost of protein food choices. *Public Health Nutrition*, *18*(11), 1–7. http://doi.org/10.1017/S1368980014002377

Spendlove, J., Mitchell, L., Gifford, J., Hackett, D., Slater, G., Cobley, S., & O'Connor, H. (2015). Dietary Intake of Competitive Bodybuilders. *Sports Medicine (Auckland, N.Z.)*, *45*(7), 1041–63. http://doi.org/10.1007/s40279-015-0329-4

Stellingwerff, T., Maughan, R. J., & Burke, L. M. (2011). Nutrition for power sports: Middle-distance running, track cycling, rowing, canoeing/kayaking, and swimming. *Journal of Sports Sciences*, *29*(SUPPL. 1), 37–41. http://doi.org/10.1080/02640414.2011.589469

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Nutrition and Athletic Performance. *Medicine & Science in Sports & Exercise*, *48*(3), 543–568. http://doi.org/10.1249/MSS.0000000000000852

USDA. (2015). 2015 – 2020 Dietary Guidelines for Americans. *U.S. Department of Health and Human Services and U.S. Department of Agriculture*, 18. http://doi.org/10.1097/NT.0b013e31826c50af

van Vliet, S., Burd, N. A., & van Loon, L. J. (2015). The Skeletal Muscle Anabolic Response to Plant- versus Animal-Based Protein Consumption. *The Journal of Nutrition*, (C), jn.114.204305-. http://doi.org/10.3945/jn.114.204305

Viner, R. T., Harris, M., Berning, J. R., & Meyer, N. L. (2015). Energy Availability and Dietary Patterns of Adult Male and Female Competitive Cyclists with Lower than Expected Bone Mineral Density. *International Journal of Sport Nutrition and Exercise Metabolism*, *25*(6), 594–602. http://doi.org/10.1123/ijsnem.2015-0073

Whitehouse, G., & Lawlis, T. (2017). Protein supplements and adolescent athletes: A pilot study investigating the risk knowledge, motivations and prevalence of use. *Nutrition & Dietetics: The Journal of the Dietitians Association of Australia*. http://doi.org/10.1111/1747-0080.12367

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., ... Murray, C. J. L. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*. http://doi.org/10.1016/S0140-6736(18)31788-4

CONTRIBUTION III:

The Athlete's Plate Education Program: An Experiential Intervention

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Current State: Preparation for submission

Abstract

The Athlete's Plate (AP) is a visual tool to help athletes adjust their food and fluid intake to variable training loads. To educate athletes on how to use the AP, the AP Education Program was developed. The purpose of this study was to evaluate the AP Education Program in a real-life setting with elite athletes involved in current training. An explanatory mixed methods design was used to collect quantitative and qualitative data. Data were collected at an elite training center. Twenty-six resident or visiting female and male elite athletes, some with disabilities, volunteered for the study. The AP Education Program includes: 1) a 30-minute PowerPoint presentation delivered by a sport dietitian, 2) completion of The AP Education Survey (TAPES) to test athletes' understanding and knowledge of the tool post-education; and, 3) an opportunity to go through the a dining experience to the AP tool into practice by making a plate. Survey scores were analyzed to evaluate knowledge acquisition. A score of (10.5 pts) or 70% was set as minimum score indicating passing. Qualitative data from the experiential phase were analyzed using an observational study to evaluate the behavior of athletes when making their plates and identify areas of improvement of the AP Education Program. Mean score of all participants on TAPES was 13.4 ± 1.5 ($89.2 \pm 9.8\%$). All, except two participants passed TAPES (92.3%) with 69% of participants scoring 14pts (93%) or higher. Athletes with disabilities, while still passing TAPES, scored lower than their abled-bodied counterparts ($p \leq 0.05$). Qualitative findings were organized in three themes: 1) personalize your plate 2) navigate the dining hall on the road to success; 3) eat more when it matters. Classroom learning coupled with practical application is interactive and serves to improve athletes' ability to understand and use the AP. Therefore, it is recommended that both educational components be included in AP Education Program. The themes identified from the qualitative analysis will be used to improve the AP Education Program.

KEYWORDS: Sport nutrition, nutrition/training periodization, nutrition education, qualitative research, mix-methods research, experiential learning

1. Introduction

Nutrition education and nutrition guidelines, influence consumer knowledge, awareness, attitudes and skills concerning healthy eating (Hawkes, Jewell, & Allen, 2013). There are different strategies to deliver nutrition education. Nutritional team talks and workshops are popular practical approaches, while general education may also simply leverage governmental Nutrient-based Dietary Guidelines (NBDG) and available materials (USDA, 2015). Each strategy is used depending on the situation, setting or target population among others (Schuster, 2012; Shilts, Johns, Lamp, Schneider, & Townsend, 2015). Nutritional recommendations are developed for each country and represent NBDG, which are often converted into Food-based Dietary Guidelines (FBDG) for easier comprehension in the target population. Several countries have developed FBDG and have translated them into visual tools using different graphic representations, such as plates or pyramids, to help translate the nutritional message to the target population (Bach-Faig et al., 2011; Chrisman & Diaz Rios, 2019). While these tools need to be validated to ensure they meet recommended nutrient intakes, it is also important to educate people on how to use them (Shilts et al., 2015). Experiential education programs have been used in different settings such as in the garden or kitchen and in dining halls to translate nutrition knowledge to skill acquisition (Amin et al., 2018; Gibbs et al., 2013; Parmer, Salisbury-Glennon, Shannon, & Struempler, 2009).

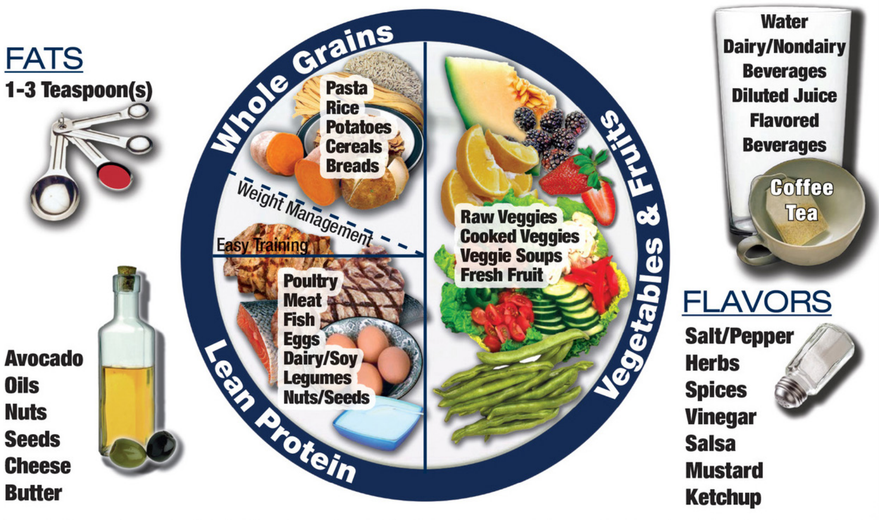
The experience of choosing food is not only influenced by attempting to meet optimal nutrition, but it is also influenced by taste, smell, familiarity, cultural and social factors (Pawlak, Malinauskas, & Rivera, 2009). For this reason, it is important to consider the dimensions of food beyond nutrition when implementing nutrition education strategies. Typically, nutrition education programs have focused on formal presentations in classroom formats or formal curriculum implementations as complementary education, for example in collegiate athletes (Jacob et al., 2016; Parks et al., 2016). There is some evidence that supplementary experiential interventions, with hands on experiences, result in better knowledge outcomes, skill acquisition, and experiences. Ellis, Brown, Ramsay, & Falk (2018) found a positive effect on self-efficacy and food preparation of collegiate athletes with hands-on cooking classes (Ellis et al., 2018). Levy & Auld, (2004) also found that cooking classes instead of cooking demonstrations increase self-efficacy of athletes when cooking their own food. Thus, experiential learning when developing nutritional interventions, is important.

The Athlete's Plate is a visual tool to help athletes adjust their food and fluid intake to variable training loads. Training load is defined by the product of training intensity and volume (Foster et al., 2001). In the AP model, training load is expressed as easy (E), moderate (M) and hard (H) training (figure 3.5). The AP used in this study was validated by registered sport dietitians (RDs), creating plates for hypothetical athlete scenarios and against international sport nutrition recommendations (Reguant-Closa, Harris, Lohman, & Meyer, 2019). The AP Education Program includes the visual plates, a presentation given by an RD that describes how to use the plates, and a survey that tests athletes' understanding of the tool post-presentation, followed by an observation of athletes' behaviors making their plates in a dining hall. The AP Education Program was developed by the Sport Nutrition Graduate Program at the University of Colorado Colorado Springs (UCCS) alongside the AP. The AP education program, with educational materials (handouts for athletes posters and labeling ideas of the dining halls) can be found at www.uccs.edu/swell/athletesplate.

Athletes have specific energy and nutrient needs to ensure optimal performance and health depending on their training load (Broad, 2019; Thomas, Erdman, & Burke, 2016). The AP was designed as a practical teaching and learning tool to help athletes and RDs working with them adjust diets to training load in a visual and intuitive manner. The aim of the AP is not to give recommendations that fit all in a prescriptive approach, but to be an educational tool that provides athletes with a better understanding that increased training loads require proportionally more carbohydrates and fats, while gradually reducing fiber from raw and unrefined, whole foods, especially prior to and after hard training/competition. The AP model does not prescribe precise quantities of food, number of plates, or even the variable vessels from which food is consumed. The tool aims to maintain athletes' freedom to make the right choice based on individual performance and health needs as well as ath-

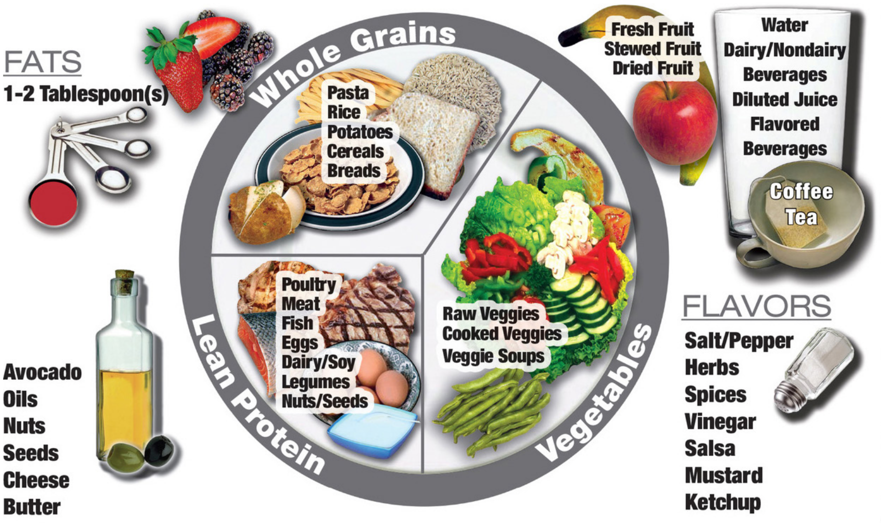
FIGURE 3.5
Athlete's Plate model training load definition

TRAINING TYPE



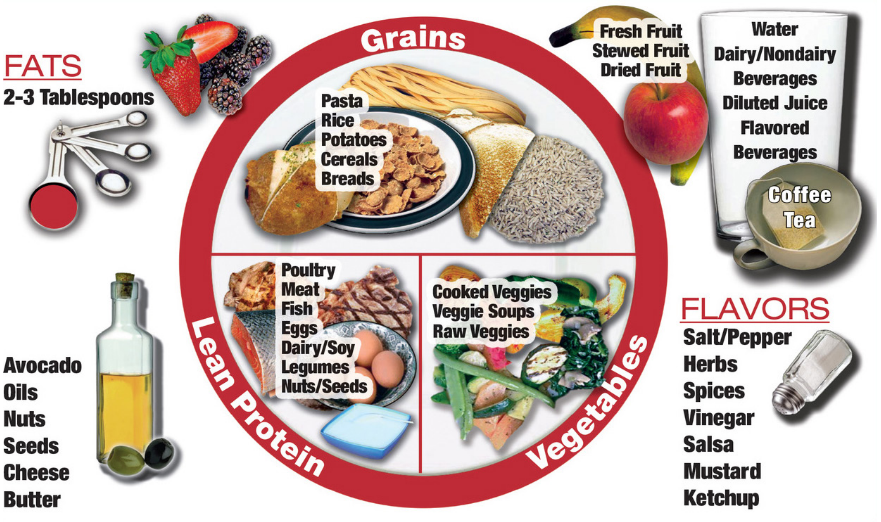
EASY TRAINING

- 1 easy session per day
- 1 technical/skill-based session
- Recovery day or off season
- Weight loss



MODERATE TRAINING

- 1–2 moderate sessions per day
- Technical/skill-based training
- 1 moderate to hard training session with >24 hours of recovery



HARD TRAINING/ COMPETITION

- 2–3 sessions per day
- High volume and/ or intensity training
- Intense training phases with focus on adaptation (e.g., heavy lifting, altitude training)
- Races, tournaments, time trials

letes' cultural preferences. Basic sport nutrition recommendations considered in the AP tool are: 1) increasing carbohydrate and fat intake with training load (Burke, Hawley, Wong, & Jeukendrup, 2011; Stellingwerff, Maughan, & Burke, 2011); 2) maintaining optimal protein quantity and quality to ensure prompt muscle recovery (Phillips & Van Loon, 2011); 3) decreasing fiber with increased training load to avoid digestive problems (de Oliveira, Buruni, & Jeukendrup, 2014); 4), and including a wide variety of foods to ensure sufficient nutrient intakes (Broad, 2019; Thomas et al., 2016).

The purpose of this study was to evaluate the AP Education Program in a real-life setting with elite athletes involved in current training. For the purpose of this study, we focused on elite athletes, understanding that the AP model applies to a broad range of competitive levels, sports, and ages. While it was an opportunity to conduct a study with this population, it also presented challenges. When conducting research in elite athletes in a real-life setting, the shorter the interference with training the better. For this reason and to decrease the burden on the athletes, an explanatory mixed methods design was used to collect both quantitative and qualitative data at an elite training center facility. Our research focused on the AP Education Program, evaluating in-classroom and dining-hall experiential education with elite athletes with and without disabilities. This intervention aligns with the diffusion of innovation theory framework (Dearing & Cox, 2018; Diker et al., 2013) as it brings an experiential and innovative component into nutrition education for athletes. Since this study is not only focused on a formal educational setting such as the classroom, but also emphasized the athletes' ability to apply their knowledge in practice, an observational analysis of athletes' behaviors in the dining hall was conducted.

To our knowledge there is little information on how athletes understand and apply sport nutrition knowledge gained from educational interventions. Moreover, very little attention has been paid to the behaviors and interactions of athletes when making their plates in a dining hall setting. It is important to evaluate decision making of athletes when exposed to variable menu and food choices in training centers, as appropriate food selection impacts recovery and performance acutely, while also contributing to the long-term maintenance of health. In addition, the dining hall experience and whether the menu provides adequate variety and balance and connects successfully with the labeling system and educational outreach are all critical components of elite athlete support (Cole et al., 2018; Pelly, Meyer, Pearce, Burkhart, & Burke, 2014). The entire food experience, including appearance, aesthetics, tastes and smells, as well as individual preference and cultural orientation, has to be integrated when evaluating and optimizing athletes' food choices in dining halls. Thus, there are many pieces that need to be included when evaluating athlete's ability and decision-making to create their own plates to meet sport nutrition needs.

This mixed methods study addressed the need to better understand the effectiveness of the AP Education Program. This program originally included a 30-minute PPT presentation followed by the administration of AP Education Survey (TAPES) (see appendix); however, it was uncertain how the athletes applied the knowledge they gained from this intervention. Thus, this study included a secondary analysis (qualitative) of the phenomenon of athletes creating their plates in a real-world setting though an observational analysis of the athletes in the dining hall at the facility where they trained.

2. Methods

An explanatory sequential mixed-methods design was selected for this study. Quantitative (QN) data were collected first and qualitative (QL) data second. The QL data enriches the study in this type of two-phase design, helping to explain or build upon the QN results (J. W. Creswell & Plano Clark, 2011). In the past years, mixed methods research has gained momentum in most sciences. In nutritional sciences, while not yet widely used, qualitative research has been used to analyze the development of educational programs and identify barriers to behavior change and evaluate experiential interventions using food experiences (Amin et al., 2018; Gibbs et al., 2013). Qualitative research depends on a variety of methods for collecting data. For this study, participant-observation was selected to see if and how athletes, who participated in the formal presentation, applied their new learning in a real-life setting of an elite training center's dining hall.

Participants

Twenty-six elite athletes, with (n=8) and without disabilities (n=18), participated in this study. Athletes were recruited at three different times. Group I (7 males, 1 female; 21.6 ± 1.4 yrs.) consisted of elite triathletes without disabilities. Group II (4 males, 4 females; 24.6 ± 9.7 yrs.) consisted of elite athletes with variable disabilities including visual impairment. Group III (5 males, 5 females; 22.8 ± 0.8 yrs.) consisted of elite triathletes without disabilities. The two triathlon teams (group I and III) were attending a two-week training camp at the facility at different times; 16 of the 18 athletes were new to the facility. Group II was comprised of athletes with some disabilities who were in residence at the facility. Data analysis is divided into two groups comparing group I and group III (athletes without disabilities) with group II (athletes with disabilities).

Experimental design/intervention design and data collection

The following three-phase intervention based on the AP Education Program was implemented. First, a 30-minute presentation was delivered by an RD. The presentation included an introduction into the AP model and general concepts of periodized nutrition and fueling and how to adjust food intake to variable training loads and competition situations using practical examples. Second, a survey, called the AP Education Survey (TAPES) was administered immediately to test athletes' knowledge post-presentation. Third, athletes received the opportunity to make their own plates, based on their current training load, in the training center's dining hall by two trained observers. Group I and II participated in all three phases of the study but group III did not participate in the observational analysis.

Data were collected in two phases. First, the QN data were collected via TAPES administered post-educational (classroom) session followed by QL data collection in the dining hall. For the QL data collection, researchers kept field notes related to adaptations made for group II after their educational (classroom) session, as some of the athletes were partially or fully visually impaired and some adaptations had to be made on the PPT presentation. More details on the QL data collection and analysis can be found under the participant-observer data in this methods section.

The sequence of the intervention for group I and II are described below.

Group I: 1) participated in the first training session of the day, 2) received the PPT presentation, 3) completed the survey (TAPES), and 4) went to the dining hall for lunch with intention to make the AP best suited for their current training load. They had a classroom session scheduled after lunch but no training session.

Group II: 1) participated in two training sessions during the day, 2) received the PPT presentation, 3) completed TAPES, and 4) went to the dining hall for dinner after the last training session of the day with intention to make the AP best suited for their current training load.

The study was approved by the University of Colorado, Colorado Springs (UCCS) Institutional Review Board, with all subjects signing an approved written informed consent form before the PPT.

The Athlete´s Plate Education Survey

The AP Educational Survey (TAPES) was designed by the authors specifically for this study (see appendix). Content validity of TAPES was obtained through 10 sport nutrition experts. The TAPES survey was sent to ten RDs who were familiar with the AP and researchers and/or practitioners in their field. Their feedback was considered and the survey was modified to ensure expert content validity. The survey includes: 1) 8 questions about demographics (age, sport, gender, level of competition) and prior knowledge of the AP, 2) 15 questions related to understanding of AP scored as true, false or I don't know (correct answers received one point with a maximum attainable score of 15 indicating 100%), and 3) a question about the usefulness of the AP as nutrition tool and space to add general comments about the AP. It was assumed that answering 70% of questions correctly would meet satisfactory or sufficient understanding of the AP following the criteria by (www.ed.gov). A We chose to perform a post-test only, as this study was conducted in an elite setting and we wanted minimal interference with their usual training program. The aim of this study was to ensure athletes gained enough knowledge after the PPT presentation so they could create their own plate in the dining hall. Thus, a benchmark seemed more practical considering the nature of this study.

Participant-Observer Data

Participant-based observation took place in the dining hall where the athlete's behavior relative to making a plate was observed. Athletes knew they were being observed. Observation included the making of their plate from the food offered and eating the food they selected. During this time, they were observed by the lead researcher and a second researcher, who acted in the capacity of inter-rater reliability checking. The two researchers were trained in observational data collection. They observed how the AP system was used by the athletes and analyzed the setting appearance, acts, events, processes, communication, interaction, and behaviors according to Glesne, (2011). Validity was accomplished by assessing whether the information obtained though data collection was accurate. Two means of verification were used: inter-rater reliability and an audit by a qualitative expert.

Once data collection was complete researchers followed recommendations for the data analysis complied from a rigorous synthesis of prior recommendations and concepts from published sources

(O'Brien, Harris, Beckman, Reed, & Cook, 2014; Raskind et al., 2019). Specifically Creswell's (2003), Hatch's (2002) and Saldaña's (2009) procedures were followed. First, each researcher read through all their notes independent of one another to get a sense of the whole (Creswell, 2003). During the second reading, the researchers began line-by-line coding, which is the process of organizing the material into key themes of descriptions of the setting, the actions of participants and events of note (Creswell, 2003). In our case, key successes were identified and highlighted line-by-line and margin notes taken in an initial step of decoding to expose underlying meanings (Hatch, 2002). Salient meanings, or domains, were then identified and encoded (Saldaña, 2009). Because little was known about the phenomenon under study, researchers did not use an *a priori* coding system because guessing ahead of time what these codes might be, would destroy validity (Morse, 2015). After encoding silent meanings, the researchers met (peer debrief) to discuss and refine the "meaning units" they identified during their initial analysis (Creswell, 2003). Where discrepancies occurred, differences were discussed, domains (or codes) modified, and agreement reached. A typological analysis was agreed upon "meaning units" into overreaching themes or descriptive categories. Finally, the themes that emerged were: 1) personalize your plate, 2) navigate the dining hall on the road to success, and 3) eat more when it matters.

To ensure the validity of qualitative research, a clarification of researcher bias (subjectivity analysis) and the rich, thick description of each of the observations created by the researchers was examined via external audit by a qualitative researcher expert (Kluge MA). Where there was 'disconfirming evidence' (Creswell & Plano Clark, 2011) these discrepancies were further examined by the two observers, and the external auditor, resulting in agreement to alter if needed. These two means of verification procedures (external audit and inter-rater reliability), contributed to the trustworthiness of this study according to Glesne (2011).

Statistical Analysis

Statistical analyses were performed using SPSS (IBM, version v.25.0, Armonk, NY). Continuous data were not normally distributed, so non-parametric tests were used to evaluate group differences. To evaluate the differences in TAPES scores between athletes with and without disabilities, a Mann-Whitney U test was performed. Significance was set at $p \leq 0.05$ for all analyses.

3. Results

1. The Athlete´s Plate Education Survey

The mean score of all participants on TAPES was 13.4+1.5 (89.2 ± 9.8%). Of all athletes, 92.3% passed the TAPES, with 69% of participants scoring with 14pts (93%) or higher. Two participants (belonging to group I and group II) scored below 70%, and thus, did not pass the survey. A statistical difference ($p \leq 0.05$) in TAPES scores between athletes with and without disabilities was found (table 3.8). Prior AP knowledge and TAPES scores were analyzed. A total of 57.7% of participants had prior knowledge of the AP before this study. There was no difference in TAPES scores between participants who had prior AP knowledge and/or education on the AP and those who had not ($p > 0.05$).

TABLE 3.8
TAPES mean scores by group of athletes (n=26)

	ATHLETES WITHOUT DISABILITIES (group I and III) (n=18)	ATHLETES WITH DISABILITIES (group II) (n=8)	P-VALUE
TAPES Total	13.8 ± 1.2	12.4 ± 1.7	0.026[1]
TAPES Score (%)	92.2 ± 8.0	82.5 ± 10.7	0.026[1]

*All values are presented as mean ± std. dev. TAPES Total represents the score out of 15.
[1]Mann-Whitney U Test; significance p≤0.05

2. Observational analysis

Three themes emerged from the QL analysis: 1) "personalize your plate", 2) "navigate the dining hall on the road to success", and 3) "eating more when it matters". Narratives describing how the researchers adapted the delivery of the educational intervention for the group with visual impairment (group II), the setting (the dining hall itself), and the actions and events that took place in it, including outlier experiences, are below in italics. For the observational analysis at the dining hall only group I (athletes without disabilities) and group II (athletes with disabilities) participated in this portion of the study. Group III did not participate in the observational analysis.

Theme 1: " Personalize your plate"

This theme reflects data collected in the classroom. During the PPT presentation, all three groups (I, II, III) of athletes were very interested in the lecture, asking lots of questions, not only about the plates, but also about conventional vs organic agriculture, eating less meat, GMO food, etc. The lead researcher was pleasantly surprise that these additional questions were raised and that their predisposition to learn and be attentive during our presentation was high.

Because there were critical lessons learned during the classroom session with Group II, a description of their experience is highlighted below. This account is written in the first person, from the lead researcher's perspective as a participant-observer.

On a cold winter day in December one week before Christmas and at dinner time, 8 elite athletes, hair still wet and faces red having just left practice at the swimming pool, came to our presentation. They looked tired and hungry but they seemed "at home" as a team, telling jokes among them before we started. It is the first presentation I am doing without my adviser in the room to support me and this seems a complicated crowd. I was prepared to deliver the power point (PPT) presentation prepared for this study, but I was not prepared to have visually impaired athletes in the room. I quickly improvised and adapted the presentation, carefully describing in detail the features of the plates pictured on the PPT to make sure everyone understood what I was speaking about. During the presentation the blind athletes were clearly concentrated, trying not to miss any portion of my explanation. I could see their hands making an imaginary plate and dividing it into the quantities and type of food I was describing. They were also taking notes on their phones.

After the classroom presentation both researchers left to get to the dining hall to prepare for the observational analysis while two additional RDs stayed to help the blind athletes fill out TAPES post-presentation. Some of the visually impaired athletes needed help reading the survey and the consent forms, as we did not have forms in braille.

Theme 2: "Navigate the dining hall on the road to success"

This theme provides an account of how the athletes translated the knowledge gained in the classroom to the dining hall. The descriptive language used following the general depiction of the dining hall is intended to take the reader on a journey through all aspects of the experience. Because there are distinct differences between groups I & II, we have provided a description of each of these groups' experiences.

After swiping their badges to get into the dining hall, athletes can view the day's menu. The first station is the salad bar full of bright, fresh vegetables and homemade salads. On the wall to the right of the salad bar, all three Athlete's Plates are on display in large frames to catch the athlete's attention and help them match their food to their training day. At the end of the salad bar is an area where athletes can create their own sandwiches with varying types of breads and bagels. Moving across to the hot line, they can fill up on oatmeal (breakfast) or pasta (lunch/dinner). The hotline spread changes daily but always provides hard boiled eggs, scrambled eggs, potatoes, breakfast meat and sometimes a special such as pancakes or French toast. At lunch and dinner the hotline serves up a vegetable, grain, vegetarian/vegan dish and 2 types of meat and fish. Further down the line is the grill station where athletes can personalize an omelet or egg order at breakfast and a burger (meat or vegan) grilled chicken breast and oven fries at lunch or dinner. On the opposite side of the servery is the recovery bar, drinks, desserts and cereal. The recovery bar is designed for athletes to grab a quick snack before or after a training session. Here they will find chocolate milks, nuts/seeds and nut butters, granola, homemade muffins, yogurt parfaits and fruit. Next to the recovery bar, there is a soft serve ice cream machine and a dessert cabinet full of delicious homemade desserts. Cereals and milk as well as drinks are down the line and present at every meal. At the very end of the servery, opposite of the entrance, athletes can access the fusion station. Some days, this station is utilized for a special dish such as a stir fry, soup or rice bowl, with nutrient proportions matching the moderate AP. The servery is open and inviting with three entrances into the dining area where athletes can come and go as they please, jumping from station to station, without any specific line to follow and getting as many plates as their stomachs desire. As a consequence, the image of the dining hall at rush hour was similar to bees swarming a hive. Athletes were darting around the different food stations, aiming to create the perfect plate to satiate their hunger and please their palate while optimizing their training needs.

Group I:

It was a sunny summer day and the big windows at the dining hall allowed the sunbeams to bathe at lunchtime when the triathletes came in. Typical of lunchtime, the dining hall was bustling with athletes, coaches and administrators; the athletes, in particular, were jockeying around, likely in anticipation of satiating their starvation. After all, it was almost 1pm and their next session was at 2pm; they did not have time to lose.

The first group of four young triathletes stopped by the dining hall doors apparently discussing which foods to choose and which strategy to follow. Suddenly, they all marched together straight into the first section of the food line: the salad station. With colorful casual sports clothing adorning their tired, similarly-shaped-fit-lean bodies, they blended into the jumble of other people, aromas, buzz and love that the food line produced; in a way a harmonized dance following a cacophony of tasty melodies. Reunited near the raw vegetables and dressings they glanced at us (the observers) and whispered among themselves, possibly hesitating to consult with one another about what to choose, what is recommended. Finally, they appeared to come to a verdict of what they were going to eat. This moment of vacillation was brief and, as a surge in the others behind them jolted them forward, they dispersed around the food line, continuing to create their plates with individual paintbrushes. Most athletes started their plate creation from the salad bar and added raw and cooked veggies. They quickly moved to other stations and complemented the plate They appeared comfortable designing their plates and choosing the food without hesitation. When crossing with each other, traveling about the buffet, they tittle-tattled about the plate content and smiled at each others' choices. Ten minutes later, the second group of triathletes appeared and diffused quickly and without hesitation to the different food stations as if they were coordinated ballerinas performing on stage. One of the triathletes lined for the grill station, patiently waiting, leaning on one leg, clearly hungry, began eating his salad from his plate previously created at the salad bar. As the persistent athlete continued to wait at the grill station (with almost no more salad on his plate), others complementing their plates with drinks, dressings and fruits started savoring their plates together sitting around a big table. Finally, the patient athlete got his piece of grilled chicken breast, burger bun, and mustard and sat around the table with the others.

It is a packed camp week for the triathletes; they have a theory classroom session in the afternoon. Observing the different plates of the athletes, we perceive a common theme of salad, cooked veggies and fruit topped with some protein rich foods and carbohydrates forming an easy/moderate plate distribution.

Group II:

The dining hall was calm when the first athlete came in. It was a dark night on a cold winter day when athletes entered the dining hall and warmed their bodies with the perfumed air of the food ready to be served. The soft, toasty and sweet smell revealed it was potato nachos day (known as Irish nachos) and you can sense the excitement. They entered the dining hall with no hesitation. Most of them live here and this is their home when in training.

In contrast to the first group, this second group of athletes have various disabilities and move around dancing a different melody in function of their needs! They maneuver using a variety of adaptations they are used to. Most of them live here and this is their home when in training. *With the help of the ladder to arrive up to the buffet counter one athlete moved the step-ladder along the food line, to gain access independently to more selections. The visually impaired athletes received support from the other teammates or the food service personnel who knew their names and joked with them as they helped them describe the available food. Even though these visually impaired athletes needed assistance, they were able to orient themselves and find the different sections with no help*. In contrast to what was observed in the athletes without disabilities, the athletes with disabilities created their plates without much interaction with their teammates. However, they interacted with the kitchen staff to ask for food items or specific descriptions of food, especially the athletes with visual impairment. *Suddenly, one of the athletes approached us (the observers) with decision and asked me if she could have nachos. I asked her to recall the different food groups described in the AP model, encouraging her to make her own decision. After discussing this with me she decided to get some nachos and complement the plate with an extra salad. Smiling I sensed she was very happy with her final decision.*

It was a hard training day for this group of athletes and most of them are filling up their plates quickly. All plates seemed to have a good portion of carbohydrates, some fresh greens or cooked veggies and various portions of protein-rich foods. One of the athletes mentioned that she is vegetarian and combines beans and veggies, a stuffed potato and a glass of water.

Finally, with their plates ready on their trays they sat around the table, enjoying their meal and each others' company. Bon appetit!

Theme 3: Eat more when it matters!

This theme provides information about the application of the AP on periodized nutrition while eating more when training load increases. Theme three intends to give the reader some insights and descriptions on athlete's behaviors to eat more when it matters. Similar to theme two, descriptions of experiences of groups I & II, are differentiated.

Group I:

In general, plates have a higher proportion of green colors with a mixture of raw and cooked vegetables (greens, tomatoes carrots, broccoli, beans and peas), complemented with some rice, beans and a protein serving of chicken, pork or beef. Some of the athletes had a side bowl from the soup at the fusion station. The majority of the athletes drank water and two of them chose a juice and one a sweet sports drink to complement their meals. Some other athletes added some fresh fruits to their salads and plates. Desserts are also popular and they have yogurts or fresh fruit. Triathletes ate pretty fast, as the next session was around the corner and they are hungry. The camp week must be very exhausting, as most of the athletes emptied their plates quickly and got up for seconds. The Asian stir fry perfume captured athletes, making second plates a common theme. Others complement their AP with extra dessert and some choose dairy beverages and sports drinks.

Group II:

This group of athletes stated, at different times through the presentation, how hungry they were and mentioning the hard training day they had. Most of them are filling their plates with more than one source of carbohydrates: potato nachos, pasta, rice and sweet potatoes are popular choices. All athletes have more than one plate full of food on their trays and the majority of them also had a second plate, bowl or dessert to ensure they have all the energy they need to recover from their hard day. The carbohydrate-rich plates are complemented with broccoli, salad, tomatoes, corn, and green beans. They topped all with dressings and complemented with yogurt or fresh fruit as dessert. Mentioning the hard training day they had made some of them getting up for seconds at different times. After finishing their dinner, the athletes left the dining hall, while the two observers stayed *discussing the experience. After 30-40 minutes or so, these same athletes reappeared in the dining hall for an extra after-dinner treat. We were surprised to see them, and they were surprised to see us, as if they got caught. After a second of surprise they approached us and told us that they usually come for a pre-bed snack as the dining hall is open until bedtime. As we noticed when they entered the dining hall, these athletes are at home and we are their guests.*

4. Discussion

The results of this study overall indicate that the AP Education Program, using both classroom and experiential learning session with opportunity to apply the AP in a dining experience. However, the strategy used in this study— observation in the dining hall—in particular, identified some key points that should be considered (table 3.9).

The results on TAPES demonstrated that the majority of the athlete's acquired sufficient knowledge of the AP (with a mean score of 89.2 ± 9.8%) from the PPT presentation but two athletes failed the survey (final score ≤ 70% or 66.7% each which is a 10 out of 15), one athlete from group I and one athlete from group II. These results are higher (better knowledge) than results found in other studies while using a different knowledge questionnaire (Blennerhassett, McNaughton, Cronin, & Sparks, 2019; Doering, Reaburn, Cox, & Jenkins, 2016). All athletes answered positively, on the survey question, when asked if they thought the AP is a useful tool for improving nutrition in athletes. When comparing the three groups (group I and III with group II), athletes without disabilities had higher TAPES scores compared to athletes with disabilities ($p \leq 0.05$). Group II (which included athletes with disabilities) had some athletes with visual impairment. Being that the AP is designed as a visual tool, it is not surprising that these athletes would score lower on the test that evaluates their knowledge. While the RD giving the presentation made adaptations to the content by adding descriptive inputs, modifications were improvised and might have left out some relevant information not being able to fully explain the AP model for those athletes that could not see it. The abled-bodied athletes might have had higher sport nutrition knowledge before the presentation than the athletes with disabilities. In addition to the differences in athletes, future iterations of this intervention may also need to revisit the TAPES survey for clarity on knowledge questions. The most missed question on the TAPES survey was "Using the Athlete's Plate, the amount of fruit does not change". Of the 26 athletes, 46.2% answered this incorrectly. This could be due to the ambiguity of the question or lack of educators focusing on this in the presentation.

Theme 1 of the findings, *"personalize your plate"* is a proclamation/declaration of the need to adapt nutrition education to specific populations as shown by others (Forman, Colby, Gellar, Kavanagh, & Spence, 2015). In addition, there is gap in research conducted in athletes with disabilities and there is a need for more diversity and inclusion and sensitivity to translate educational materials and interventions to all kinds of athletes. In the future, adapted versions of the presentation need to be considered, including the adaptation of TAPES to braille, and/or allocation of additional time to have the survey read. Nevertheless, other materials might need to be developed as a tactile plate for those athletes that cannot see the educational tool.

Theme two of the findings "*navigate the dining hall on the road to success*" is an example of the importance of including experiential learning beyond the classroom when educating athletes in nutrition. Different studies have shown the importance of hands-on interventions when teaching about food and nutrition to increase nutrition knowledge but also self efficacy and acceptability of behavior change (Barnhart, Havercamp, Lorenz, & Yang, 2019; Pang et al., 2019). While it is true that the development of classroom education might be necessary to increase basic knowledge, an experiential learning environment will provide other aspects of skill building that otherwise would not get targeted. Choosing what to put on the plate is not only related to the foods' nutritional composition, but is also related to other components, such as taste, smell or cultural preferences (Diaz-Rios, Muzaffar, Meline, & Chapman-Novakofski, 2016). Moreover, eating in a dining hall is a social event and social interactions in a dining hall setting also have to be included in overall performance-oriented nutrition education (Pappadackis, Kattelmann, Weidauer, McCormack, & Colby, 2019). The observational narratives in theme two, "navigate the dining hall on the road to success" underlined differences in the confidence of athletes as they navigated through the dining area when creating their plates. The athletes in group I were visiting the training center for camp, while athletes in group II were residents. Even with the special needs of athletes in group II, regarding mobility and assistance, they were much more confident and comfortable around the dining hall when making their plates. Contrary, triathletes were more hesitant and changed more stations to decide what to put on their plates. Thus, familiarity with the environment might influence successful completion of nutritionally adequate plates, as confidence in navigating the space optimizes the output. Pappadackis et al. (2019) showed how a healthy campus dining tour intervention was associated with higher perception of availability of healthy foods and higher probability in choosing them in collegiate freshmen. In addition, cultural differences between athletes' state/country of origin and food offered at the dining hall could also influence their ability to create plates with appropriate content (Herring & Tagtow, 2016). Furthermore, the structure of the dining hall can also influence food choices. As described in the first portion of theme two "navigate the dining hall on the road to success" the structure of the dining hall, where the study took place, is very open and not linear, meaning that athletes can exercise free choice by using the stations they want, similar to a market place. A different structure of the food line could lead to a more marked food decision and plate creation (Hanks, Just, Smith, & Wansink, 2012) While variety generates perceived freedom of choice, it can also add a burden to the athlete when deciding what to eat. Currently, supermarkets, dining halls and restaurants offer all kinds of foods all year round where the notion of limited availability of seasonal and local items has almost disappeared. Food has become less and less biodiverse (FAO, 2010) which is reflected in single varieties of crops such as orange carrots, Roma tomatoes, or spinach. Moreover, when adding budget restrictions in dining operations and low cooking ability of kitchen staff using raw, fresh, and unfamiliar products, the burden of labor cost might also increase. For this reason, incorporating other considerations when making the menu (food service) or educating athletes in nutrition (RD), dining halls can act as living learning laboratories and integrate food literacy opportunities that promote topics such as the AP and other food-based initiatives (e.g., local and regional foods when in season, plant-based or plant-forward strategies to promote sustainability, and awareness around protein quantity and quality, whole grain nutrition to boost dietary fiber for easy and moderate training days, and fermentation to support athlete's digestive health). Including a boarder nutrition experience will allow athletes not only to create their AP for health and performance, but also keep them engaged and interested in nutrition and the food of the region wherever they may train and compete. Paradigm shifts related to the quality and sustainability of food and diets are urgently needed, also in sport nutrition, as highlighted recently by the authors (Meyer & Reguant-closa, 2017).

Second, while the dishes offered at the dining hall were labeled with nutrition information, the observational data show that athletes in both groups did not check it but looked at the food rather than the nutritional information. This could be because the athletes already know the information on the label and do not need to check it, they do not find it useful, or they chose the food for other reasons than by its nutritional content. In addition, the AP model aims to provide the athletes with the tools to create their plate based on individual food preferences instead of following specific prescriptions of foods and quantities.

The observational analysis of the athletes with disabilities highlighted the importance of a well-educated food service staff to provide accurate information to the athletes. Efforts has gone into the education of kitchen staff about food safety and food allergies (Verstappen, Mirosa, & Thomson, 2018), with less focus on educating staff in how athletes should use educational models such as AP. As a result of this study, we recommend a complementary course for food service personnel highlighting food literacy in general and the AP and basic sport nutrition fueling strategies, specifically.

While this study did not focus on the nutritional content of AP, the observational analysis brought valuable information on the AP content made by athletes. On the road to success, the two groups of athletes adapted their plate's nutritional content according to their training day. The triathletes made plates that were characteristic of an easy/moderate training day with more vegetables and lean proteins and less processed grains. In the contrary, athletes in group II had a higher amount of processed grains and fats, moderate lean protein sources, and less vegetables, such as salads, to match the hard training plate. These observations match with the AP tool as well as with sport nutrition strategies for periodized nutrition depending on training load (Burke et al., 2011; Thomas et al., 2016). It is important to point out that some of the triathletes made plates that were low in whole grains in general, and while they might have had an easy/moderate day, they were in an intense training camp. Triathlon is a weight-sensitive sport. It has been observed that triathletes might limit their energy and carbohydrate intake (Blennerhassett et al., 2019; Doering et al., 2016). While the importance to differentiate easy and moderate from hard training days is described in the AP presentation, this might need to be reinforced in all athletes. There is also a need to educate athletes on the diversity of whole grains and how easy and moderate training loads still demand meeting dietary fiber from whole grains and other pre- and probiotic foods to promote digestive health (Reynolds et al., 2019; Rinninella et al., 2019) while hard training days or competition allow for a temporary switch to refined grains. Gastrointestinal health has been related to positive outcomes for the immune system (Shokryazdan, Faseleh Jahromi, Navidshad, & Liang, 2017), increased absorbtion of some nutrients (Jäger et al., 2020) and a possible positive effect on athletic performance (Clark & Mach, 2016), highlighting the importance of a well balanced, fiber-rich diet for active and athletic individuals.

Theme three of the findings "eat more when it matters" highlights the need to reinforce the importance to eat more when training is hard to ensure optimal fueling and recovery for training. Several studies show that especially female athletes have a hard time adjusting their energy intake to high training loads (Brook et al., 2019; Cialdella-Kam, Kulpins, & Manore, 2016; Viner, Harris, Berning, & Meyer, 2015) and the ingestion of a low quality diet can be found in both Olympic and Paralympic athletes (Abbey, Wright, & Kirkpatrick, 2017; Brook et al., 2019; Joaquim, Juzwiak, & Winckler, 2019; Lynch, Johnston, & Wharton, 2018; Madden, Shearer, & Parnell, 2017). The observational analysis captured that most athletes chose seconds after finishing their first plate. While the AP visual tool is designed as only one plate, complementary side plates or bowls or the option for a second dish needs to be discussed when educating athletes about the AP. Athletes, have specific energy and nutrient demands that increase with training load (Broad, 2019; Thomas et al., 2016). The observational analysis shows that most athletes had a second plate, bowl, dessert or drink. These findings agree with the results found in the validation of the AP where plates created by RDs often included a side dish (Reguant-Closa et al., 2019). Athletes have high energy and macronutrient requirements, therefore, one plate might not be enough to sustain their high energy needs. As a consequence, this information needs to be included in the presentation and addressed to ensure macronutrient proportions and complementary strategies to the first plate are adequately communicated, so athletes feel empowered to return for seconds or choosing desserts depending on their training load. Moreover, athletes not only eat main meals (breakfast, lunch and dinner) through the day but also snacks to optimize training and recovery before and after training (Broad, 2019; Thomas et al., 2016). While the observational analysis only analyzed the behavior of the athlete making one plate depending on their training load, snacking through the day is also covered in the PPT presentation of the AP Education Program through a fueling time-line with specific recommendations depending on training load (figure 3.6A). While less is known in athletes with disabilities, abled-bodied athletes consume snacks through the day, accounting for around 23% of the total daily energy intake (Burke et al., 2003; Parnell, Wiens, & Erdman, 2016). Thus, educating on how to time fueling strategies relative to training sessions is as critical as providing guidelines at meal times.

The main limitation of this study is the small sample size and minimal variety in the type of athletes who participated. This is due to the difficulty of athlete recruitment in research at an elite athlete training center. Moreover, this study evaluated athletes' knowledge after an in-class presentation, followed by behavior observations to study athletes' understanding of using the plates in a real-life setting. The plates were subsequently not analyzed for energy or nutritional content because this study focused on observation, limiting the interference with the athletes' daily training and eating to avoid unnecessary threats to validity. In practical settings, picture taking of the actual plates could help RDs evaluate athletes' skills in making their plates according to training load. Other options include setting up placemats illustrating the plates, while letting athletes make their plates on see-through glass plates, trying to match plates when sitting down to eat (for more information see www.uccs.edu/ swell/fc/truefood).

Taken together it is recommended to include both in-class and experiential education, such as going to the dining hall after the presentation, and teach athletes hands-on how to create their plates. This adds skill to their sport nutrition knowledge and will help them with self-efficacy to better implement eating strategies to fuel for variable training loads. More recommendations are included in table 3.9.

TABLE 3.9
Areas Identified for Improvement

AREAS	SUGGESTIONS
PPT presentation	· Needs to be more inclusive (e.g., adapt for visually impaired athletes) · Provide description that plate model is not designed to be prescriptive (in quantities) but rather intuitive, teaching athletes to eat more food, more carbohydrates, more fat, and less raw and fibrous foods at higher training loads · Include better description of why fruit moves outside of the plate and, thus, does not change
TAPES	· Review the question "Using the athlete's plate, the amount of fruit does not change
Dining hall setting	· Familiarize yourself and your athletes with the food service environment and how the food line is organized · Ensure high quality of food and food safety · Ensure culturally acceptable food · Ensure seasonality and sustainability · Ensure labeling related to the Athlete's Plate is present and provide handouts, cards, placemats, or magnets to reinforce learning · Present visually appealing dishes that promote a performance-based, sustainable menu
Food service staff	· Provide in-service on the Athlete's Plate Education Program
Complementing the plate "coming for seconds"	· Educate athletes in which training loads it is important to complement the Athlete's Plate · Include ideas how to complement the Athlete's Plate at different training loads · Consider including a "side plate" on the Athlete's Plate handouts or descriptions

In conclusion, the AP Education Program resulted in the majority of athletes acquiring sufficient knowledge on how to practically apply the AP in the dining hall using this study's methodological approach. It is recommended that nutrition education interventions include an experiential intervention to improve athlete self-efficacy in making their plates. Future research should evaluate the nutritional content of the plates created by athletes to ensure the content complies with the international sport nutrition recommendations.

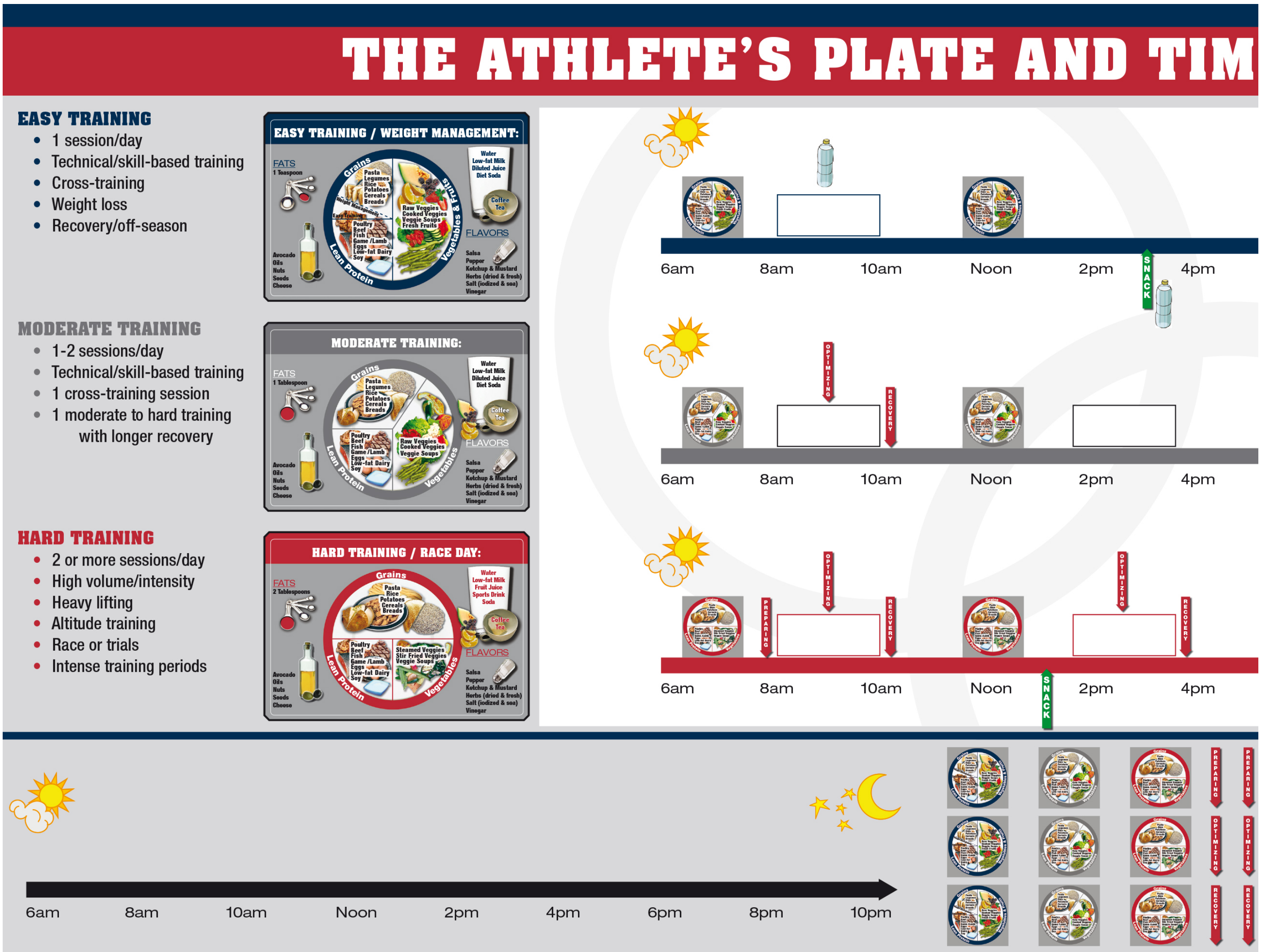
5. Acknowledgments

Special thanks to the Food and Nutrition Director, Executive Chef and staff of the elite training center for providing the perfect setting for the development of this research project as well to all athletes who voluntarily participated in this study.

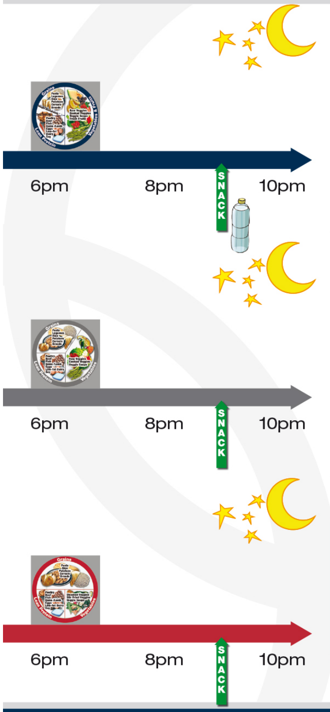
6. Appendix

FIGURE 3.6 A

The Athlete's Plate Fueling Line



ELINE FOR FUELING AND TRAINING



DAILY ATHLETE GUIDELINES
- Carbohydrates: 1.5-2 g/lb/d (3-5 g/kg/d)
- Protein for Easy Training: 0.5-0.7 g/lb/d (1-1.5 g/kg/d)
- Protein for Weight Management: up to 1.0 g/lb/d (up to 2 g/kg/d)
- Fat: 0.4 g/lb/d (0.8 g/kg/d) or narrative

THE PLATE
½ = Fruits & Vegetables *(raw or cooked)*
- Lots of nutrients with ↓ calories
- Add volume through fiber and water

< ¼ = Grains
- Fuel for performance
- Add volume through fiber

> ¼ = Lean Protein
- Maintain muscle mass
- Stay fuller longer

1 Teaspoon of Fat

FUELING FOR PERFORMANCE
- **Preparing:** use your last meal to increase fuel for your training session
- **Optimizing:** focus on hydration with water or diluted sport drink
- **Recovery:** eat a small snack or use your next meal

DAILY ATHLETE GUIDELINES
- Carbohydrate: 2.3-3.2 g/lb/d (5-7 g/kg/d)
- Protein: 0.5-0.7 g/lb/d (1-1.5 g/kg/d)
- Fat: ~0.5 g/lb/d (~ 1g/kg/d) narrative

THE PLATE
Add fruit for extra nutrients

< ½ = Vegetables
- Lots of nutrients with ↓calories

> ¼ = Grains
- Fuel for sustained performance

≤ ¼ = Lean Protein
- Build and repair muscle

1 Tablespoon of Fat

FUELING FOR PERFORMANCE
- **Preparing:** use your last meal to increase fuel for your training session
- **Optimizing:** add fuel for the more intense training session of the day
- **Recovery:** as soon as possible, add recovery nutrition to replenish losses

DAILY ATHLETE GUIDELINES
- Carbohydrates: 1.5-2 g/lb/d (3-5 g/kg/d)
- Protein for Easy Training: 0.5-0.7 g/lb/d (1-1.5 g/kg/d)
- Protein for Weight Management: up to 1.0 g/lb/d (up to 2 g/kg/d)
  - Fat: 0.4 g/lb/d (0.8 g/kg/d) or narrative

THE PLATE
Add fruit for extra nutrients

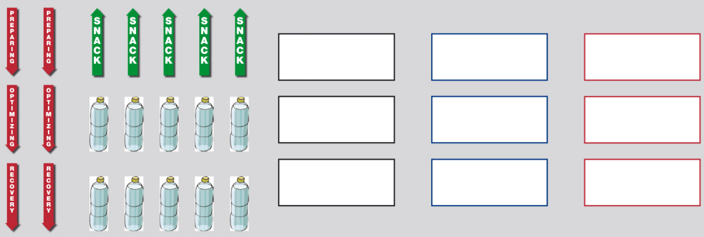
½ = Grains (less fiber)
- Easy digestion
- Fuel for peak performance
- Quick energy for recovery

¼ = Vegetables *(cooked)*
- Easy digestion
- Lots of nutrients with ↓ calories

¼ = Lean Protein
- Build and repair muscle

2 Tablespoons of Fat
- Extra energy

FUELING FOR PERFORMANCE
- **Preparing:** Fuel before training/race to support performance
- **Optimizing:** Fuel during training/race to enhance performance
  - 30-90 grams of carbohydrates/hour [if training session is longer than 60 minutes]
- **Recovery:** As soon as possible, replenish lost fuel after training/race for quick recovery
  - 0.5 g/lb/hr of carbohydrates for up to 4 hours or next meal



PREPARING
- Sports Drink
- Sport Bar
- Small Sandwich
- Pretzels
- Banana

Depending on training: your MEAL may suffice

RECOVERY
- Low fat Milk
- Cereal with milk
- Yogurt with Granola
- Sports Drink
- Sports Bar
- Fruit

Depending on training: your MEAL may suffice

OPTIMIZING
- Sports Drink
- Bars, Gels, others
- Bites of Sandwich
- Apple sauce

SNACKS
- Fresh Fruit
- Sports Drink
- Sandwich
- Cheese & Crackers
- Trail Mix

The Athlete's Plate Educational Presentation

Athlete's Plates:
An Introduction

Perdiodized Training – Periodized Nutrition

Adapting your plate to your training plan
- Simplify
  - EASY
  - MODERATE
  - HARD
- Some thoughts...
  - EASY may be catch up/recovery day
  - Prepare for hard days the night before
  - Hard weeks – hard days every day!
  - Tapering before events – moderate to hard days depending on event

Periodized Training – Periodized Nutrition!

1. Meals
   Athlete's Plates
2. Timeline (Timing)
3. Before – During – After
   Preparing – Optimizing – Recovery

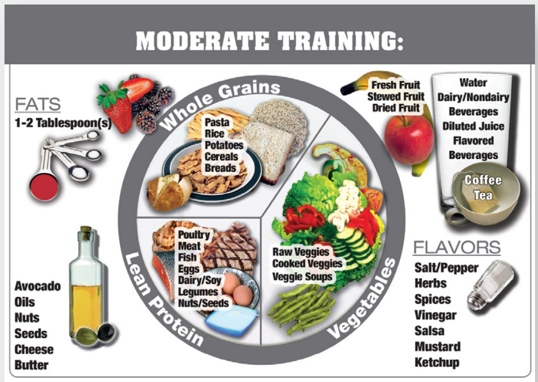
Examples: Easy Plate

Breakfasts (1–2 hrs before)

- Yogurt Parfait
  - Plain Greek yogurt
  - Fresh seasonal fruit
  - Granola sprinkles
- Veggie Omelet
  - Eggs
  - Spinach
  - Cheese
  - Olive oil
  - Crispy Rye bread

Lunches (2–3 hrs before)

- Athlete Salad
  - Dark greens
  - Seasonal veggies
  - Fresh fruit/dried fruit
  - Black beans
  - Grilled fish or chicken
  - Olive oil, balsamic
- Open faced turkey or hummus sandwich
  - Seasonal veggies on side
  - Fresh fruit & nuts



Examples: Moderate Plate

Breakfasts (1–2 hrs before)

- Cold cereal
  - Whole grain cereal
  - Seasonal fruit or berries
  - Milk
  - Greek yogurt
- Scrambled Eggs
  - Eggs
  - Spinach & tomatoes
  - Cheese
  - Olive oil
  - Whole grain toast

Lunches (2–3 hrs before)

- Sandwich Box
  - Whole grain sandwich w/ turkey, mustard, cucumber, cranberry
  - Carrots
  - Fresh fruit
  - Granola bar
- Stir Fry left-over
  - Chicken stir fry
  - Veggies
  - Brown rice
  - Fresh seasonal fruit

Examples: HARD Plate

Breakfasts (1–2 hrs before)

- Oatmeal & Eggs
  - Oatmeal cooked in milk/soy milk
  - Apple sauce
  - Honey
  - Toast w/ eggs and salsa
- Oatmeal Pancakes
  - Pancakes w/ oats
  - Bananas
  - Syrup, butter
  - Smoothie w/ frozen berries

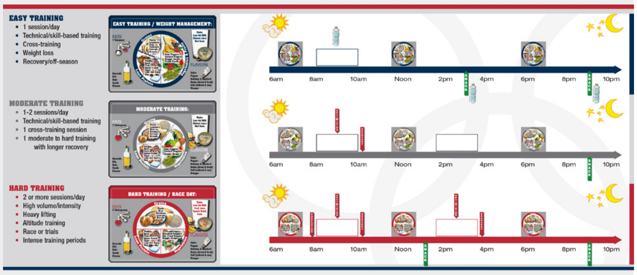
Lunches (2–3 hrs before)

- Sandwich Box
  - Light wheat bread, turkey, mustard, lettuce/tomato
  - Minestrone
  - Apple sauce
  - Honey grahams
- Pasta bowl
  - White, al-dente pasta
  - Sautéed carrots, zucchini
  - Pan seared white fish, chicken or turkey
  - Apple sauce

Periodized Training – Periodized Nutrition!

1. Meals
   - Athlete's Plates
2. Timeline (Timing)
3. Before – During – After
   - Preparing – Optimizing – Recovery

Timeline

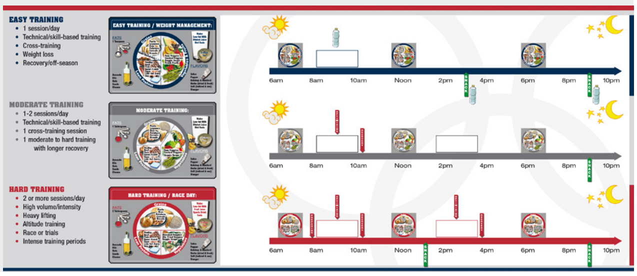


Before – During – After

1. Meals
   - Athlete's Plates
2. Timeline (Timing)
3. Before – During – After
   - Preparing – Optimizing – Recovery

Fueling Strategies

BEFORE/PREPARE!	DURING/OPTIMIZE!	POST/RECOVER!
SPORT DRINK	SPORT DRINK	SPORT DRINK
SPORT BAR	GELS	SPORT BAR
BREAD/JAM	BLOCS	SMOOTHIE
OATMEAL	SPORT BAR	FLAVORED MILK
BANANA	BREADS, RICE BALLS	RECOVERY MIX



Thank you for your participation! Take the Knowledge Survey now!

The Athlete's Plate Education Survey (TAPES)

DEMOGRAPHIC QUESTIONS (FILL IN AND CIRCLE)

Sport Gender: Male Female

Date of Birth Place where you live:

What best describes you? Athlete in camp Resident athlete

At which level do you compete? National International Olympic

Have you heard of the Athlete's Plate? Yes No don't know

Have you ever received education using the Athlete's Plate? Yes No don't know

ATHLETE'S PLATE EDUCATION SURVEY (TAPES)

1. The athlete's plate is a tool for you to learn how to adjust nutrition to training intensity and volume.

   TRUE FALSE DON'T KNOW

2. For easy training days, the athlete's plate recommends no carbohydrate (e.g., grains, vegetables, fruit).

   TRUE FALSE DON'T KNOW

3. For moderate training days, the athlete's plate has more carbohydrates (e.g., grains, vegetables, fruit) than the easy training day plate.

   TRUE FALSE DON'T KNOW

4. For easy training days, the athlete's plate recommends more vegetables.

   TRUE FALSE DON'T KNOW

5. Using the athlete's plates, the amount of fruit does not change.

   TRUE FALSE DON'T KNOW

6. For weight management using the easy plate, protein recommendations are higher.

   TRUE FALSE DON'T KNOW

7. Regardless of training intensity and volume, you should always choose high fiber foods from whole grains, fruit and vegetables.

   TRUE FALSE DON'T KNOW

8. For easy, moderate, and hard training, raw and cooked vegetables are always recommended.

   TRUE FALSE DON'T KNOW

9. Compared to moderate training days, you don't need to eat more carbohydrates (e.g., grains, vegetables, fruit) on hard training or competition days.

   TRUE FALSE DON'T KNOW

10. Using the athlete's plates, flavors (e.g., salt) are added to replace sodium lost in sweat.

TRUE FALSE DON'T KNOW

11. Using the athlete's plate, more healthy fats are recommended with higher training intensity and volume.

TRUE FALSE DON'T KNOW

12. Using the athlete's plates, the proportion of protein increases with higher training intensity or volume.

TRUE FALSE DON'T KNOW

13. Fueling strategies before, during and after exercise change with intensity and volume of training or competition.

TRUE FALSE DON'T KNOW

14. Using the athlete's plates, fluid comes from water, tea, coffee, dairy/nondairy beverages, diluted juices and flavored beverages.

TRUE FALSE DON'T KNOW

15. Fueling immediately after a hard training day is never recommended.

TRUE FALSE DON'T KNOW

Do you think the Athlete's Plate is a useful tool for improving nutrition in athletes?

YES NO DON'T KNOW

If you answered no, why not?

....

....

....

Do you have any comments regarding the Athlete's Plate?

....

....

....

Thank you for your participation! GO TEAM!

7. References

Abbey, E. L., Wright, C. J., & Kirkpatrick, C. M. (2017). Nutrition practices and knowledge among NCAA Division III football players. *Journal of the International Society of Sports Nutrition*, *14*, 13. https://doi.org/10.1186/s12970-017-0170-2

Amin, S. A., Panzarella, C., Lehnerd, M., Cash, S. B., Economos, C. D., & Sacheck, J. M. (2018). Identifying Food Literacy Educational Opportunities for Youth. *Health Education and Behavior*, *45*(6), 918–925. https://doi.org/10.1177/1090198118775485

Bach-Faig, A., Berry, E. M., Lairon, D., Reguant, J., Trichopoulou, A., Dernini, S., ... Serra-Majem, L. (2011). Mediterranean diet pyramid today. Science and cultural updates. *Public Health Nutrition*, *14*(12A), 2274–2284. https://doi.org/10.1017/S1368980011002515

Barnhart, W. R., Havercamp, S. M., Lorenz, A., & Yang, E. A. (2019). Better Together: A Pilot Study on *Cooking Matters* for Adults With Developmental Disabilities and Direct Support Professionals. *Nutrition and Metabolic Insights*, *12*, 117863881984003. https://doi.org/10.1177/1178638819840036

Blennerhassett, C., McNaughton, L. R., Cronin, L., & Sparks, S. A. (2019). Development and Implementation of a Nutrition Knowledge Questionnaire for Ultraendurance Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(1), 39–45. https://doi.org/10.1123/ijsnem.2017-0322

Broad, E. M. (2019). *Sports Nutrition for Paralympic Athletes* (2nd ed.). CRC Press.

Brook, E. M., Tenforde, A. S., Broad, E. M., Matzkin, E. G., Yang, H. Y., Collins, J. E., & Blauwet, C. A. (2019). Low energy availability, menstrual dysfunction, and impaired bone health: A survey of elite para athletes. *Scandinavian Journal of Medicine & Science in Sports*, *29*(5), 678–685. https://doi.org/10.1111/sms.13385

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences*, *29 Suppl 1*, S17-27. https://doi.org/10.1080/02640414.2011.585473

Burke, L. M., Slater, G., Broad, E. M., Haukka, J., Modulon, S., & Hopkins, W. G. (2003). Eating patterns and meal frequency of elite Australian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*(4), 521–538. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14967874

Chrisman, M., & Diaz Rios, L. K. (2019). Evaluating MyPlate After 8 Years: A Perspective. *Journal of Nutrition Education and Behavior*, *51*(7), 899–903. https://doi.org/10.1016/j.jneb.2019.02.006

Cialdella-Kam, L., Kulpins, D., & Manore, M. M. (2016). Vegetarian, Gluten-Free, and Energy Restricted Diets in Female Athletes. *Sports (Basel, Switzerland)*, *4*(4). https://doi.org/10.3390/sports4040050

Clark, A., & Mach, N. (2016). Exercise-induced stress behavior, gut-microbiota-brain axis and diet: A systematic review for athletes. *Journal of the International Society of Sports Nutrition*, *13*(1), 1–21. https://doi.org/10.1186/s12970-016-0155-6

Cole, R. E., Bukhari, A. S., Champagne, C. M., McGraw, S. M., Hatch, A. M., & Montain, S. J. (2018). Performance Nutrition Dining Facility Intervention Improves Special Operations Soldiers' Diet Quality and Meal Satisfaction. *Journal of Nutrition Education and Behavior*, *50*(10), 993–1004. https://doi.org/10.1016/j.jneb.2018.06.011

Creswell, J. (2003). *Research Design*. Thousand Oaks, California: SAGE Publications Ltd.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: SAGE Publications.

de Oliveira, E. P., Buruni, R. C., & Jeukendrup, A. E. (2014). Gastrointestinal Complaints During Exercise : Prevalence , Etiology , and Nutritional Recommendations. *Sports Medicine*, *44*(Suppl 1), S79–S85. https://doi.org/10.1007/s40279-014-0153-2

Dearing, J. W., & Cox, J. G. (2018). Diffusion Of Innovations Theory, Principles, And Practice. *Health Affairs*, *37*(2), 183–190. https://doi.org/10.1377/hlthaff.2017.1104

Diaz-Rios, L. K., Muzaffar, H., Meline, B., & Chapman-Novakofski, K. (2016). Talk, Heart, Hands: A Culturally Sensitive Approach to Nutrition Education for Latinos With Young Children. *Journal of Nutrition Education and Behavior*, *48*(6), 425-429.e1. https://doi.org/10.1016/j.jneb.2016.03.008

Diker, A., Cunningham-Sabo, L., Bachman, K., Stacey, J. E., Walters, L. M., & Wells, L. (2013). Nutrition Educator Adoption and Implementation of an Experiential Foods Curriculum. *Journal of Nutrition Education and Behavior*, *45*(6), 499–509. https://doi.org/10.1016/j.jneb.2013.07.001

Doering, T. M., Reaburn, P. R., Cox, G., & Jenkins, D. G. (2016). Comparison of Postexercise Nutrition Knowledge and Postexercise Carbohydrate and Protein Intake between Australian Masters and Younger Triathletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *26*(4), 338–346. https://doi.org/10.1123/ijsnem.2015-0289

Ellis, J., Brown, K., Ramsay, S., & Falk, J. (2018). Changes in Student-Athletes' Self-Efficacy for Making Healthful Food Choices and Food Preparation Following a Cooking Education Intervention. *Journal of Nutrition Education and Behavior*, *50*(10), 1056–1058. https://doi.org/10.1016/j.jneb.2017.10.002

FAO. (2010). *Sustainable diets and biodiversity*. Rome: Food and Agriculture Organisation of the United Nations (FAO). https://doi.org/10.1017/S002081830000607X

Forman, A., Colby, S. E., Gellar, L., Kavanagh, K., & Spence, M. (2015). My Painted Plate: Art Enhances Nutrition Education with Children. *Journal of Nutrition Education and Behavior*, *47*(4), S57. https://doi.org/10.1016/j.jneb.2015.04.152

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115.

Gibbs, L., Staiger, P. K., Johnson, B., Block, K., Macfarlane, S., Gold, L., … Ukoumunne, O. (2013). Expanding Children's Food Experiences: The Impact of a School-Based Kitchen Garden Program. *Journal of Nutrition Education and Behavior*, *45*(2), 137–146. https://doi.org/10.1016/j.jneb.2012.09.004

Glesne, C. (2011). *Becoming Qualitative Researchers: An Introduction*. (Pearson, Ed.) (4th ed.). Boston.

Hanks, A., Just, D. R., Smith, L. E., & Wansink, B. (2012). Healthy Convenience: Nudging Students toward Healthier Choices in the Lunchroom. *Journal of Public Health*, *34*(3), 370–376. https://doi.org/10.1093/pubmed/fds003

Hatch, J. (2002). *Doing qualitative reserach in educational settings*. Sunny Press.

Hawkes, C., Jewell, J., & Allen, K. (2013). A food policy package for healthy diets and the prevention of obesity and diet-related non-communicable diseases: the NOURISHING framework. *Obesity Reviews*, *14*, 159–168. https://doi.org/10.1111/obr.12098

Herring, D., & Tagtow, A. (2016). MyPlate, MyState—Personalizing Your Plate with Your Local Flavors, Foods, and Recipes. *Journal of the Academy of Nutrition and Dietetics*, *116*(8), 1239–1240. https://doi.org/10.1016/j.jand.2016.06.004

Jacob, R., Lamarche, B., Provencher, V., Laramée, C., Valois, P., Goulet, C., & Drapeau, V. (2016). Evaluation of a Theory-Based Intervention Aimed at Improving Coaches' Recommendations on Sports Nutrition to Their Athletes. *Journal of the Academy of Nutrition and Dietetics*, *116*(8), 1308–1315. https://doi.org/10.1016/j.jand.2016.04.005

Jäger, R., Zaragoza, J., Purpura, M., Iametti, S., Marengo, M., Tinsley, G. M., … Taylor, L. (2020). Probiotic Administration Increases Amino Acid Absorption from Plant Protein: a Placebo-Controlled, Randomized, Double-Blind, Multicenter, Crossover Study. *Probiotics and Antimicrobial Proteins*. https://doi.org/10.1007/s12602-020-09656-5

Joaquim, D. P., Juzwiak, C. R., & Winckler, C. (2019). Diet Quality Profile of Track-and-Field Paralympic Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, 1–7. https://doi.org/10.1123/ijsnem.2018-0361

Levy, J., & Auld, G. (2004). Cooking Classes Outperform Cooking Demonstrations for College Sophomores. *Journal of Nutrition Education and Behavior*, *36*(4), 197–203. https://doi.org/10.1016/S1499-4046(06)60234-0

Lynch, H., Johnston, C., & Wharton, C. (2018). Plant-based diets: Considerations for environmental impact, protein quality, and exercise performance. *Nutrients*, *10*(12). https://doi.org/10.3390/nu10121841

Madden, R., Shearer, J., & Parnell, J. (2017). Evaluation of Dietary Intakes and Supplement Use in Paralympic Athletes. *Nutrients*, *9*(11), 1266. https://doi.org/10.3390/nu9111266

Meyer, N., & Reguant-closa, A. (2017). " Eat as If You Could Save the Planet and Win !" Sustainability Integration into Nutrition for Exercise. *Nutrients*, *9*(412). https://doi.org/10.3390/nu9040412

Morse, J. (2015). Critical analysis of Strategies for Determining Rigor in Qualitative Inquiry. *Qualitative Health Research*, *25*(9), 1212–1222. https://doi.org/10.1177/1049732315588501

O'Brien, B. C., Harris, I. B., Beckman, T. J., Reed, D. A., & Cook, D. A. (2014). Standards for Reporting Qualitative Research: A Synthesis of Recommendations. *Academic Medicine*, *89*(9), 1–7. https://doi.org/10.1097/ACM.0000000000000388

Pang, B., Memel, Z., Diamant, C., Clarke, E., Chou, S., & Harlan, G. (2019). Culinary medicine and community partnership: hands-on culinary skills training to empower medical students to provide patient-centered nutrition education. *Medical Education Online*, *24*(1), 1630238. https://doi.org/10.1080/10872981.2019.1630238

Pappadackis, P., Kattelmann, K., Weidauer, L., McCormack, L., & Colby, S. (2019). P122 The Effects of a Campus Dining Tour Intervention on First Year Students Perception of Healthfulness of Environment. *Journal of Nutrition Education and Behavior*, *51*(7), S87. https://doi.org/10.1016/j.jneb.2019.05.498

Parks, R. B., Helwig, D., Dettmann, J., Taggart, T., Woodruff, B., Horsfall, K., & Brooks, M. A. (2016). Developing a Performance Nutrition Curriculum for Collegiate Athletics. *Journal of Nutrition Education and Behavior*, *48*(6), 419-424.e1. https://doi.org/10.1016/j.jneb.2016.03.002

Parmer, S. M., Salisbury-Glennon, J., Shannon, D., & Struempler, B. (2009). School Gardens: An Experiential Learning Approach for a Nutrition Education Program to Increase Fruit and Vegetable Knowledge, Preference, and Consumption among Second-grade Students. *Journal of Nutrition Education and Behavior*, *41*(3), 212–217. https://doi.org/10.1016/j.jneb.2008.06.002

Parnell, J., Wiens, K., & Erdman, K. (2016). Dietary Intakes and Supplement Use in Pre-Adolescent and Adolescent Canadian Athletes. *Nutrients*, *8*(9), 526. https://doi.org/10.3390/nu8090526

Pawlak, R., Malinauskas, B., & Rivera, D. (2009). Predicting intentions to eat a healthful diet by college baseball players: applying the theory of planned behavior. *Journal of Nutrition Education and Behavior*, *41*(5), 334–339. https://doi.org/10.1016/j.jneb.2008.09.008

Pelly, F., Meyer, N. L., Pearce, J., Burkhart, S. J., & Burke, L. M. (2014). Evaluation of Food Provision and Nutrition Support at the London 2012 Olympic Games: The Opinion of Sports Nutrition Experts. *International Journal of Sport Nutrition and Exercise Metabolism*, *24*(6), 674–683. https://doi.org/10.1123/ijsnem.2013-0218

Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. *Journal of Sports Sciences*, *29*(sup1), S29–S38. https://doi.org/10.1080/02640414.2011.619204

Raskind, I. G., Shelton, R. C., Comeau, D. L., Cooper, H. L., Griffith, D. M., & Kegler, M. C. (2019). A review of qualitative data analysis practices in health education and health behavior research. *Health Education and Behavior*, *46*(1), 32–39. https://doi.org/10.1177/1090198118795019

Reguant-Closa, A., Harris, M. M., Lohman, T. G., & Meyer, N. L. (2019). Validation of the Athlete's Plate Nutrition Educational Tool: Phase I. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(6), 628–635. https://doi.org/10.1123/ijsnem.2018-0346

Reynolds, A., Mann, J., Cummings, J., Winter, N., Mete, E., & Te Morenga, L. (2019). Carbohydrate quality and human health: a series of systematic reviews and meta-analyses. *The Lancet*, *393*(10170), 434–445. https://doi.org/10.1016/S0140-6736(18)31809-9

Rinninella, E., Cintoni, M., Raoul, P., Lopetuso, L. R., Scaldaferri, F., Pulcini, G., … Mele, M. C. (2019). Food Components and Dietary Habits: Keys for a Healthy Gut Microbiota Composition. *Nutrients*, *11*(10). https://doi.org/10.3390/nu11102393

Saldaña, J. (2009). *The coding manual for qualitative researchers*. SAGE Publications Ltd.

Schuster, E. (2012). Personalizing MyPlate: Easy Changes for Eating Habits. *Journal of Nutrition Education and Behavior*, 44(4), 387.e5. https://doi.org/10.1016/j.jneb.2012.03.005

Shilts, M. K., Johns, M. C., Lamp, C., Schneider, C., & Townsend, M. S. (2015). A Picture Is Worth a Thousand Words: Customizing MyPlate for Low-Literate, Low-Income Families in 4 Steps. *Journal of Nutrition Education and Behavior*, 47(4), 394-6.e1. https://doi.org/10.1016/j.jneb.2015.04.324

Shokryazdan, P., Faseleh Jahromi, M., Navidshad, B., & Liang, J. B. (2017). Effects of prebiotics on immune system and cytokine expression. *Medical Microbiology and Immunology*, *206*(1), 1–9. https://doi.org/10.1007/s00430-016-0481-y

Stellingwerff, T., Maughan, R. J., & Burke, L. M. (2011). Nutrition for power sports: Middle-distance running, track cycling, rowing, canoeing/kayaking, and swimming. *Journal of Sports Sciences*, *29*(SUPPL. 1), 37–41. https://doi.org/10.1080/02640414.2011.589469

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Nutrition and Athletic Performance. *Medicine & Science in Sports & Exercise*, *48*(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

USDA. (2015). 2015 – 2020 Dietary Guidelines for Americans. *U.S. Department of Health and Human Services and U.S. Department of Agriculture*, 18. https://doi.org/10.1097/NT.0b013e31826c50af

Verstappen, J., Mirosa, M., & Thomson, C. (2018). Using the System-Practice Framework to Understand Food Allergen Managment Practices at College Catering Operations: A Qualitative Study. *Journal of the Academy of Nutrition and Dietetics*, *118*(3), 421–430. https://doi.org/10.1016/j.jand.2017.05.017

Viner, R. T., Harris, M., Berning, J. R., & Meyer, N. L. (2015). Energy Availability and Dietary Patterns of Adult Male and Female Competitive Cyclists with Lower than Expected Bone Mineral Density. *International Journal of Sport Nutrition and Exercise Metabolism*, *25*(6), 594–602. https://doi.org/10.1123/ijsnem.2015-0073

CONTRIBUTION IV:

The Environmental Impact of the Athlete's Plate Nutrition Education Tool

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Abstract

Periodized nutrition is necessary to optimize training and enhance performance through the season. The Athlete's Plate (AP) is a nutrition education tool developed to teach athletes how to design their plates depending on training load (e.g., volume × intensity), from easy (E), moderate (M) to hard (H). The AP was validated, confirming its recommendations according to international sports nutrition guidelines. However, the AP had significantly higher protein content than recommended (up to 2.9 ± 0.5 g·kg^{-1}·d^{-1}; $p < 0.001$ for H male). The aim of this study was to quantify the environmental impact (EnvI) of the AP and to evaluate the influence of meal type, training load, sex and registered dietitian (RD). The nutritional contents of 216 APs created by 12 sport RDs were evaluated using Computrition Software (Hospitality Suite, v. 18.1, Chatsworth, CA, USA). The EnvI of the AP was analyzed by life cycle assessment (LCA) expressed by the total amount of food on the AP, kg, and kcal, according to the Swiss Agricultural Life Cycle Assessment (SALCA) methodology. Higher EnvI is directly associated with higher training load when the total amount of food on the plate is considered for E (5.7 ± 2.9 kg CO_2 eq/day); M (6.4 ± 1.5 kg CO_2 eq/day); and H (8.0 ± 2.1 kg CO_2 eq/day). Global warming potential, exergy and eutrophication are driven by animal protein and mainly beef, while ecotoxicity is influenced by vegetable content on the AP. The EnvI is influenced by the amount of food, training load and sex. This study is the first to report the degree of EnvI in sports nutrition. These results not only raise the need for sustainability education in sports nutrition in general, but also the urgency to modify the AP nutrition education tool to ensure sports nutrition recommendations are met, while not compromising the environment.

KEYWORDS: sports nutrition; protein; periodized nutrition; environmental impact; nutrition education; sustainability; life cycle assessment

1. Introduction

Everything we produce and consume has an impact on the environment. Due to its relevance, the environmental impact (EnvI) of food production has not only been a topic of interest in the scientific community, but also a cause for social mobilization. It has been reported that food production and processing have an impact on climate change, generating around 26% of total greenhouse gas emissions (GhGe), using 61% of fresh water and 38% of the global ice-free land surface (Notarnicola et al., 2016; Poore & Nemecek, 2018). Many factors influence the degree of EnvI along the food supply chain, including pre-production, such as agricultural inputs, agricultural production and food processing, and post-production, such as distribution, retail and waste (Notarnicola et al., 2016; Ridoutt, Hendrie, & Noakes, 2017; Vermeulen, Campbell, & Ingram, 2012). Thus, each food product will have a different EnvI. For example, the production of animal proteins, such as red meat and dairy products, has higher GhGe, water and land use than plant-based proteins (Gerber et al., 2013; Sabaté, Sranacharoenpong, Harwatt, Wien, & Soret, 2014). As a consequence, daily food choices have a direct impact on the environment (Poore & Nemecek, 2018; Willett et al., 2019). Furthermore, food choices also have an impact on human health (Sam Soret & Sabate, 2014; Swinburn et al., 2011; Tilman & Clark, 2014).

Red meat and processed meat have been associated with a higher risk of chronic disease and cancer (Bouvard et al., 2015), and a high consumption of processed food, rich in fat and sugar, is associated with a higher prevalence of obesity and diabetes in developed and developing countries (Swinburn et al., 2019, 2011). Finally, climate change in itself (e.g., wild fires and air pollution) as well as other environmental impacts (e.g., pollutants) can also have an impact on human health (Guarnieri & Balmes, 2014; Manisalidis, Stavropoulou, Stavropoulos, & Bezirtzoglou, 2020).

Life cycle assessment (LCA) is one of the most frequently used methodologies to evaluate the EnvI of foods and diets across the food chain (Nemecek, Jungbluth, Canals, & Schenck, 2016). Life cycle assessment is a suitable methodology to identify priority areas, also called environmental hotspots. Hotspots can be found in the area of food choices, entire food groups, or in food processing. In the past, LCA studies have calculated the EnvI of single foods, highlighting the impact of meat, and especially red meat, on the environment (Gerber et al., 2013). Recently, LCA studies have focused on modeled diets or a typical dietary pattern (Batlle-Bayer, Bala, García-Herrero, et al., 2019; Castañé & Antón, 2018; Dooren & Aiking, 2014). Scarborough et al. (2014) evaluated different eating patterns and found a difference between high meat eaters and vegans (7.19 kg CO_2 eq/d vs. 2.89 kg CO_2 eq/d, respectively) (Scarborough et al., 2014). Similar results were found in other studies (Masset, Soler, Vieux, & Darmon, 2014; Ripple et al., 2014; Samuel Soret et al., 2014; Westhoek et al., 2014). Furthermore, most studies focused on the evaluation of only one single environmental issue (e.g., GhGe), with few studies using a more comprehensive approach that considers different EnvI categories (e.g., ecotoxicity, biodiversity, water and land use) due to the complexity of LCA methodology (Castellani, Sala, & Benini, 2017; Nemecek et al., 2016). Whereas GhGe, land, and water use are more frequently captured in LCA, the topic of biodiversity is still difficult to measure. However, the alarming loss of plant and animal species (FAO, 2010) and its relationship to food production indicates that EnvI of human diets should also include biodiversity. Finally, it is also possible to evaluate EnvI through the planetary boundary framework (Steffen et al., 2015), which attempts to examine human activity in reference to the boundaries of earth's resilience. The framework considers the environmental limits within a safe operating space, while capturing multiple variables in one framework (e.g., climate change, biodiversity, land use, etc.). The framework highlights the importance of linking all human activities to each of the different planetary boundaries when assessing their impact, which also includes food production and consumption. Thus, similar to LCA, this framework can help to set planetary priorities related to dietary guidelines such as meat and dairy products. Taking a more comprehensive approach when studying the EnvI is recommended.

The trilemma of health, environment and diet has to be understood from a perspective that there is a sweet spot between meeting dietary recommendations for health (and performance), while not compromising life on Earth. The EAT-Lancet commission recently published a paper calling for the "Great Food Transformation" from sustainable production to healthful consumption, highlighting the importance to address this issue from both environmental and nutritional sciences perspectives together. "Win-Win-Win" solutions must be prioritized that promote co-benefits when healthy eating comes from sustainable production (Willett et al., 2019). Most of the current literature has been focused on the general population, whereas the diets of athletes and active people have not yet been addressed. Athletes and active individuals are advised to consume more food, including protein, according to greater needs from physical activity and sports training (Thomas, Erdman, &

Burke, 2016). While national dietary guidelines from various countries and world health organizations also recommend increasing physical activity for health and longevity, protein recommendations generally remain at conservative levels, except for older adults and in weight loss (Daly et al., 2014; Nowson & O'Connell, 2015; Te Morenga & Mann, 2012). Considering the latter, it may be the diets of the "Healthy & Wealthy", as indicated by Garnett (2016), that continue to omit considerations of EnvI, while over-emphasizing muscle mass, physique, and weight (Garnett, 2016). Thus, there is an urgency to adapt nutrition recommendations for active and athletic individuals and integrate the links among environment, health, and performance to promote "Win-Win-Win" solutions in these populations (Lynch, Johnston, & Wharton, 2018; Meyer & Reguant-closa, 2017).

The Athlete's Plate (AP) is a nutrition education tool specifically designed for athletes and active people. The aim of the AP is to help sports dietitians working with athletes or athletes themselves adjust food intake according to changes in training volume and intensity (defined in the training methodology literature as training load (Foster et al., 2001)). The AP is different from a nutrition education tool for the general population, as it adjusts the composition of the major food groups on the plate to training load without being too descriptive (Figure 3.7). The AP supports the concept of nutrition periodization based on changes in training load throughout the annual training and competition plan. Following the concept of training load and nutrition periodization, three plates were designed: easy (E), moderate (M) and hard (H) training, and validated to ensure they meet international sports nutrition guidelines (see Reguant-Closa et al. (2019) for the details on the AP validation).

Sports nutrition recommendations for athletes are higher for energy and most macro- and micronutrients compared with the general population to ensure optimal health and adaptation to training so that performance capacity can be improved (Thomas et al., 2016). Specific guidelines exist to raise energy, carbohydrate, and fat intakes based on variable training loads. For protein, it is recommended that athletes consume between 1.2 and 2 $g{\cdot}kg^{-1}{\cdot}day^{-1}$, or 0.3 $g{\cdot}kg^{-1}{\cdot}day^{-1}$, which is 150–250% higher than the recommendation for the average person (Moore et al., 2015; Phillips & Van Loon, 2011; Thomas et al., 2016). In some cases, higher amounts of protein have also been recommended (Phillips, 2014) and identified in athletes' diets (Spendlove et al., 2015). Moreover, sports nutrition guidelines recommend high-quality protein sources that contain essential amino acids, especially leucine, to enhance muscle protein synthesis and promote repair of muscle tissues. For this reason, sports nutrition practice has been prioritizing animal and, specifically dairy protein, especially post-exercise (Burd, Gorissen, van Vliet, Snijders, & van Loon, 2015). Very little research exists on single or combined plant protein sources and their effect on muscle protein synthesis (Babault et al., 2015; van Vliet, Burd, & van Loon, 2015). Hence, it is not surprising that a higher than recommended amount of protein, and especially animal protein, was also found when the AP was validated (Reguant-Closa et al., 2019). Knowing that animal proteins have a higher EnvI than plant proteins (Poore & Nemecek, 2018; Sabaté et al., 2014), it appears a prudent next step to investigate EnvI, alongside the health and performance effects, of athletes' diets. Finally, it is well known that westernized countries consume more protein and, specifically more meat, than what is recommended (Berryman, Lieberman, Fulgoni, & Pasiakos, 2018). Because protein recommendations for athletes are nearly two times higher than those for non-athletes, there is great concern that active, westernized populations consume protein, and specifically meat, in quantities beyond the need for optimal health, muscular development, and performance, while negatively impacting the environment.

FIGURE 3.7

The Athlete's Plate Nutrition Education Tool

Thus, exploring environmental priority areas, including animal protein consumption, but also others, is the first step to evaluating EnvI of athletes' diets, and specifically the AP model. Introducing changes to the AP, based on this study, will offer an evidence-based justification for making this educational tool specifically, and sports nutrition, more environmentally sustainable. This is the first study in sports nutrition that integrates LCA. Environmental research in sports nutrition is urgently needed, as recently highlighted by Meyer et al. (2020).

Therefore, the purpose of this study was to quantify the EnvI of the AP and evaluate the influence of meal type, training load, sex and RD, to provide general recommendations to decrease the EnvI of the AP model and to make it more environmentally sustainable. This study is the first to explore EnvI in sports nutrition. We hypothesized that the AP's EnvI will increase with training load and be higher than the EnvI of diets reported in the literature for the general population. We also hypothesized that the EnvI will differ among meals, sex, and RDs.

2. Materials and Methods

This study assessed the EnvI of the AP created during the validation of the AP (see more detail described at Reguant-Closa et al. (2019)). Briefly, for the validation of the AP, 216 plates were analyzed. The plates were created by sport RDs familiar with the AP, addressing the following: differences in sex (females (F) and males (M)), meals (breakfast (B), lunch (L), and dinner (D)) and training load (easy (E), moderate (M), and hard (H)). Each RD reported to the dining hall at the Colorado Springs Olympic and Paralympic Training Center (CSOPTC) at separate times, without previously knowing the menu of the day. While adjusting their plate to the hypothetical scenario assigned, RDs were not confined to a plate or a dish but they could use all the dishes available, add more food to the same plate, use a plate or side bowl, or add a dressing, shake or dessert on the side. In total, each RD created 18 plates following the AP model for different training loads, meals, and sex. These plate data, made by RDs, were subsequently used to evaluate the EnvI of the AP using LCA. The methodological details regarding LCA are described below.

2.1. Life Cycle Assessment of the Athlete's Plate

Life cycle assessment is a standardized methodology regulated by ISO 14040:2006, which includes four different phases to systematically evaluate the EnvI of a product or a service system through all stages of its life cycle (Castellani et al., 2017; *ISO 14040:2006*). To evaluate the EnvI of the plates created during the validation of the AP (Reguant-Closa et al., 2019), an LCA was conducted. The food contents of each plate and detailed recipes were obtained from the AP validation (Reguant-Closa et al., 2019). For this LCA study, the Swiss Agricultural Life Cycle Assessment (SALCA) method was used (Gaillard & Nemecek, 2009). Figure 3.8 represents a schema of the different LCA phases according to ISO 14040:2006. For a detailed update on LCA and food, see Nemecek et al. (2016). In the next sections, each of these phases are briefly described in more detail.

2.1.1. Goal and Scope Definition

Phase 1 of LCA defines the goal of the study (what we want to analyze), the system boundary (inputs and outputs quantified within a selected boundary such as from cradle to plate), the functional unit (FU; how the EnvI data are expressed according to the goal of the study), and the EnvI categories studied. The goal of the current study was to analyze the EnvI of the AP created from the data of a previously published study (Reguant-Closa et al., 2019).

The system boundaries included the agricultural production and all the downstream processes (post-farm processes) up to food preparation and the final AP using the ingredients available at the CSOPTC dining hall kitchen. The following phases were considered: agricultural production, including the manufacture of production means (like fertilizers, pesticides, fuels, etc.), processing and packaging, transport (within the country and imported transport distances and means when applicable), storage and cooking (when applicable). Pre or post-consumer waste was not included in this study. When a fresh product did not include any processing, for example, fresh apples, that phase/step of the inventory was considered zero. See Figure 3 for more details on the system boundaries of this study.

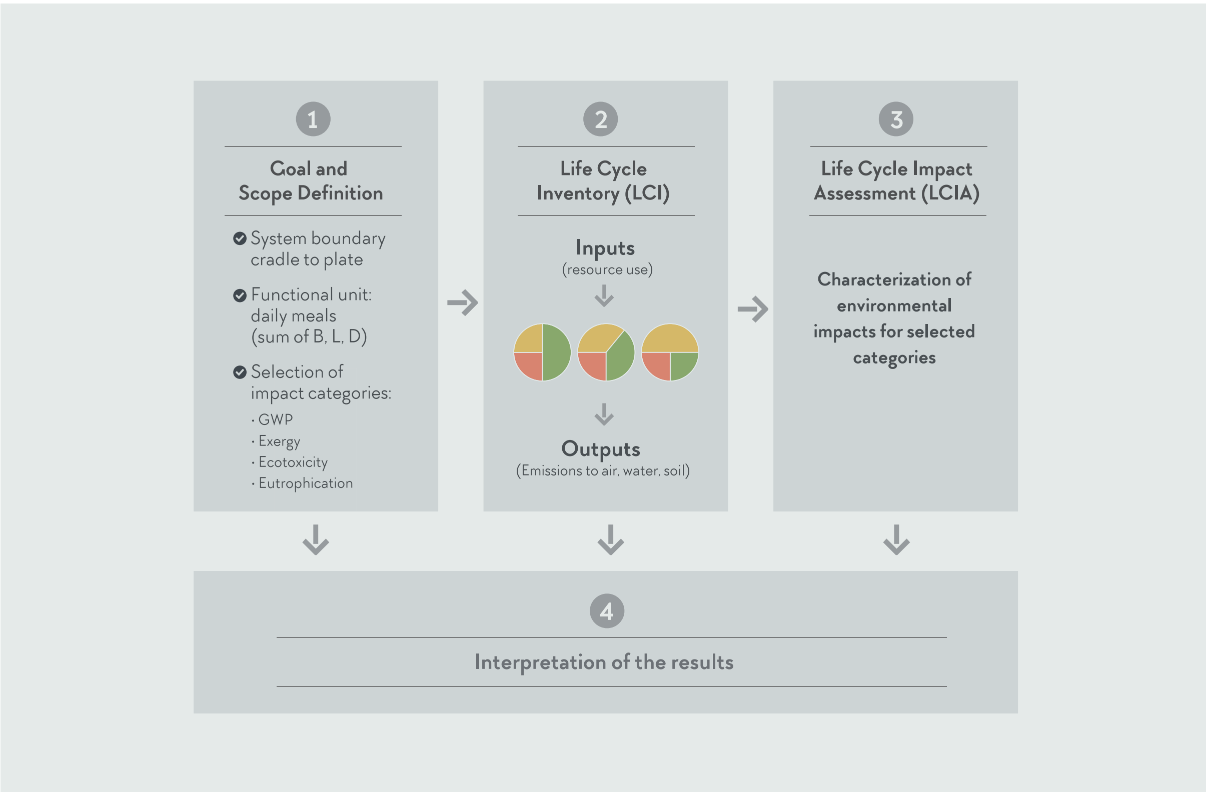

FIGURE 3.8

Diagram of the Athlete's Plate (AP) life cycle assessment phases, with Phase 1 defining the goal (to evaluate the environmental impact (EnvI) of the AP) and scope of the study. The scope includes the system boundary which was defined from cradle to AP. Phase 1 also includes the choice of functional unit (FU), which expresses the data according to the goal of the study. This study used general FUs (per plate; per kg of food on the plate; per 1000 kcal) for comparison purposes. Phase 1 also includes the selection of EnvI categories quantified, which included global warming potential (GWP), exergy, ecotoxicity, and eutrophication. During Phase 2, which focuses on the life cycle inventory (LCI), all the inventories for the different foods were created depending on their inputs and outputs. Phase 3 which is the life cycle impact assessment (LCIA) in which the different inventories were analyzed for the EnvI categories selected. Phase 4 (Results) includes the interpretation of the results.

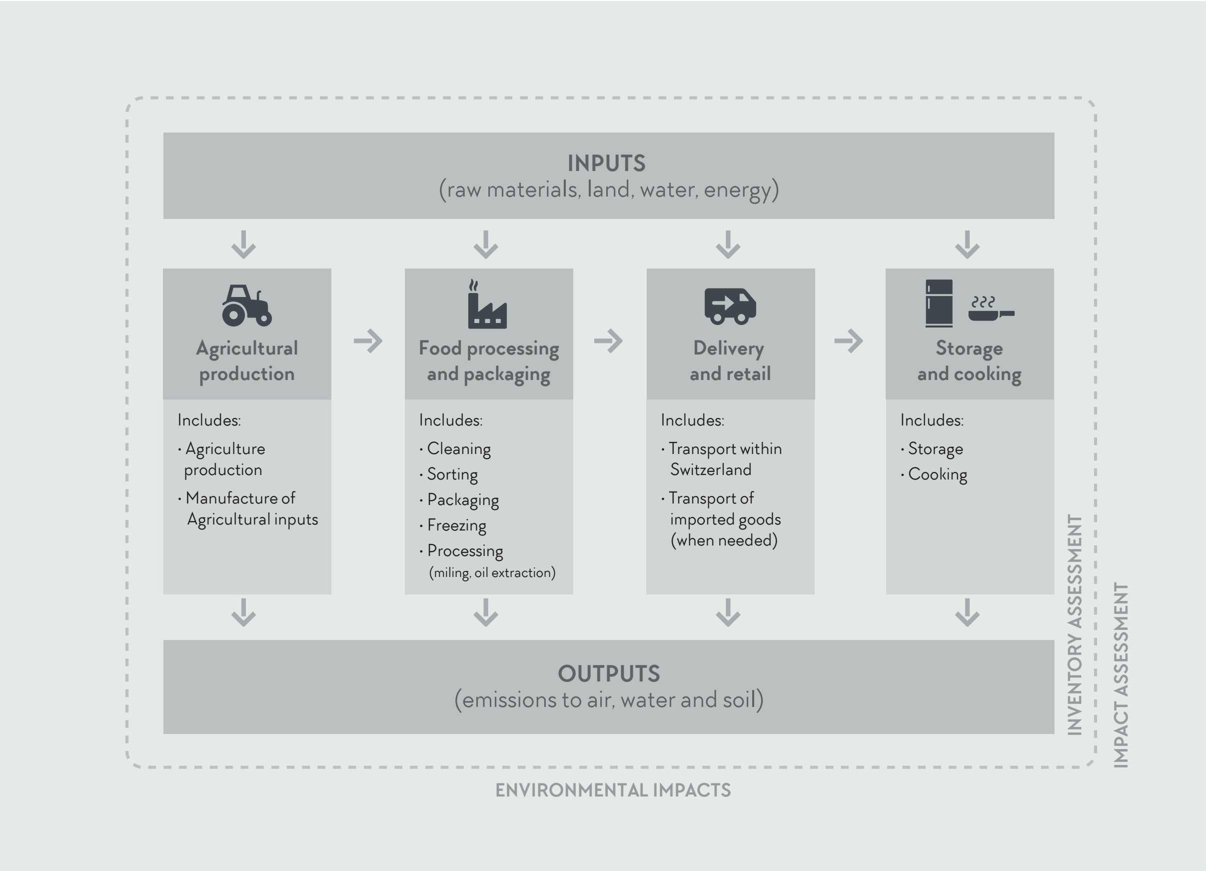

FIGURE 3.9

System boundaries of the Athlete's Plate life cycle assessment used for the current study, ranging from production to consumer use. It includes all steps from agricultural production, processing, and packaging to transport, storage, and cooking.

Environmental impacts in LCA are represented relative to an FU. Choosing the FU is a critical decision in LCA, as it affects the outcome and interpretation of the results (Masset, Soler, et al., 2014; Saarinen, Fogelholm, Tahvonen, & Kurppa, 2017). Generally, the EnvI of foods is expressed per unit of product (grams) or calories (kcal). In LCA studies, with focus on nutrition and the human diet, the choice of FU depends on the goal of the study and, if selected relative to the food or nutrient function of interest, provides a more relevant representation of EnvI (Sonesson, Davis, Hallström, & Woodhouse, 2019), although this is not always clear (Van Kernebeek, Oosting, Feskens, Gerber, & De Boer, 2014). Only recently have FUs been specifically adapted to the functions of foods and nutrients, but most studies also provided EnvI using standardized units, so the study results may be compared (Berardy, Johnston, Plukis, Vizcaino, & Wharton, 2019; Fulgoni, Keast, & Drewnowski, 2009; Sonesson et al., 2019). In the AP model, each plate fulfills a pre-determined energy and nutrient need that maintains health and optimizes performance based on international sports nutrition standards, some of which are expressed relative to body mass (BM) at the 3 training loads (E, M, H). For this reason and for comparison purposes, the EnvI of the AP was expressed 1) per plate, 2) per kg of food on the plate, and 3) per 1000 kcal.

Four environmental categories were selected to analyze the EnvI of the AP. Impact categories measure the EnvI of a product summing various substance emissions into one single measure to quantify their effect on the global or local environment. Most studies on LCA only focused on one EnvI category (e.g., GWP), but it is important to add multiple indicators to obtain a boarder representation of the impact. In this study, four EnvI categories were selected (Table 3.10).

TABLE 3.10
Description of the environmental impact categories

ENVIRONMENTAL IMPACT CATEGORIES	DESCRIPTION
GWP (kg CO2eq)	• GWP is the potential effect of GhGe on the climate. • Main GhG contributing to GWP of food systems are: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). For industrial processes some hydrocarbons can also contribute. • The use of fossil fuels, ruminant production, use of nitrogen fertilizer or organic matter decomposition, increase GhGe (IPCC, 2013).
Exergy (MJ)	• Considered as the use of all renewable and non-renewable resources that are used when making a product. • Exergy covers the use of land, water, energy carriers (renewable and non-renewable), minerals, metals, as well as biomass extracted from natural systems (e.g., during deforestation) (Alvarenga, Dewulf, Van Langenhove, & Huijbregts, 2013; Bösch, Hellweg, Huijbregts, & Frischknecht, 2007).
Ecotoxicity (aquatic) (kg 1,4DB eq)	• Represents the effect of a substance on the on the aquatic ecosystem. • The toxic effect of a substance depends on its environmental chemistry (exposure) and the effects of the substance on the organisms that come into contact with it.
Eutrophication (aquatic and terrestrial) (person × year)	• Represents aquatic and terrestrial accumulation of nitrogen and phosphorus from application of excess fertilizer with subsequent agricultural runoff. Leads to algae growth and oxygen deficiency in marine environments (Hauschild & Pooting, 2005).

GWP: global warming potential; GhGe: green house gas emissions; units for each environmental impact category in parenthesis are defined as: GWP (kilogram equivalents of carbon dioxide); exergy (megajoule); ecotoxicity (kilograms of 1,4 dichlorobenzene equivalents); eutrophication (person × year).

2.1.2. Life Cycle Inventory (LCI)

Life cycle inventory is Phase 2 of the LCA analysis, where the inventories for each food/ingredient are analyzed according to the system boundaries defined in Phase 1. For each item, an inventory is created that includes all environmental inputs and outputs. This process, while complicated and extensive, is the core of LCA, as it determines the validity of the data.

The quantification of the EnvI of food ingredients is very challenging due to the multitude of ingredients, origins, production and processing, and transport. The AP analyzed in this study included a wide variety of foods and ingredients. Some of the plates were composed with more than 100 ingredients. Due to the complexity of analyzing all the ingredients and to help simplify the analysis of the AP by LCA, assumptions had to be made and some ingredients were dismissed, aggregated or proxies were used. The dismissed products were those that represented a small portion of the plates (such as food additives, spices, some ultra-processed foods). Furthermore, where no data were available for some of the items analyzed, proxies were used. The different ingredients were aggregated into the following groups and subgroups: (1) dairy (milk, yogurt, soft cheese, hard cheese); (2) meat (beef, poultry, pork, processed meats); (3) eggs; (4) fish; (5) vegetables; (6) fruits; (7) grains (grains, breakfast cereals and bread); (8) legumes (all legumes except soy, soy); (9) seeds; (10) sprouts; (11) nuts; (12) sugar (honey, sugar); (11) beverages (includes fruit juices and sweet beverages); (13) dressings (olive oil and mayonnaise based dressing) and (14) others. The other food categories included all ingredients that were only present on 1–2 plates in small quantities and inventories were not available or it was not possible to classify them in one of the previously described groups. An average value of all 13 groups was considered for the "others" group (see Table 3.13A for a detailed description of group aggregations).

To achieve the goals of this study, detailed and specific LCA data were required to analyze the high variety of foods and products, which was not available for the US situation. It was therefore decided to analyze the data from a Swiss perspective, where access to more detailed data were available. Thus, for this study, the Swiss Agricultural Life Cycle Assessment (SALCA) method was used (Gaillard & Nemecek, 2009). In this study, both primary and secondary data were used. The executive chef and manager of the CSOPTC Food and Nutrition Services provided the primary kitchen data through interviews. It included detailed ingredient composition for processed food and recipes, packaging, storage means and times, cooking means and times, details of procurement, and origin of products. Secondary data necessary to complete the inventories for each stage were obtained using the Ecoinvent (v3.4 cut-off by classification) and SALCA databases, supplemented with data from the literature when needed. Inventories were adjusted (such as: electricity mixes, transport distances and agricultural production) and adapted to the system boundaries of the study when needed (see Table 3.14A for a description of the assumptions).

2.1.3. Life Cycle Impact Assessment (LCIA)

Life cycle impact assessment is Phase 3 of an LCA and includes the characterization of EnvI for the different inventories created in LCI based on the selected EnvI categories (see Phase 1, Table 3.10). Inputs and outputs collected in the LCI phase were transformed into impacts. The SALCA 1.10 method was used to evaluate the results of this study. Impacts were calculated using SimaPro version 8.5.2.0 (PRé Sustainability, LE Amersfoort, Netherlands).

2.1.4. Statistical Analysis

Means and standard deviations were calculated for the EnvI of plates for all 12 RDs with the three training loads expressed (1) per plate, (2) per kg of food, and (3) per 1000 kcal. Pearson product correlations were calculated among the four EnvI indicators across RDs, training loads, sex, and meals to indicate the relationships (n = 216). Correlation analyses were also carried out among specific foods and GWP, exergy, ecotoxicity and eutrophication. Standard deviations within training load were combined (the three squared SDs per training load and RDs were averaged over the training load in order to estimate the between RD variation) for each RD to compare the variability in the four EnvI indicators across the 12 RDs.

Sources of variation among RDs were investigated using a factorial treatment plan and repeated measures ANOVA in three separate analyses. The first analysis was with the main effect of RDs (n = 12), training load (n = 3) and sex (n = 2) using a 12 × 3 × 2 factorial plan. The second analysis was with RDs, meal and sex in a 12 × 3 × 2 factorial plan. The third analysis combined training load, meal and sex in a 3 × 3 × 2 factorial plan to test for second-order interactions. The 3 separate analyses were carried out because of the insufficient number of degrees of freedom for completing a 12 × 3 × 3 × 2 factorial analysis.

Outliers were considered as a minimum of 3 standard deviations away from the mean and were evaluated by RD, meal and training load. Standard variations and coefficient of variation by training load for each RD were used to investigate individual variability of each RD.

3. Results

3.1. Descriptive Data

To quantify the EnvI of the food content of the plates, a first data analysis was performed between training load and the four EnvI categories. The EnvI of the AP varied with training load. The results are shown in daily means ± SD for all meals together (i.e., breakfast, lunch, and dinner) at the three training loads (E, M, H) and expressed by the four EnvI categories (Table 3.11). Values are expressed by three different FUs, using absolute (per plate) and relative (per kg and 1000 kcal) values. These values reflect daily intakes, including the three main meals of the day (B, L, D) without snacks.

TABLE 3.11
Athlete's Plate daily totals (sum of breakfast (B), lunch (L), and dinner (D)) by training load.

		EASY	MODERATE	HARD
		Mean ± SD (*n* = 72)	Mean ± SD (*n* = 72)	Mean ± SD (*n* = 72)
Total food weight (kg)		2.6 ± 0.6	2.4 ± 0.7	2.7 ± 0.7
GWP (kg CO_2 eq)	Per Plate	5.3 ± 1.9	6.0 ± 1.1	8.0 ± 1.9
	Per Kg	2.6 ± 0.8	2.5 ± 0.4	2.5 ± 0.3
	1000 kcal	3.1 ± 1.0	2.6 ± 0.5	2.5 ± 0.5
Exergy (MJ)	Per Plate	149.0 ± 64.1	171.0 ± 40.1	241.1 ± 73.7
	Per Kg	72.8 ± 26.2	71.9 ± 19.6	73.7 ± 13.6
	1000 kcal	84.7 ± 25.2	75.1 ± 17.4	76.1 ± 16.2
Ecotoxicity (kg 1,4DB eq)	Per Plate	2.6 ± 1.2	3.4 ± 1.6	3.7 ± 1.6
	Per Kg	1.3 ± 0.5	1.4 ± 0.5	1.1 ± 0.4
	1000 kcal	1.6 ± 0.9	1.5 ± 0.7	1.2 ± 0.6
Eutrophication (person × year)	Per Plate	0.0125 ± 0.0083	0.0121 ± 0.0037	0.0165 ± 0.0061
	Per Kg	0.0079 ± 0.0079	0.0056 ± 0.0023	0.0058 ± 0.0028
	1000 kcal	0.0077 ± 0.0061	0.0053 ± 0.0016	0.0053 ± 0.0018

Units for each environmental impact category in parenthesis are defined as: Global warming potential (GWP; kilogram equivalents of carbon dioxide); exergy (megajoule); ecotoxicity (kilograms of 1,4 dichlorobenzene equivalents); eutrophication (person × year). Data represent environmental impact categories for easy, moderate, and hard training loads.

A correlation analysis was performed in order to analyze synergies and trade-offs among EnvI categories and for specific food groups. A positive correlation indicates a synergy, while a negative correlation represents a trade-off. Correlation coefficients among the computed environmental indicators ranged from $r = 0.86$ to $r = -0.05$, with the higher correlations found between GWP and exergy (see Table 3.15A). Due to the lower correlation among the different EnvI categories, results in the next sections are expressed by all four categories. Correlation analysis among the total EnvI of the AP and each food group category was performed for each impact category. Relatively high correlation coefficients were found between the total impact per plate and the impact for beef (GWP ($r = 0.64$); exergy ($r = 0.70$)). The same was found for the food categories of milk (GWP ($r = 0.50$); exergy ($r = 0.48$)) and eggs (GWP ($r = 0.43$); exergy ($r = 0.40$)). For ecotoxicity, higher correlations were found for vegetables ($r = 0.73$) and legumes ($r = 0.64$). For eutrophication, higher correlations were found for legumes ($r = 0.55$) and fish ($r = 0.57$).

3.2. The Influence of Different Foods on the Total Environmental Impact

In order to evaluate the contribution of each food group on the EnvI of AP as well as for each EnvI category studied, pie diagrams were developed for each training load (Figure 3.10). Pie diagrams are an ideal tool to provide an analysis of the contribution from each food group to the total EnvI of AP. Pie diagrams show that the total EnvI of the AP was affected more by meat and dairy than legumes and grains but the effect was specific to the EnvI category considered. For example, meat contributed more to GWP and exergy, vegetables and legumes to ecotoxicity, and legumes and fish to eutrophication (Figure 3.10). When evaluating each food group more closely, meats such as beef and chicken are the main contributors to GWP and exergy (Figure 3.15A). When analyzing the plates individually, all plates with meat had a higher EnvI than those without meat (GWP = 2.5 and 1.6 kg CO_2 eq respectively). If we consider different meat groups, the mean GWP values were higher when plates included beef (GWP = 3.6 kg CO_2 eq) compared with pork (GWP = 2.9 kg CO_2 eq) and poultry (GWP = 2.2 kg CO_2 eq). Although some food groups had a higher EnvI than others, the total EnvI of the AP is always a result of a combination of the different foods groups. Moreover, the contribution of each food group to the total EnvI of the AP depends on the impact category evaluated. Figure 3.10 is a representation by EnvI category of the contribution of each food group by training load.

3.3. Sources of Variation Among RDs

To evaluate sources of variation among RDs, meal type, training load and sex, a factorial treatment plan and repeated measures ANOVA was performed. ANOVA is used to verify if the mean EnvI differs among RDs, training load, meal and sex (main effects). Analysis I was based on a 12 × 3 × 2 factorial design to examine the main effects of RD ($n = 12$), training load (E, M, H) and sex (F, M). Analysis II (12 × 3 × 2) examined the main effects of RD, meal (B, L, D) and sex (M, F). And analysis III (3 × 3 × 2) tested training load, meal, and sex. All three factorial analyses were performed per plate.

Analysis I showed a significant main effect on training load for GWP ($p = 0.024$), exergy ($p = 0.018$) but not for ecotoxicity ($p > 0.05$) and eutrophication ($p > 0.05$). Differences were also found between sex for GWP ($p \leq 0.05$), exergy ($p \leq 0.05$) and ecotoxicity ($p \leq 0.05$), but not eutrophication, with males having a higher EnvI than females. There was a significant linear effect for training load for ecotoxicity

($p \leq 0.05$) and exergy ($p \leq 0.05$), but not for GWP or eutrophication (as training load increases, EnvI increases). There were no significant interactions for the four analyzed EnvI categories ($p > 0.05$).

Analysis II showed a significant or almost significant quadratic effect of meal for GWP ($p = 0.065$), exergy ($p = 0.166$), ecotoxicity ($p \leq 0.05$) and eutrophication ($p = 0.047$). This indicates that the EnvI values for breakfast are lower, while for lunch and dinner they are higher (Figure 3.11). In addition, statistically significant differences between sex were found for GWP ($p \leq 0.05$), exergy ($p \leq 0.05$) and eutrophication ($p \leq 0.05$), but not for ecotoxicity. Males have a higher EnvI than females. For ecotoxicity, there is a significant effect for training load ($p \leq 0.05$) and meal ($p \leq 0.001$), with no effect for sex ($p = 0.17$). There was a significant linear effect of meal for GWP ($p \leq 0.05$) and ecotoxicity ($p \leq 0.05$), but not for eutrophication and exergy.

Analysis III was used to test for additional interactions without considering RDs. For both GWP ($p \leq 0.05$) and exergy ($p \leq 0.05$), there was a significant interaction among sex, meal, and training load, characterized by a non-parallel evolution of the interaction lines (Figure 3.12).

The two-way interaction is significant for the two independent variables, training load and meal, for both GWP ($p \leq 0.05$) and exergy ($p \leq 0.05$), but neither for sex and meal nor for sex and training load. The former means that the impact of the variable meal on GWP and exergy depends on training load. This means that the interpretation of the main effect GWP and exergy is incomplete and/or mis- leading.

3.4. Outliers and Consistency of the Data

Figure 3.13 shows the distribution of the four EnvI categories studied divided by training load and meals. Some potential outliers were identified and checked for plausibility. In all cases, outliers occurred because of variations in meat on selected plates and/or the combination of foods high in EnvI. Furthermore, the outliers differed based on the EnvI categories. As a consequence, it was decided to keep outliers in the data ($n = 216$).

Combined standard deviations were calculated to compare the variation within RDs when making the AP (Table 3.12). Registered dietitian six was the one with the lowest variation among the four EnvI categories followed by RDs four and seven. As shown above, in Section 3 of the results, RD twelve was more variable for all four EnvI categories than all other RDs. Registered dietitian 12 had an SD of 3.8 with a variance ratio of 14/2.6, or 5.4, compared to a typical SD of 1.6 (Table 3.12).

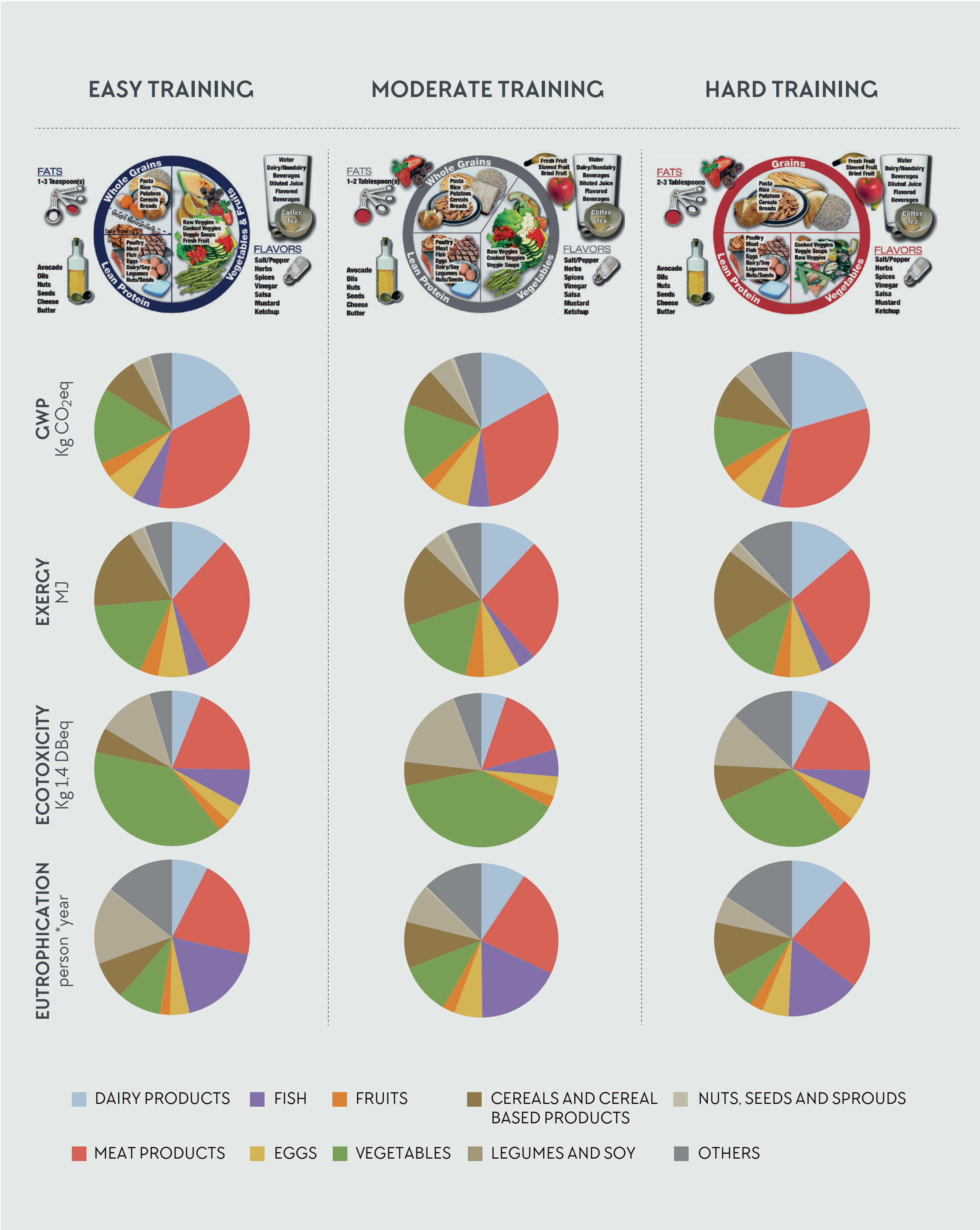

FIGURE 3.10

The contribution of each food group (aggregated) by training load and environmental impact category per plate. Figure 3.10 shows that meat and dairy contributed more to GWP and exergy, vegetables and legumes to ecotoxicity, and legumes and fish to eutrophication.

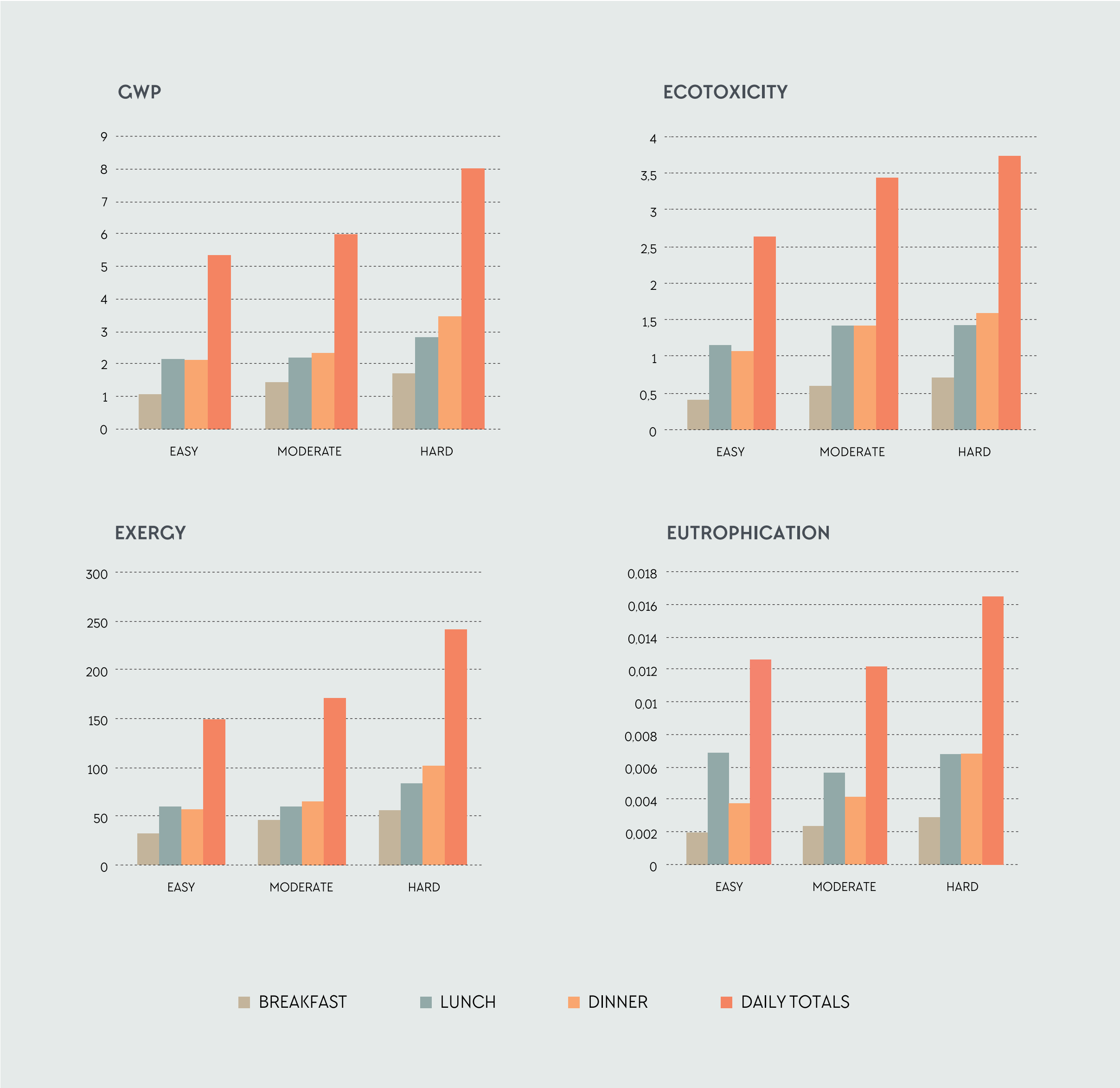

FIGURE 3.11

Meals and training load distribution of the four environmental impact categories. Values represented are per plate. Daily totals represent the sum of breakfast, lunch and dinner.

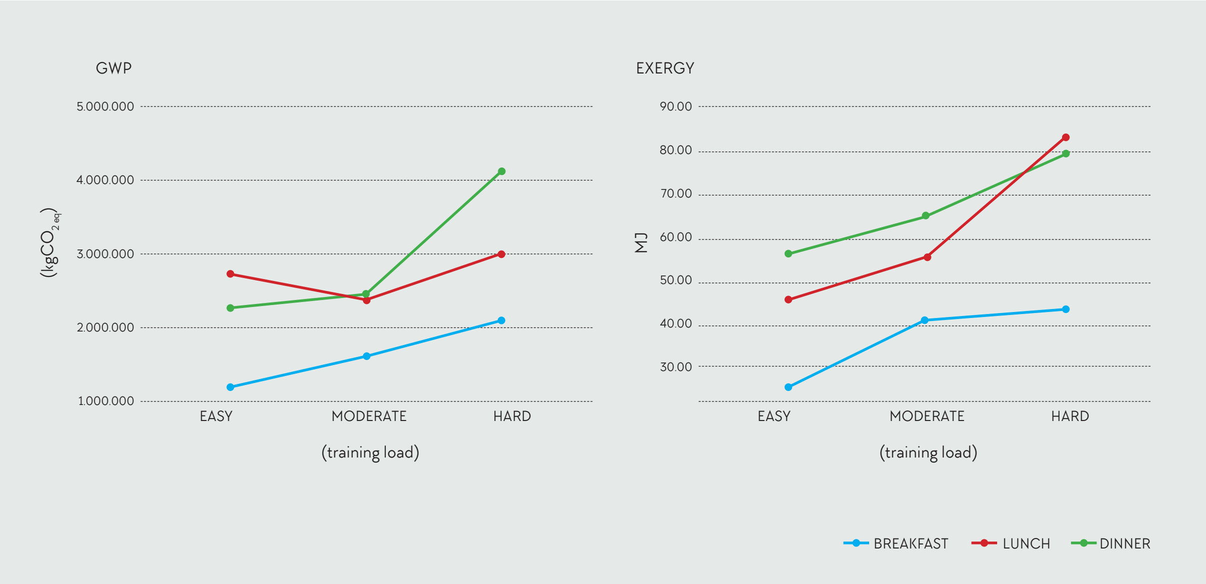

FIGURE 3.12

Two-way interaction for GWP and exergy: (a) GWP. Female two-way interaction (meal × training load) for GWP. (b) Exergy. Male two-way interaction (meal × training load) for exergy.

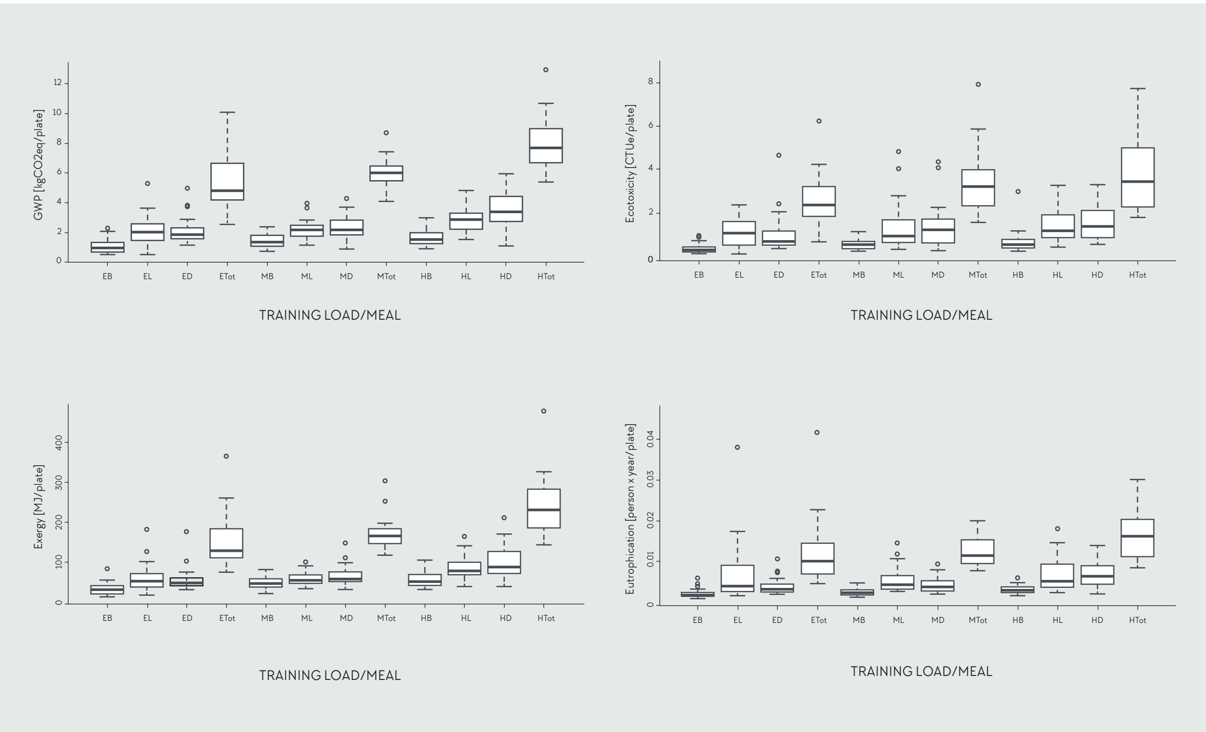

FIGURE 3.13

Boxplots by training load and meals for all four environmental categories. EB: Easy breakfast; EL: easy lunch; ED: easy dinner; Etot: easy daily totals; MB: moderate breakfast; ML: moderate lunch; MD: moderate dinner; Mtot: moderate daily totals; HB: hard breakfast; HL: hard lunch; HD: hard dinner; Htot: hard daily totals.

TABLE 3.12

Standard deviation of the environmental impacts of the 12 dietitians (easy, moderate and hard plates) for daily totals (sum of breakfast, lunch and dinner).

DIETITIAN	GWP ($kg\ CO_2eq$)		EXERGY (MJ)		ECOTOXICITY (kg 1.4DB eq)		EUTROPHICATION (person x year)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	6.1	2.2	180.6	64.9	2.8	1.0	0.0155	0.0033
2	6.0	1.9	155.0	27.2	4.1	1.5	0.0134	0.0059
3	6.3	1.4	162.3	29.3	2.8	0.7	0.0090	0.0019
4	6.0	1.0	169.2	19.2	3.2	1.1	0.0127	0.0023
5	6.3	1.7	169.3	42.2	3.4	1.7	0.0182	0.0137
6	4.9	0.6	140.4	11.7	1.9	0.5	0.0086	0.0008
7	5.8	1.0	157.5	25.8	2.3	0.4	0.0111	0.0044
8	7.3	1.1	194.1	31.5	3.4	0.6	0.0114	0.0023
9	6.0	1.5	183.8	70.0	3.1	1.4	0.0165	0.0055
10	7.3	1.8	208.8	45.6	4.1	1.5	0.0165	0.0057
11	7.2	1.4	214.3	41.6	5.4	1.7	0.0188	0.0054
12	8.0	3.8	309.1	114.7	2.7	1.0	0.0130	0.0059

Means and combined standard deviations (obtained by calculating the three squared SDs per training load and RD and averaged over the training load in order to estimate the between RD variation). Means and SDs were calculated to compare variability in the four environmental indicators across the 12 RDs. Units for each environmental impact category in parenthesis are defined as: GWP (kilogram equivalents of carbon dioxide); exergy (megajoule); ecotoxicity (kilograms of 1,4 dichlorobenzene equivalents); eutrophication (person × year).

4. Discussion

The purpose of this study was to quantify the EnvI of the AP and evaluate the influence of meal type, training load, sex and RD. This study is the first to explore EnvI in sports nutrition. The results of this study may lead to adjustments to the AP nutrition education tool to guide the development of the sustainable AP meant to be a visual tool for the diets of athletes and active individuals today and in future years. The findings show that the EnvI of the AP varies by training load, but this depends on the FU. The EnvI of the AP is mainly influenced by the total amount of food on the plate, the food group combinations, meal type (B, L, D), and RDs.

4.1. Descriptive Data

As expected, Section One of the results shows that training load is the main factor influencing the EnvI of the AP for the four EnvI categories. When adjusted by weight of food (kg) or energy equivalent (kcal), the EnvI of the AP no longer rises with increasing training load. In fact, it is rather the opposite when using 1000 kcal as FU, showing similar or slightly lower EnvI at higher training loads. These differences are due to adjusting the quantity of food to a sole unit such as kg or kcal, giving rise to other aspects of foods, such as food composition on the plate. This emphasizes the necessity to express the values of EnvI relative to the most adequate FU. Several studies have highlighted the importance of using an FU that links nutrition and EnvI of diets (Batlle-Bayer, Bala, Lemaire, et al., 2019; Masset, Vieux, & Darmon, 2015; Nemecek et al., 2016; Sonesson, Davis, Flysjö, Gustavsson, & Witthöft, 2017). While human diets fulfill many functions, one function is to supply a required number of calories and nutrients. In the case of the AP, the three different training loads provide different amounts of calories and macronutrient distributions and, as a consequence, fulfill a different training/competition function. Further research is needed to evaluate the EnvI of the athlete's diet relative to nutrients essential for performance beyond energy (such as carbohydrate intake, protein quality, or iron). For example, the hard AP fulfills the function to replenish glycogen stores for intense training. Higher training loads require higher energy and carbohydrate intakes to adequately perform as well as replenish glycogen stores, as broadly described in the sports nutrition literature (Burke, Hawley, Wong, & Jeukendrup, 2011; Thomas et al., 2016). Athletes should obviously not consume less energy during hard training days for environmental reasons. They should focus on achieving greater energy and carbohydrate intakes, while meeting but not exceeding protein recommendations. A plausible solution to reducing the EnvI of the hard training day plate is to lower or eliminate the animal protein portion on the plate and focus on carbohydrates. Some studies highlighted how plant-based diets can be beneficial for athletes due to their higher carbohydrate content (Barnard et al., 2019; Burd, Beals, Martinez, Salvador, & Skinner, 2019), as athletes often have carbohydrate intakes below recommendations (Manore, Patton-Lopez, Meng, & Sung Wong, 2017; Viner, Harris, Berning, & Meyer, 2015). Hence, making sports nutrition recommendations for hard training days or competition that promote optimal carbohydrate availability with less or no meat offer environmental protection and an evidence-based approach to performance enhancement. While the easy and moderate training day plates have smaller food quantities, they still incur a higher EnvI when containing meat. Thus, promoting plant-forward (e.g., flexitarian) (Derbyshire, 2017) and plant-based meals across all training loads still helps athletes to achieve carbohydrate and protein intakes, while reducing the total EnvI of the AP. Athletes who balance energy expenditure from sport with sufficient calories, carbohydrate, and protein, as recommended, are at low to no risk for low protein intakes, even with a plant-based approach (American Dietetic Association, 2009).

Gastrointestinal (GI) discomfort is a frequent issue in athletes, especially on hard/competitive training days (de Oliveira, Buruni, & Jeukendrup, 2014; Jeukendrup, 2017). Plant-based and forward strategies may lead to greater dietary fiber intakes, which could, at least temporarily, increase GI discomfort (de Oliveira et al., 2014; Jeukendrup, 2017) in athletes. Sports dietitians should help athletes with the selection of more refined carbohydrate sources (e.g., white pasta) as recommended by the AP for hard training days. In addition, adopting a step-wise approach with unfamiliar plant-based foods (e.g., beans, grains, tofu, nuts, seeds), preparation (e.g., cooking, sprouting, fermenting), and timing of ingestion in training first before using them in competition is common practice in sports nutrition. Finally, food and eating are embedded in culture and tradition and eating before competing might also contribute to the athlete's psychological preparation. The future of sports nutrition should therefore continue to focus on the individual, while gradually integrating environmental education of food choices when best suited.

The results of this study (reported as the sum of breakfast, lunch and dinner) show an average GWP for easy (5.3 ± 1.9 kg CO_2 eq), moderate (6.0 ± 1.1 kg CO_2 eq) and hard (8.0 ± 1.9 kg CO_2 eq) days.

To our knowledge, there are no previous studies that have quantified the EnvI of athletes' diets or plates made according to changes in training load. In comparison with the general population, our results show a higher EnvI especially, but not only, for hard training days. Several studies show GhG emissions ranging from as low as 2.9 kg CO_2 eq·d^{-1}·person^{-1} (vegan) and up to 7.9 kg CO_2 eq·d^{-1}·person^{-1} (high meat eaters) using standard diets and food diaries (Hyland, Henchion, McCarthy, & McCarthy, 2017; Murakami & Livingstone, 2018; Scarborough et al., 2014; Vieux, Soler, Touazi, & Darmon, 2013). Considering underreporting, even higher emissions are expected (Murakami & Livingstone, 2018). Methodological inconsistencies, such as the type of data sources, system boundaries, LCA methods as well as different dietary assessments used and populations studied, are common reasons for variability. The majority of studies have been conducted in non-exercising populations. There are currently no studies in athletes. Thus, the higher EnvI found in this study compared with other studies was expected, as the AP is targeted to athletes, meeting the needs of high energy expenditure. In addition, the results of this study are reported as the sum of breakfast, lunch and dinner, excluding snacks. Considering that snacks provide around 23% of the total daily energy intake in athletes (Burke et al., 2003; Erdman, Tunnicliffe, Lun, & Reimer, 2013), if anything, this study underestimates the EnvI of the AP. Different studies, addressing both the health and EnvI of diets in developed and developing countries, suggested a decrease in overall caloric consumption or at least energy density (Swinburn et al., 2019) for weight control and for the overconsumption of calories in westernized countries. Masset et al. (2014) studied French diets relative to calories and energy density and recommended both strategies to reduce the EnvI of diets. These recommendations might be good for the general population. Athletes and active individuals need to consume more energy and nutrient-rich foods to match energy expenditure to daily training load. As a consequence, recommending foods with lower EnvI for individuals and groups who need to eat more food with greater energy and nutrient density should be done cautiously to ensure that daily needs are met and EnvI is not too high.

A correlation analysis of the computed environmental indicators showed that the different indicators were not highly correlated, with the exception of GWP and exergy. Previous studies have shown that the strong correlation between GWP and exergy is related to similar key driving variables such as the use of fossil fuels (Nemecek, Dubois, Huguenin-Elie, & Gaillard, 2011). Since not all EnvI indicators correlate but rather complement each other, all four should be included for a comprehensive picture of the EnvI of the AP, as has been recommended by others in LCA research (Nemecek, Huguenin-Elie, et al., 2011).

4.2. The Influence of Different Foods on the Total Environmental Impact

Section Two of the results evaluated the contribution of each food group on the total EnvI of the AP. Whereas meat and dairy products show greater EnvI than legumes and grains, results vary by EnvI category and the types and quantities of food on the AP. Some food groups account for a greater EnvI of the AP than others, and thus, become more pressing environmental priorities (see Figure 3.15A). Similar to other studies (Eshel, Shepon, Makov, & Milo, 2014; Scarborough et al., 2014; Sam Soret & Sabate, 2014; Westhoek et al., 2014), the current results show that meat is the food group that accounts for the highest EnvI in all categories studied across all plates, except for ecotoxicity, where vegetables have a higher impact. All plates with meat had a higher EnvI impact than those without meat. The plates with beef (GWP = 3.6 kg CO_2 eq) had a higher GWP than the plates with poultry (GWP = 2.2 kg CO_2 eq) and double the GWP than the plates without meat (GWP = 1.6 kg CO_2 eq). Poultry, without skin, is one of the most consumed meats among athletes, as it is lower in fat than red meat. It is known that red meat has a higher EnvI than poultry or pork, but because poultry is so frequently used by athletes, it plays a relevant role in the EnvI of the AP (Figure 3.15A). Following meat, the dairy group also contributed to the EnvI of the AP. Dairy products are also frequently recommended to and used by athletes, especially for a meal addition or in recovery nutrition (Elliot, Cree, Sanford, Wolfe, & Tipton, 2006; Lunn et al., 2012). Most studies evaluating post-exercise protein synthesis used milk, whey, and casein as sources of high-quality protein. In the current study, dairy products showed high EnvI for GWP, exergy and eutrophication. For the AP, dairy products account for nearly 25% of the plate's EnvI contribution to GWP.

Sports nutrition recommendations include higher protein needs for athletes compared with the general population. In fact, protein recommendations are more than double for athletes. Moreover, in some specific cases, such as during energy restriction, even higher protein intakes are advised in the athletic population to avoid losses in lean mass (Hector & Phillips, 2017; Phillips, 2014), promote thermogenesis, and satiety (Clifton et al., 2014; Halton & Hu, 2004). Unfortunately, recommendations for athletes do not differentiate protein sources and generally focus on animal protein (Burd et al., 2015; Doering, Reaburn, Phillips, & Jenkins, 2016). The AP validation study found that both moderate and hard plates exceeded protein recommendations for athletes. When protein sources were assessed, it was found that 70% of all protein originated from animal sources (Reguant-Closa et al., 2019). While several authors (Lynch et al., 2018; Meyer & Reguant-closa, 2017) have voiced concerns about such recommendations in the face of sustainability, no study has attempted to quantify the EnvI of athletes' diets. Thus, this study is the first to report the degree of EnvI of athletes' diets in general. We show higher GWP compared with the general population (Burd et al., 2015; Hector & Phillips, 2017; Lunn et al., 2012), pointing mostly to the contribution of animal protein to the AP's EnvI. While high protein diets might seem an athletic issue, such diets are also recommended to the elderly to prevent sarcopenia (Daly et al., 2014; Paddon-Jones et al., 2015; Te Morenga & Mann, 2012) and are gaining popularity not only in weight loss but also to fulfill fitness and general wellness goals. Thus, the EnvI of these recommendations should be considered and integrated into future dietary guidelines for everyone. As described by Garnett (2016) we need to find an equilibrium between nutrition recommendations, health and EnvI considerations globally and not only focus on the diets of the "healthy & wealthy".

While the quantity of animal protein has to be considered when discussing the impact on human health and the environment, with meat being a major contributor to environmental degradation and deterioration of health, the quality of the protein also matters. Protein quality impacts musculoskeletal development and athletic performance (Phillips & Van Loon, 2011; Rowlands et al., 2014). The aim of this study was to explore the EnvI of the AP made by sports RDs and the variability among training load, meal and sex and not to simulate the AP model to evaluate lower protein on the plate or substitutions for meat. This study also did not evaluate how substitutions for meat (e.g., with beans), while beneficial for the environment, would impact protein quality or performance. This is an area of needed future research. As previously mentioned, our concern relates more to the protein quantity of the AP and how educational efforts, in this case using the AP, integrate environmental causes.

Regarding the quality of protein, different LCA studies have used protein and essential amino acids as FUs in the general population (Berardy et al., 2019; Sonesson et al., 2017). Berardy et al. (2019) studied LCA data relative to the digestible indispensable amino acid score (DIAAS) of single protein-rich animal and plant-based food sources. They showed that nuts, beans, insects, fish or protein powders (from pea, soy or whey) provided the highest efficiency with the least EnvI, while beef, cheese, and some processed refined grains (such as rice or egg pasta) were the least efficient and had the highest EnvI. However, the list of products and serving sizes analyzed in the current study was not extensive enough (due to the lack of availability of some data) and we did not analyze the combination of different protein sources (animal with plant-based combinations) or culinary techniques that could complement or increase amino acid availability of plant-based sources (Cabrera-Ramírez et al., 2020; Jäger et al., 2020). In athletes, only limited research has integrated DIAAS of plant-based diets. Ciuris, Lynch, Wharton, & Johnston, (2019) showed lower DIAAS and muscle mass and strength in endurance athletes on plant-based diets compared to athletes on meat-centric diets. Athletes are high users of protein supplements (Abbey, Wright, & Kirkpatrick, 2017; Jovanov et al., 2019; Madden, Shearer, & Parnell, 2017). Protein powders have been shown to provide an efficient protein source with a good amino acid profile (Berardy et al., 2019). However, recent studies pointed toward the importance of whole intact proteins from milk or eggs, rather than their isolates (e.g., whey or albumin), for muscle protein synthesis (Burd et al., 2019; van Vliet, Beals, Martinez, Skinner, & Burd, 2018). Thus, it is unclear whether protein powders are the solution for both skeletal muscle and the environment. Finally, recent health concerns have also added reservations regarding protein supplementation in athletes (Kårlund et al., 2019). Kårlund et al. (2019) studied the possible damaging effects of these products specifically, and high protein intakes in general, on the gut microbiome, suggesting possible negative consequences for both health and performance (Clark & Mach, 2016; Kårlund et al., 2019; Xu & Knight, 2015). While still insufficient, studies are appearing on plant-based protein powders and combinations of plant-based protein foods and their effects on muscle recovery (Babault et al., 2015; van Vliet et al., 2015). Furthermore, plant-forward strategies (Derbyshire, 2017) and the addition of insects (Churchward-Venne, Pinckaers, van Loon, & van Loon, 2017) might also be a possible strategy for active and athletic omnivores to integrate more environmentally friendly approaches (van Huis et al., 2013) that also promote performance and health.

In addition to meat and dairy, processed foods have a higher EnvI than unprocessed, fresh foods when expressed relative to GWP and exergy (Canning, Charles, Huang, Polenske, & Waters, 2010) and generally lower nutritional content (Drewnowski et al., 2015). The food groups with the highest EnvI in the current study were meat and dairy products. However, processed foods such as frozen and canned vegetables, fruits, and legumes, also contributed to the higher values for GWP and exergy. When fresh vegetables were compared with frozen or canned vegetables, GWP was 0.9 vs. 3.3 kg CO_2 eq, respectively. Even though we did not evaluate the EnvI of each step of the food chain, the analysis of processed foods vs. unprocessed food inventories revealed significant differences. Vegetables were the main contributor to the EnvI for ecotoxicity. Ecotoxicity relates to intensive pesticide use in conventional agriculture. Taken together, conventionally grown and/or processed vegetables were both identified as an environmental priority in the current study. Integrating fresh and seasonal food decreases GWP and exergy, while organic vegetables would lead to lower ecotoxicity.

Finally, total EnvI of the AP is determined by different food group combinations (Figure 3.10 and Figure 3.15A). Based on Reguant-Closa et al. (2019), the plate design might inadvertently lead to higher protein intakes because proteins from animal sources tend to be prioritized in sports, and milk is listed twice under protein and as a beverage. It also appears that the visual tool facilitates the identification of animal-based foods over plant-based alternatives, which may have contributed to the increased animal-based protein sources on the plates made by RDs (Reguant-Closa et al., 2019) and the higher EnvI of the AP. A possible synergy to reduce the EnvI of the AP would be to decrease total meat and dairy content and increase plant-based options, including whole grains and legumes (not canned). Finally, APs with normal to high amounts of meat and/or dairy should not also include high amounts of plant-based proteins such as quinoa or legumes to avoid high EnvI from high-protein combinations. Such high protein combinations are most likely due to current food trends (e.g., quinoa) and menu design by All-You-Care-To-Eat dining. The sustainable AP will need to integrate these potential redundancy issues by an overall de-emphasis of animal-based proteins and promotion of plant-based and forward strategies.

4.3. Sources of Variation Among RDs

Section Three of the results analyzed the main effects and interactions among RD, training load, meal, and sex using different factorial analyses. The results of this study confirm the hypothesis that the EnvI of the AP is dependent on training load. In addition, this study shows that EnvI varies according to meal, sex and RDs. When evaluating the effects of the different variables, interactions are important as they represent the combined effects of factors in the dependent measure. There was a significant main effect for training load and sex for all impact categories except for eutrophication. There was also a significant main effect for meal for all impact categories. Finally, the analysis shows that there was a significant interaction between RD and meal. This interaction indicates that the EnvI differs by RD when creating plates by meal type (B, L, D). Figure 3.12 shows the significant interaction between training load, meal, and sex for GWP and exergy for female and male, respectively, with greater EnvI for lunch and dinner and higher training loads. For meals, breakfast is generally smaller than the other meals, with less protein content compared with lunch and dinner (Reguant-Closa et al., 2019), although this was not consistently the case in this study. Some breakfasts had higher EnvI (see Figure 3.13) than lunch or dinner. In athletes, breakfasts are not always the smallest meals. In fact, if breakfast is a pre-event meal, it might be larger than the other meals. Similar results were also found in other studies. Gillen et al. (2017) found a lower proportion of protein at breakfast (19%) compared with lunch (24%) and dinner (38%). In athletes, this could be explained by the periodization and distribution of food through the day relative to training sessions. Sports nutrition recommendations and the AP promote a diet lower in fiber and moderate in protein with higher amounts of refined carbohydrates, especially before training, with increasing training load to promote performance. This may be manifested by greater amounts of fiber and protein back-loaded at dinnertime compared with pre-training meals, such as breakfast and lunch. Athletes' meal size, composition, and timing of ingestion vary greatly among sports and training phases, and thus, cannot be generalized as in the non-athletic population. Finally, in this study, breakfast was more plant-based or plant-forward compared to lunch and dinner, which included almost all meat portions consumed. This explains the lower EnvI of breakfast and reflects an opportunity for RDs to design and athletes to eat more plant-forward and plant-based lunches and dinners as a strategy to decrease the total EnvI of the AP.

4.4. Outliers and Consistency of the Data

Section Four of the results indicates the variability of RDs when creating the plates (Table 3.12). There is inherent variability in dietary data (Basiotis, Welsh, Cronin, Kelsay, & Mertz, 1987), which translates to the variability in EnvI data found in this study. In addition, data collection was performed in an "All-You-Care-To-Eat" dining hall with a high variability of foods from which to choose, which added another layer of variability.

Sports nutrition recommendations are typically made in energy and nutrients and per kg of body mass but not specific to the types of foods, which is at the discretion of the athlete's preference, the RD's counseling practices and philosophy, and food services' performance menu design. The AP is a visual tool but it is unclear which aspects are more important in guiding professionals and their athletes to adjust food intake to training load: the pictures on the plates, the colors, or the changing contribution of food groups. To our knowledge, there are currently no sports nutrition recommendations that integrate EnvI except for these articles (Lynch et al., 2018; Meyer et al., 2020; Meyer & Reguant-closa, 2017), and the RDs in this study were trained in sports nutrition and not in the environmental aspects of food choices. The AP validation study showed that protein recommendations were exceeded for moderate and hard training loads (Reguant-Closa et al., 2019). Thus, RDs should not hesitate to tackle protein recommendations in practical settings, especially considering that athletes have sport science support teams who can monitor muscle mass and performance changes over time. Inter-professional research and collaboration could identify optimal protein intakes that still meet daily requirements but are not an environmental liability. In the future, training RDs about the EnvI of the food system, and specifically when teaching athletes which foods to choose and food service professionals in designing performance-based menus, will be an important strategy to integrate sustainability practices and ensure consistency among professionals.

4.5. Limitations

One limitation of this study is that we did not quantify organic vs. conventional farming systems. Whereas animal protein has a high impact on the plates for GWP, exergy and eutrophication, vegetables have a higher impact on ecotoxicity, as shown in Figure 3.10. This is mainly due to the use of pesticides in conventional compared to organic production; the latter results in lower ecotoxicity (Fantke & Jolliet, 2016; Tuomisto, Hodge, Riordan, & Macdonald, 2012). The fact that some of the products used at the kitchen of the CSOPTC are organic (rice, legumes, some fruits and vegetables, etc.) but were not accounted for in this analysis would have resulted in lower ecotoxicity from the vegetable category. Further LCA studies for meals and diets in the general and athletic population should include the impact of different production systems. Beans also had a higher impact in comparison with other studies (Sabaté et al., 2014), due to the fact that most beans used were canned. Thus, preference should be given to fresh, seasonal fruit and vegetables and dry beans.

While this study tried to quantify the EnvI of real plates for athletes made by RDs following the AP model, developing the inventories for this LCA study was complicated and had some limitations. First, the list of ingredients considered for this study was very broad and different assumptions were made (Table 3.14A). For the analysis, we needed a large number of inventories, covering a wide range of different food products and sufficiently detailed to represent the EnvI in the best possible way. Such a comprehensive dataset was not available for the US case, corresponding to our list of ingredients, so we decided to adapt the study to Switzerland because Swiss data, which fulfilled these criteria, were available. Efforts were made to create a consistent data set. Therefore, LCI data not developed for Switzerland were adapted to the Swiss case (e.g., transport, electricity mixes) and the system boundaries of this study, while the data analyzed regarding the composition of the AP were based on the AP made in the dining hall of the CSOPTC. This presents a limitation of the study, but institutional food service facilities share many similarities. Additionally, sports nutrition recommendations are similar around the world, with staple foods recommended worldwide for athletes (e.g., pasta, rice, chicken or yogurt among others). However, we should assume some possible impacts on the results of this study, had US LCI data been used. First, the electricity mix in the US is based more on fossil fuel, which would have increased GWP and exergy, especially for food transformation and storage processes (e.g., cooking and freezing) (U.S. Energy Information Administration, 2018). Second, longer transport distances are expected within the US, which also increases GWP and exergy (Weber & Scott, 2008). Differences in other impact categories could be expected, but are unknown and this study did not analyze them.

4.6. Recommendations

It was beyond the scope of this study to model an environmentally sustainable AP. Nevertheless, the findings allow for the identification of environmental priority areas (also called hotspots) that enable opportunities for education. To make changes and lower EnvI of the AP (and athletes' diets), Figure 3.14 shows hotspots and possible solutions. To promote environmental sustainability in athletes we recommend athletes: (1) adjust energy, carbohydrate, and fat intake to the recommendations according to training loads, (2) reduce protein intake to the recommended level, (3) replace some animal protein with plant protein, (4) within the animal protein fraction, prioritize milk, eggs, poultry and pork over ruminant meat and cheese, (5) use fresh, seasonal, regional, and unprocessed foods and (6) limit frozen and canned products and reconsider protein powders that result in protein surplus, (7) obtain education in environmental issues of food choices when creating plates and (8) consider individual and cultural preferences.

Taken together, adjusting the AP, in combination with training in environmental nutrition and integration into dietetics practice and menu design (e.g., food combinations), is a necessary next step to address environmental sustainability in sports nutrition. A recent paper by the EAT-Lancet Commission 2019 urged for the "Great Food Transformation", recommending a reference diet with an average of approximately 300 g of meat per person per week for human and environmental health (Willett et al., 2019). Athletes may exceed this number on a daily basis. Thus, the current data should raise urgency and awareness in athletes, teams, and organizations that food for athletes impacts the environment, especially at higher training loads and if rich in meat and dairy products. Besides greater energy and nutrient intakes, athletes also travel frequently, use new and diverse equipment, and have a high consumption of packaged foods. While certain aspects of being an athlete cannot easily be modified, changing dietary habits not only for health and performance, but also the environment, presents synergies that are urgently needed.

FIGURE 3.14

The Environmental Athlete's Plate.

5. Conclusions

To our knowledge, this is the first study to address EnvI in sport nutrition. The results of this study show that the EnvI of the AP is influenced by the amount of food on the plates but dependent on the FU. Moreover, the EnvI of the AP is influenced by the EnvI category analyzed and the food group combination, increasing when multiple high protein foods (especially meat and dairy) are included on the same plate. In addition, the analysis showed a significant main effect between training load and meal for almost all impact categories, with a higher EnvI for lunch and dinner and for the hard training plate. As the recommendations from this study point to a reduction in animal protein, with a subsequent increase in plant-forward and plant-based strategies, more research is needed on these substitutions in athletes. Reducing the amount of total protein, and especially animal protein, on the plates to the recommended intake, and including occasional plant-based meals, also in omnivores, will lower the EnvI of the AP. Recommendations for athletes and active individuals cannot be exempt from the urgency to address the sustainability of diets. This study showed high variability in the EnvI of the AP among RDs, which highlights the opportunity for education to decrease the EnvI of the AP, while maintaining an adequate diet for sport performance and health. Finally, this paper highlights the importance of trans- and interdisciplinary collaborations, not only among sport and health professionals, but also nutrition and environmental scientists, as this is needed in the twenty-first century.

6. Acknowledgments

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7. Appendix

TABLE 3.13 A
Food group aggregations

AGGREGATION OF FOODS	GROUPS INCLUDED	SUBGROUPS
DAIRY	Milk products	–
	Yogurt	–
	Cheese products	Soft cheese and hard cheese
MEAT	Beef	–
	Poultry	–
	Pork	–
	Processed meats	–
FISH	Fish	–
EGGS	Egg	–
VEGETABLES	Fresh vegetables	Specific inventories for vegetables where created when possible
	Canned vegetables	Specific inventories for vegetables where created when possible
	Frozen vegetables	–
FRUITS	Fresh fruits	Specific inventories for vegetables where created when possible
	Frozen fruits	Specific inventories for vegetables where created when possible
GRAINS	Grain simple	Includes pasta, rice, bulgur, oats, etc.
	Bread	–
	Processed cereals	Includes breakfast cereals with sugar and pro–cessing
LEGUMES	Legumes without soy canned	–
	Soy beans	–
	Tofu	–
NUTS	Nuts in general	–
	Peanuts	–
	Peanut butter	–
SEEDS	Seeds	–
SPROUDS	Sprouts	–
SUGAR	Honey	–
	Sugar	–
BEVERAGES	Bottled fruit juice	–
	Wine	–
	Sports drinks	–
SPICES	Spices	–
DRESSINGS	Olive oil vinaigrette dressing	–
	Mayonnaise based dressing	–
OTHERS	Others	–

TABLE 3.14 A:
Athlete's Plate study LCA Assumptions

STAGE	ASSUMPTIONS
AGRICULTURE PRODUCTION	– When a product is produced in Switzerland (ex. Apples) agricultural production in Switzerland was selected. Existing inventories from ecoinvent or SALCA were selected. – When a product is not produced in Switzerland (ex. avocado) main importing countries are considered.
PROCESSING	Due to the difficulty of accounting of all the individualities of processing steps due to the wide range of ingredients considered for this study, some assumption were considered on this life-cycle stage: – Existing ecoinvent inventories were used for processing (including: cleaning, sorting, milling, cheese making, sterilization, freezing process, etc.) – In highly perishable vegetables and fruits (example: berries) adapted inventories were used due to the difference of manufacture. – In some cases, storage time of fresh product in the processing plant and short transport distances between plants (20km) was included on the processing inventories of ecoinvent. Those were also included in this study. – When the inventory was not specific to Switzerland, electricity mixes were adapted to Switzerland.
PACKAGING	– Packaging was in some cases already included in the processing inventories from ecoinvent. – When it was not included, it was added. – When specific packaging data were available (type, weight, etc.) from the primary data collected during the study in the kitchen, packaging was adapted to this specific case.
TRANSPORT	– Transport distances inside Switzerland are assumed to be an average of 100km. 50km by train and 50km done by lorry. When frozen or cooled products were considered, transport means included frozen or cold conditions. – Import transport distances and means were added when there was not production in Switzerland based on main importing countries to Switzerland. Inventories from ecoinvent were considered.
STORAGE	– Added storage time was considered for fresh products at the kitchen and was added on the inventories. Time of storage was divided into freezer and fridge depending on the product. Time of storage varies from 3 days up to 6 months depending on the product and was adapted individually for each inventory depending on the primary data collected at the kitchen. – Electricity mixes were adapted to Switzerland. – Dry storage was not considered.
COOKING	– Cooking inventories available at ecoinvent were used. – Cooking times and means (oven, stove, etc.), were adapted to each particular case following primary data collected at the kitchen and the recipes available. – Electricity mixes were adapted to Switzerland.

TABLE 3.15 A:
Correlation of the four environmental indicators by daily totals (sum of B, L, D) and by plate.

	GWP (kg CO_2 eq)	Exergy (MJ)	Ecotoxicity (kg 1.4DB eq)	Eutrophication (person x year)
GWP	1	0.86	0.69	0.26
Exergy	0.86	1	0.45	0.28
Ecotoxicity	0.69	0.45	1	0.44
Eutrophication	0.26	0.28	0.44	1

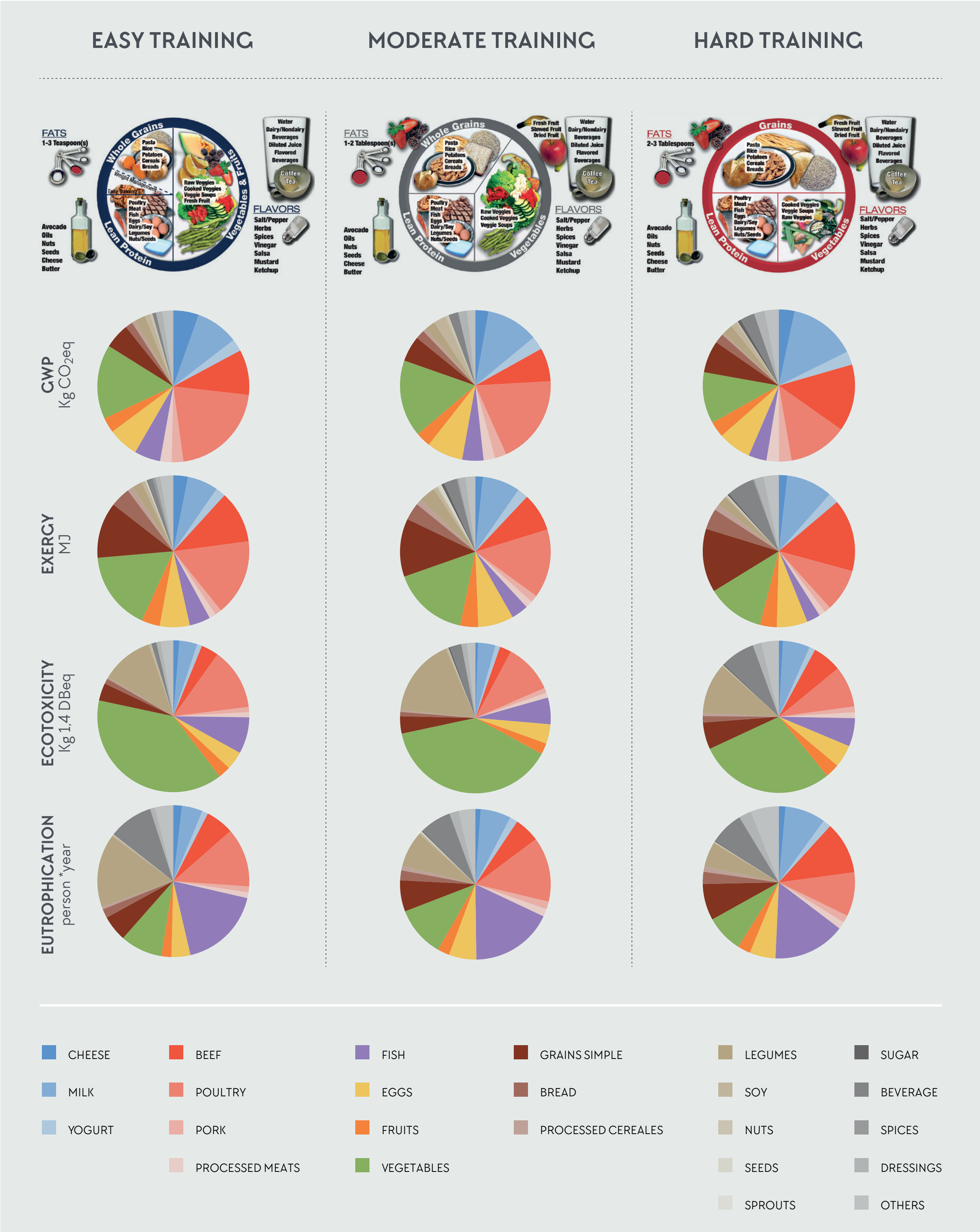

FIGURE 3.15 A:

The contribution of each food group by training load and environmental impact category per plate.

8. References

Abbey, E. L., Wright, C. J., & Kirkpatrick, C. M. (2017). Nutrition practices and knowledge among NCAA Division III football players. *Journal of the International Society of Sports Nutrition*, *14*, 13. https://doi.org/10.1186/s12970-017-0170-2

Alvarenga, R. A. F., Dewulf, J., Van Langenhove, H., & Huijbregts, M. A. J. (2013). Exergy-based accounting for land as a natural resource in life cycle assessment. *The International Journal of Life Cycle Assessment*, *18*(5), 939–947. https://doi.org/10.1007/s11367-013-0555-7

American Dietetic Association. (2009). Position of the American Dietetic Association: vegetarian diets. *Journal of the American Dietetic Association*, *109*(7), 1266–1282. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19562864

Babault, N., Païzis, C., Deley, G., Guérin-Deremaux, L., Saniez, M.-H., Lefranc-Millot, C., & Allaert, F. A. (2015). Pea proteins oral supplementation promotes muscle thickness gains during resistance training: a double-blind, randomized, Placebo-controlled clinical trial vs. Whey protein. *Journal of the International Society of Sports Nutrition*, *12*(1), 3. https://doi.org/10.1186/s12970-014-0064-5

Barnard, N., Goldman, D., Loomis, J., Kahleova, H., Levin, S., Neabore, S., & Batts, T. (2019). Plant-Based Diets for Cardiovascular Safety and Performance in Endurance Sports. *Nutrients*, *11*(1), 130. https://doi.org/10.3390/nu11010130

Basiotis, P. P., Welsh, S. O., Cronin, F. J., Kelsay, J. L., & Mertz, W. (1987). Number of days of food intake records required to estimate individual and group nutrient intakes with defined confidence. *The Journal of Nutrition*, *117*(9), 1638–1641. https://doi.org/10.1093/jn/117.9.1638

Batlle-Bayer, L., Bala, A., García-Herrero, I., Lemaire, E., Song, G., Aldaco, R., & Fullana-i-Palmer, P. (2019). The Spanish Dietary Guidelines: A potential tool to reduce greenhouse gas emissions of current dietary patterns. *Journal of Cleaner Production*, *213*, 588–598. https://doi.org/10.1016/j.jclepro.2018.12.215

Batlle-Bayer, L., Bala, A., Lemaire, E., Albertí, J., García-Herrero, I., Aldaco, R., & Fullana-i-Palmer, P. (2019). An energy- and nutrient-corrected functional unit to compare LCAs of diets. *Science of the Total Environment*, *671*, 175–179. https://doi.org/10.1016/j.scitotenv.2019.03.332

Berardy, A., Johnston, C. S., Plukis, A., Vizcaino, M., & Wharton, C. (2019). Integrating protein quality and quantity with environmental impacts in life cycle assessment. *Sustainability*, *11*, 2747. https://doi.org/10.3390/su11102747

Berryman, C. E., Lieberman, H. R., Fulgoni, V. L., & Pasiakos, S. M. (2018). Protein Intake Trends and Conformity With the Dietary Reference Intakes in the United States: Analysis of the National Health and Nutrition Examination Survey, 2001-2014. *The American Journal of Clinical Nutrition*, *108*(2). https://doi.org/10.1093/AJCN/NQY088

Bösch, M. E., Hellweg, S., Huijbregts, M. A. J., & Frischknecht, R. (2007). Applying cumulative exergy demand (CExD) indicators to the ecoinvent database. *The International Journal of Life Cycle Assessment*, *12*(3), 181–190. https://doi.org/10.1065/lca2006.11.282

Bouvard, V., Loomis, D., Guyton, K. Z., Grosse, Y., Ghissassi, F. El, Benbrahim-Tallaa, L., … Bandaletova, T. (2015). Carcinogenicity of consumption of red and processed meat. *The Lancet Oncology*, *16*(16), 1599–1600. https://doi.org/10.1016/S1470-2045(15)00444-1

Burd, N. A., Gorissen, S. H., van Vliet, S., Snijders, T., & van Loon, L. J. (2015). Differences in postprandial protein handling after beef compared with milk ingestion during postexercise recovery: a randomized controlled trial. *American Journal of Clinical Nutrition*, *102*(4), 828–836. https://doi.org/10.3945/ajcn.114.103184

Burd, Nicholas A, Beals, J. W., Martinez, I. G., Salvador, A. F., & Skinner, S. K. (2019). Food-First Approach to Enhance the Regulation of Post-exercise Skeletal Muscle Protein Synthesis and Remodeling. *Sports Medicine (Auckland, N.Z.)*, *49*(Suppl 1), 59–68. https://doi.org/10.1007/s40279-018-1009-y

Burke, L. M., Hawley, J. A., Wong, S. H. S., & Jeukendrup, A. E. (2011). Carbohydrates for training and competition. *Journal of Sports Sciences*, *29 Suppl 1*, S17-27. https://doi.org/10.1080/02640414.2011.585473

Burke, L. M., Slater, G., Broad, E. M., Haukka, J., Modulon, S., & Hopkins, W. G. (2003). Eating patterns and meal frequency of elite Australian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*(4), 521–538. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14967874

Cabrera-Ramírez, A. H., Luzardo-Ocampo, I., Ramírez-Jiménez, A. K., Morales-Sánchez, E., Campos-Vega, R., & Gaytán-Martínez, M. (2020). Effect of the nixtamalization process on the protein bioaccessibility of white and red sorghum flours during in vitro gastrointestinal digestion. *Food Research International (Ottawa, Ont.)*, *134*, 109234. https://doi.org/10.1016/j.foodres.2020.109234

Canning, P., Charles, A., Huang, S., Polenske, K. R., & Waters, A. (2010). Energy Use in the U.S. Food System. *Energy*, (94).

Castañé, S., & Antón, A. (2018). Assessment of the nutritional quality and environmental impact of two food diets: A Mediterranean and a vegan diet. *Journal of Cleaner Production*, *167*, 929–937. https://doi.org/10.1016/j.jclepro.2017.04.121

Castellani, V., Sala, S., & Benini, L. (2017). Hotspots analysis and critical interpretation of food life cycle assessment studies for selecting eco-innovation options and for policy support. *Journal of Cleaner Production*, *140*, 556–568. https://doi.org/10.1016/j.jclepro.2016.05.078

Churchward-Venne, T. A., Pinckaers, P. J. M., van Loon, J. J. A., & van Loon, L. J. C. (2017). Consideration of insects as a source of dietary protein for human consumption. *Nutrition Reviews*, *75*(12), 1035–1045. https://doi.org/10.1093/nutrit/nux057

Ciuris, C., Lynch, H. M., Wharton, C., & Johnston, C. S. (2019). A Comparison of Dietary Protein Digestibility, Based on DIAAS Scoring, in Vegetarian and Non-Vegetarian Athletes. *Nutrients*, *11*(12), 3016. https://doi.org/10.3390/nu11123016

Clark, A., & Mach, N. (2016). Exercise-induced stress behavior, gut-microbiota-brain axis and diet: A systematic review for athletes. *Journal of the International Society of Sports Nutrition*, *13*(1), 1–21. https://doi.org/10.1186/s12970-016-0155-6

Clifton, P. M., Condo, D., Keogh, J. B., Skov, A. R., Toubro, S., Rønn, B., … Noda, M. (2014). Long term weight maintenance after advice to consume low carbohydrate, higher protein diets--a systematic review and meta analysis. *Nutrition, Metabolism, and Cardiovascular Diseases : NMCD, 24*(3), 224–235. https://doi.org/10.1016/j.numecd.2013.11.006

Daly, R. M., Connell, S. L. O., Mundell, N. L., Grimes, C. A., Dunstan, D. W., & Nowson, C. A. (2014). Protein-enriched diet , with the use of lean red meat , combined with progressive resistance training enhances lean tissue mass and muscle strength and reduces circulating IL-6 concentrations in elderly women : a cluster randomized controlled trial 1 – 4. *The American Journal of Clinical Nutrition, 99,* 899–910. https://doi.org/10.3945/ajcn.113.064154.Sarcopenia

de Oliveira, E. P., Buruni, R. C., & Jeukendrup, A. E. (2014). Gastrointestinal Complaints During Exercise : Prevalence , Etiology , and Nutritional Recommendations. *Sports Medicine, 44*(Suppl 1), S79–S85. https://doi.org/10.1007/s40279-014-0153-2

Derbyshire, E. J. (2017). Flexitarian Diets and Health: A Review of the Evidence-Based Literature. *Frontiers in Nutrition*, *3*(January), 1–8. https://doi.org/10.3389/fnut.2016.00055

Doering, T. M., Reaburn, P. R., Phillips, S. M., & Jenkins, D. G. (2016). Post-Exercise Dietary Protein Strategies to Maximize Skeletal Muscle Repair and Remodeling in Masters Endurance: A Review. *International Journal of Sports Nutrition and Exercise Metabolism*, *26*(2), 168–178. https://doi.org/10.1123/ijsnem.2015-0102

Dooren, C. Van, & Aiking, H. (2014). Defining a nutritionally healthy , environmentally friendly , and culturally acceptable Low Lands Diet. In *Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food Sector (LCA Food 2014)*. San Francisco USA: ACLCA, Vashon, WA, USA.

Drewnowski, A., Rehm, C. D., Martin, A., Verger, E. O., Voinnesson, M., & Imbert, P. (2015). Energy and nutrient density of foods in relation to their carbon footprint. *American Journal of Clinical Nutrition*, *101*(1), 184–191. https://doi.org/10.3945/ajcn.114.092486

Elliot, T. A., Cree, M. G., Sanford, A. P., Wolfe, R. R., & Tipton, K. D. (2006). Milk ingestion stimulates net muscle protein synthesis following resistance exercise. *Medicine and Science in Sports and Exercise*, *38*(4), 667–674. https://doi.org/10.1249/01.mss.0000210190.64458.25

Erdman, K. A., Tunnicliffe, J., Lun, V. M., & Reimer, R. A. (2013). Eating patterns and composition of meals and snacks in elite Canadian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *23*(3), 210–219. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23114732

Eshel, G., Shepon, A., Makov, T., & Milo, R. (2014). Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States. *Proceedings of the National Academy of Sciences*, 1402183111-. https://doi.org/10.1073/pnas.1402183111

Fantke, P., & Jolliet, O. (2016). Life cycle human health impacts of 875 pesticides. *International Journal of Life Cycle Assessment*, *21*(5), 722–733. https://doi.org/10.1007/s11367-015-0910-y

FAO. (2010). *Sustainable diets and biodiversity*. Rome: Food and Agriculture Organisation of the United Nations (FAO). https://doi.org/10.1017/S002081830000607X

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A New Approach to Monitoring Exercise Training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115.

Fulgoni, V. L., Keast, D. R., & Drewnowski, A. (2009). Development and validation of the nutrient-rich foods index: a tool to measure nutritional quality of foods. *The Journal of Nutrition*, *139*(8), 1549–1554. https://doi.org/10.3945/jn.108.101360

Gaillard, G., & Nemecek, T. (2009). Swiss agricultural life cycle assessment (SALCA): an integrated environmental assessment concept for agriclture. In *Int. Conf. "Integrated Environmental Assessment of Agriculture and Sustainable Development, Setting the Agenda for Science and Policy."* (pp. 134–135). Egmon aan Zee, The Netherland. AgSap Office, Wagebingen University.

Garnett, T. (2016). Plating up solutions. *Science*, *353*(6305), 1202–1204.

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., … Tempio, G. (2013). *Tackling Climate Change Through Livestock-A global assessment of emissions and mitigation opportunities*. *FAO, Rome*. Rome.

Gillen, J. B., Trommelen, J., Wardenaar, F. C., Brinkmans, N. Y. ., Versteegen, J. J., Jonvik, K. L., … van Loon, L. J. C. (2017). Dietary protein intake and distribution patterns of well-trained Dutch athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*(2), 105–114. https://doi.org/10.1123/ijsnem.2016-0154

Guarnieri, M., & Balmes, J. R. (2014). Outdoor Air Pollution and Asthma. *Lancet (London, England)*, *383*(9928). https://doi.org/10.1016/S0140-6736(14)60617-6

Guinée, J., Gorrée, M., Heijungs, R., Huppes, G., Klejin, R., de Koning, A., … Weidema, B. (2001). *Life cycle assessment - An operational guide to the ISO standards.* Den Haag and Leiden, Netherlands.

Halton, T. L., & Hu, F. B. (2004). The Effects of High Protein Diets on Thermogenesis, Satiety and Weight Loss: A Critical Review. *Journal of the American College of Nutrition*, *23*(5), 373–385. https://doi.org/10.1080/07315724.2004.10719381

Hauschild, M., & Pooting, J. (2005). *Spatial differentiation in life cycle impact assessment - the EDIP 2003 methodology.* Copenhagen.

Hayer, F., Bockstaller, C., Gaillard, G., Mamy, L., Nemecek, T., & Strassemeyer, J. (2010). Multi-criteria comparison of eco-toxicity models focused on pesticides. *7th Int. Conf. on LCA in the Agri-Food Sector, Noranicola, B. (Eds). Bari, Italy*, 305–310.

Hector, A., & Phillips, S. M. (2017). Protein Recommendations for Weight Loss in Elite Athletes: A Focus on Body Composition and Performance. *International Journal of Sport Nutrition and Exercise Metabolism*, *32*, 1–26. https://doi.org/10.1123/ijsnem.2017-0273

Hyland, J. J., Henchion, M., McCarthy, M., & McCarthy, S. N. (2017). The climatic impact of food consumption in a representative sample of Irish adults and implications for food and nutrition policy. *Public Health Nutrition*, *20*(4), 726–738. https://doi.org/10.1017/S1368980016002573

IPCC. (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* (T. F. Stocker, Ed.). Cambridge, United Kingdom and New York.1535: Cambridge University Press.

ISO 14040:2006. Environmental management - Life Cycle Assessment - Principles and Framework. (2006).

Jäger, R., Zaragoza, J., Purpura, M., Iametti, S., Marengo, M., Tinsley, G. M., … Taylor, L. (2020). Probiotic Administration Increases Amino Acid Absorption from Plant Protein: a Placebo-Controlled, Randomized, Double-Blind, Multicenter, Crossover Study. *Probiotics and Antimicrobial Proteins*. https://doi.org/10.1007/s12602-020-09656-5

Jeukendrup, A. E. (2017). Training the Gut for Athletes. *Sports Medicine*, *47*(s1), 101–110. https://doi.org/10.1007/s40279-017-0690-6

Jovanov, P., Đorđić, V., Obradović, B., Barak, O., Pezo, L., Marić, A., & Sakač, M. (2019). Prevalence, knowledge and attitudes towards using sports supplements among young athletes. *Journal of the International Society of Sports Nutrition*, *16*(1), 27. https://doi.org/10.1186/s12970-019-0294-7

Kårlund, A., Gómez-Gallego, C., Turpeinen, A. M., Palo-Oja, O. M., El-Nezami, H., & Kolehmainen, M. (2019). Protein supplements and their relation with nutrition, microbiota composition and health: Is more protein always better for sportspeople? *Nutrients*, *11*(4), 1–19. https://doi.org/10.3390/nu11040829

Lunn, W. R., Pasikos, S. M., Colletto, M. R., Karfonta, K. E., Carbone, J. W., Anderson, J. M., & Rodriguez, N. R. (2012). Chocolate Milk and Endurance Exercise Recovery. *Medicine & Science in Sports & Exercise*, 44(4), 682–691. https://doi.org/10.1249/MSS.0b013e3182364162

Lynch, H., Johnston, C., & Wharton, C. (2018). Plant-based diets: Considerations for environmental impact, protein quality, and exercise performance. *Nutrients*, *10*(12). https://doi.org/10.3390/nu10121841

Madden, R., Shearer, J., & Parnell, J. (2017). Evaluation of Dietary Intakes and Supplement Use in Paralympic Athletes. *Nutrients*, *9*(11), 1266. https://doi.org/10.3390/nu9111266

Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health*, *8*, 8–14. https://doi.org/10.3389/FPUBH.2020.00014

Manore, M. M., Patton-Lopez, M. M., Meng, Y., & Sung Wong, S. (2017). Sport Nutrition Knowledge, Behaviors and Beliefs of High School Soccer Players. *Nutrients*, *9*(350), 1–14. https://doi.org/10.3390/nu9040350

Masset, G., Soler, L. G., Vieux, F., & Darmon, N. (2014). Identifying sustainable foods: The relationship between environmental impact, nutritional quality, and prices of foods representative of the french diet. *Journal of the Academy of Nutrition and Dietetics*, *114*(6), 862–869. https://doi.org/10.1016/j.jand.2014.02.002

Masset, G., Vieux, F., & Darmon, N. (2015). Which functional unit to identify sustainable foods? *Public Health Nutrition*, *18*(13), 2488–2497. https://doi.org/10.1017/S1368980015000579

Masset, G., Vieux, F., Verger, E. O., Soler, L. G., Touazi, D., & Darmon, N. (2014). Reducing energy intake and energy density for a sustainable diet: A study based on self-selected diets in French adults. *American Journal of Clinical Nutrition*, *99*(6), 1460–1469. https://doi.org/10.3945/ajcn.113.077958

Meyer, N. L., Reguant-Closa, A., & Nemecek, T. (2020). Sustainable Diets for Athletes. *Current Nutrition Reports*, 1–16. https://doi.org/10.1007/s13668-020-00318-0

Meyer, N., & Reguant-closa, A. (2017). " Eat as If You Could Save the Planet and Win !" Sustainability Integration into Nutrition for Exercise. *Nutrients*, 9(412). https://doi.org/10.3390/nu9040412

Moore, D. R., Churchward-Venne, T. A., Witard, O., Breen, L., Burd, N. A., Tipton, K. D., & Phillips, S. M. (2015). Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *70*(1), 57–62. https://doi.org/10.1093/gerona/glu103

Murakami, K., & Livingstone, M. B. E. (2018). Greenhouse gas emissions of self-selected diets in the UK and their association with diet quality: is energy under-reporting a problem? *Nutrition Journal*, *17*(1), 27. https://doi.org/10.1186/s12937-018-0338-x

Nemecek, T., Dubois, D., Huguenin-Elie, O., & Gaillard, G. (2011). Life cycle assessment of Swiss farming systems: I. Integrated and organic farming. *Agricultural Systems*, *104*(3), 217–232. https://doi.org/10.1016/j.agsy.2010.10.002

Nemecek, T., Huguenin-Elie, O., Dubois, D., Gaillard, G., Schaller, B., & Chervet, A. (2011). Life cycle assessment of Swiss farming systems: II. Extensive and intensive production. *Agricultural Systems*, *104*(3), 233–245. https://doi.org/10.1016/j.agsy.2010.07.007

Nemecek, T., Jungbluth, N., Canals, L. M., & Schenck, R. (2016). Environmental impacts of food consumption and nutrition: where are we and what is next? *The International Journal of Life Cycle Assessment*, 607–620. https://doi.org/10.1007/s11367-016-1071-3

Notarnicola, B., Sala, S., Anton, A. O., Mclaren, S. J., Saouter, E., & Sonesson, U. (2016). The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.06.071

Nowson, C., & O'Connell, S. (2015). Protein Requirements and Recommendations for Older People: A Review. *Nutrients*, *7*(8), 6874–6899. https://doi.org/10.3390/nu7085311

Paddon-Jones, D., Campbell, W. W., Jacques, P. F., Kritchevsky, S. B., Moore, L. L., Rodriguez, N. R., & van Loon, L. J. (2015). Protein and healthy aging. *American Journal of Clinical Nutrition*, *101*(6), 1339S-1345S. https://doi.org/10.3945/ajcn.114.084061

Phillips, S. M. (2014). A Brief Review of Higher Dietary Protein Diets in Weight Loss: A Focus on Athletes. *Sports Medicine*, *44*, 149–153. https://doi.org/10.1007/s40279-014-0254-y

Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. *Journal of Sports Sciences*, *29*(sup1), S29–S38. https://doi.org/10.1080/02640414.2011.619204

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Reguant-Closa, A., Harris, M. M., Lohman, T. G., & Meyer, N. L. (2019). Validation of the Athlete's Plate Nutrition Educational Tool: Phase I. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(6), 628–635. https://doi.org/10.1123/ijsnem.2018-0346

Ridoutt, B. G., Hendrie, G. A., & Noakes, M. (2017). Dietary strategies to reduce environmental impact: A critical review of the evidence. *Advances in Nutrition*, *8*(6), 933–946. https://doi.org/10.3945/an.117.016691

Ripple, W. J., Smith, P., Haberl, H., Montzka, S. A., McAlpine, C., & Boucher, D. H. (2014). Ruminants, climate change and climate policy. *Nature Climate Change*, 4(1), 2–5. https://doi.org/10.1038/nclimate2081

Rowlands, D. S., Nelson, A. R., Phillips, S. M., Faulkner, J. A., Clarke, J., Burd, N. A., ... Stellingwerff, T. (2014). *Protein-leucine fed dose effects on muscle protein synthesis after endurance exercise*. *Medicine and Science in Sports and Exercise* (Vol. 47). https://doi.org/10.1249/MSS.0000000000000447

Saarinen, M., Fogelholm, M., Tahvonen, R., & Kurppa, S. (2017). Taking nutrition into account within the life cycle assessment of food products. *Journal of Cleaner Production*, *149*, 828–844. https://doi.org/10.1016/j.jclepro.2017.02.062

Sabaté, J., Sranacharoenpong, K., Harwatt, H., Wien, M., & Soret, S. (2014). The environmental cost of protein food choices. *Public Health Nutrition*, *18*(11), 1–7. https://doi.org/10.1017/S1368980014002377

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Climatic Change*, *125*(2), 179–192. https://doi.org/10.1007/s10584-014-1169-1

Sonesson, U., Davis, J., Flysjö, A., Gustavsson, J., & Witthöft, C. (2017). Protein quality as functional unit – A methodological framework for inclusion in life cycle assessment of food. *Journal of Cleaner Production*, *140*, 470–478. https://doi.org/10.1016/j.jclepro.2016.06.115

Sonesson, U., Davis, J., Hallström, E., & Woodhouse, A. (2019). Dietary-dependent nutrient quality indexes as a complementary functional unit in LCA: A feasible option? *Journal of Cleaner Production*, *211*, 620–627. https://doi.org/10.1016/j.jclepro.2018.11.171

Soret, Sam, & Sabate, J. (2014). Sustainability of plant-based diets : back to the future 1 – 3, 100, 476–482. https://doi.org/10.3945/ajcn.113.071522.1

Soret, Samuel, Mejia, A., Batech, M., Jaceldo-Siegl, K., Harwatt, H., & Sabaté, J. (2014). Climate change mitigation and health effects of varied dietary patterns in real-life settings throughout North America. *American Journal of Clinical Nutrition*, *100*(SUPPL. 1), 490–495. https://doi.org/10.3945/ajcn.113.071589

Spendlove, J., Mitchell, L., Gifford, J., Hackett, D., Slater, G., Cobley, S., & O'Connor, H. (2015). Dietary Intake of Competitive Bodybuilders. *Sports Medicine (Auckland, N.Z.)*, *45*(7), 1041–1063. https://doi.org/10.1007/s40279-015-0329-4

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., ... Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Swinburn, B. A., Kraak, V. I., Allender, S., Atkins, V. J., Baker, P. I., Bogard, J. R., ... Dietz, W. H. (2019). The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission report. *The Lancet*, *393*(10173), 791–846. https://doi.org/10.1016/S0140-6736(18)32822-8

Swinburn, B. A., Sacks, G., Hall, K. D., McPherson, K., Finegood, D. T., Moodie, M. L., & Gortmaker, S. L. (2011). The global obesity pandemic: Shaped by global drivers and local environments. *The Lancet*, *378*(9793), 804–814. https://doi.org/10.1016/S0140-6736(11)60813-1

Te Morenga, L., & Mann, J. (2012). The role of high-protein diets in body weight management and health. *British Journal of Nutrition*, *108*(S2), S130–S138. https://doi.org/10.1017/S0007114512002437

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Medicine and Science in Sports and Exercise*, *48*(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature*, *515*(7528), 518–522. https://doi.org/http://www.nature.com/nature/journal/v515/n7528/full/nature13959.html

Tuomisto, H. L., Hodge, I. D., Riordan, P., & Macdonald, D. W. (2012). Does organic farming reduce environmental impacts? – A meta-analysis of European research. *Journal of Environmental Management*, *112*, 309–320. https://doi.org/10.1016/j.jenvman.2012.08.018

U.S. Energy Information Administration. (2018). U.S. energy facts explained - consumption and production - U.S. Energy Information Administration (EIA). Retrieved October 26, 2019, from https://www.eia.gov/energyexplained/us-energy-facts/

van Huis, A., Itterbeeck, J. Van, Klunder, H., Mertens, E., Halloran, A., Muir, G., & Vantomme, P. (2013). *Edible insects. Future prospects for food and feed security*. *Food and Agriculture Organization of the United Nations* (Vol. 171). https://doi.org/10.1017/CBO9781107415324.004

Van Kernebeek, H. R. J., Oosting, S. J., Feskens, E. J. M., Gerber, P. J., & De Boer, I. J. M. (2014). The effect of nutritional quality on comparing environmental impacts of human diets. *Journal of Cleaner Production*, *73*, 88–99. https://doi.org/10.1016/j.jclepro.2013.11.028

van Vliet, S., Beals, J. W., Martinez, I. G., Skinner, S. K., & Burd, N. A. (2018). Achieving optimal post-exercise muscle protein remodeling in physically active adults through whole food consumption. *Nutrients*, *10*(2). https://doi.org/10.3390/nu10020224

van Vliet, S., Burd, N. A., & van Loon, L. J. (2015). The Skeletal Muscle Anabolic Response to Plant- versus Animal-Based Protein Consumption. *The Journal of Nutrition*, (C), jn.114.204305-. https://doi.org/10.3945/jn.114.204305

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate Change and Food Systems. *Annual Review of Environment and Resources*, *37*(1), 195–222. https://doi.org/10.1146/annurev-environ-020411-130608

Vieux, F., Soler, L.-G., Touazi, D., & Darmon, N. (2013). High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. *The American Journal of Clinical Nutrition*, (9), ajcn.035105. https://doi.org/10.3945/ajcn.112.035105

Viner, R. T., Harris, M., Berning, J. R., & Meyer, N. L. (2015). Energy Availability and Dietary Patterns of Adult Male and Female Competitive Cyclists with Lower than Expected Bone Mineral Density. *International Journal of Sport Nutrition and Exercise Metabolism*, *25*(6), 594–602. https://doi.org/10.1123/ijsnem.2015-0073

Weber, C. L., & Scott, H. (2008). Food-Miles and the Relative Climate Impacts of Food Choices in the\nUnited States. *Environmental Science & Technology*, *42*(10), 3508–3513. https://doi.org/10.1021/es702969f

Westhoek, H., Lesschen, J. P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., … Oenema, O. (2014). Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Global Environmental Change*, *26*, 196–205. https://doi.org/10.1016/j.gloenvcha.2014.02.004

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., … Murray, C. J. L. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. *The Lancet*, *393*(10170), 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4

Xu, Z., & Knight, R. (2015). Dietary effects on human gut microbiome diversity. *British Journal of Nutrition*, *113*(S1), S1–S5. https://doi.org/10.1017/S0007114514004127

CHAPTER

4

DISCUSSION

“The world has enough for everyone’s need, but not enough for everyone’s greed”

Mahatma Gandhi

4.1 Overall discussion

This dissertation examined the relationship between three main constructs: environmental sustainability, sport nutrition and nutrition education. Collectively, the results suggest that there is a need for a better inclusion of these topics into the field of sport nutrition. The overall goal of this dissertation was to develop sustainability principles applicable to athletes that may be integrated into practical guidelines aligned with periodized sport nutrition concepts using the Athlete's Plate Education Tool.

While the Integration of environmental sustainability into nutrition has been of interest in recent years, it is still in development stages, and more needs to be done to include environmental sustainability into nutrition guidelines (FAO, 2016). In addition, the integration of sustainability into sport nutrition is less studied and fewer efforts have been made in this direction (Lynch, Johnston, & Wharton, 2018). This dissertation highlighted the lack but necessity of inclusion of environmental sustainability into sport nutrition while providing ideas on how to be addressed and implemented. Contribution I *"Eat as if you could save the planet and win! Sustainability integration into sport nutrition"* provides an overview and areas where this inclusion could take place. In the last section of the paper different areas on how integration could be made by athletes, sport dietitians, food service operations and sport organizations and institutions are highlighted. While contribution I includes several discussion points, ten main areas and ideas highlighted in the paper are summarized below as a practical take home message: **1)** Reduce quantity of meat and choose from better sources; **2)** Replace animal proteins with alterative plant protein sources such as combined vegetable protein sources or insects; **3)** Include protein flip menus (with less meat and dairy); **4)** Improve vegetarian menus, boost rather than compromise nutrients, while protein remains at moderate yet recommended levels for athletes; **5)** Increase the biodiversity on your plate for you and the planet (from plants, grains and fruits among others); **6)** Choose local and seasonal foods to promote nutrient density; **7)** Bring nutrition education out of the classroom and include food literacy in nutrition education (such as: team dinners, Olympic vegetable gardens and cooking classes); **8)** Integrate training sessions at farms so athletes get outside and learn where and how their food is grown; **9)** Be aware of food waste in your institution and find ways to reduce it; **10)** Make your sporting events more sustainable and promote initiatives such as the Green Sport Alliance, value-based food systems, and food literacy for everyone, including food service staff.

Whilst contribution I proposes different frameworks to bring environmental sustainability into the field of sport nutrition, contribution II highlights the importance to transfer sport nutrition guidelines in a practical manner to athletes and active individuals. Contribution II *"Validation of the Athlete's Plate Nutrition Educational Tool: Phase I"* shows how the Athlete's Plate is a valid tool to teach athletes about periodized nutrition for energy, carbohydrates, fat and fiber but not for protein, as it exceeded protein recommendations for moderate and hard plates. This is a common issue in sport nutrition—protein intake and recommendations in athletes are commonly higher than needed (Spendlove et al., 2015). This paper also provided data on the protein content of the plates, highlighting that 70% came from animal protein sources, while only 30% of total protein originated from plant-based proteins. Plates analyzed in this study were created by registered sport dietitians (experts) as performed by other validation studies in sports (Mettler, Mannhart, & Colombani, 2009). One of the possible reasons for this higher than recommended animal protein distribution could be because current sport nutrition recommendations emphasize the importance of quantity and quality of protein to optimize muscle adaptation to training and to enhance recovery. Research has focused mainly on animal protein and, especially from dairy products, and this is may be why these sources were chosen by the experts (Burd, Gorissen, van Vliet, Snijders, & van Loon, 2015; Kanda et al., 2016; Lunn et al., 2012; Phillips, Tang, & Moore, 2009). Moreover, there is very little research on plant-based protein sources and their effect on muscle protein synthesis and recovery (Babault et al., 2015; Phillips et al., 2009). As found by others (Gillen et al., 2017), the results of this study also established different distribution of proteins depending on meal type. Lower protein content was found at breakfast compared with lunch and dinner. As timing is also important when ensuring muscle adaptation to training, a better distribution of protein should be recommended that focuses on training and meal timing (Areta et al., 2013; Moore, Camera, Areta, & Hawley, 2014). Nevertheless, the sum of all meals analyzed in this study shows an overall high daily protein content of the diet of athletes. Considering that this study did not evaluate the snacks athletes eat through the day, which can account up to 23% of daily intake (Burke et al., 2003; Parnell, Wiens, & Erdman, 2016), it is expected that these results likely underreport total daily protein content on the plates. It is well known that animal protein sources have a higher EnvI than plant-based sources (Sabaté, Sranacharoenpong, Harwatt, Wien, & Soret, 2014). Due to the high protein content on the plates found by contribution II, it was hypothesized that the plates created in this study would have a high environmental impact due to animal protein. This hypothesis was confirmed by contribution IV. Contribution II is a good example why there is a need to integrate environmental sustainability into sport nutrition. In an attempt to promote muscle growth and recovery through higher amounts of protein, there is also an expected side effect from the extra protein that would result in a significant increase the environmental impact of the plates. Aiking (2014) proposed an approach to decrease the environmental impact of the diet, primarily through meat reduction, as follows: 1) eating one-third less protein (when over-consuming, such as in the found in the Athlete's Plate validation results); 2) replacing one-third with plant-derived protein; 3) ensuring the remaining animal protein is sourced from a high quality animal protein and coming from less red meat. As a conclusion and to integrate the findings of contribution II discussed in a practical manner five recommendations are proposed: **1)** Reduce animal protein on the plates (especially beef and dairy); **2)** Include more plant-based protein sources on the plates; **3)** Balance high protein foods from plants and animal sources on the same plate (e.g., avoid quinoa + lentils + beef + milk shake); **4)** Re-design the plate using the protein flip concept, moving meat to the periphery or making it a topping and not the centerpiece of the plate; **5)** More protein is not better. Distribute protein intake equally throughout the day according to sport nutrition guidelines.

Contribution III complements Contribution I and II bringing the importance of educating athletes on how to use the Athlete's Plate as well as how to create their own plates, as a nutritional education tool is only useful if the target population understands and knows how to use it. Contribution III found that the formal standardized power point presentation provides the athletes sufficient knowledge about the plates' sport nutrition principles. Using a survey (TAPES), athletes scored high out of a total of 15 points 13.4±1.5 (89.2±9.8%). While it is important to acquire sufficient knowledge, it is also important to be able to put it into practice. It is very difficult to change and modify behaviors of people, but more studies have highlighted the importance of experiential learning on improving nutrition knowledge, self-efficacy and, as a consequence, behavior change (Brown & Tenison, 2018; Diker et al., 2013; Heim, Stang, & Ireland, 2009; Skouteris et al., 2013). Food literacy is a term used to define everyday practicalities associated with healthy eating beyond just the food per se. Vidgen & Gallegos (2014) defined food literacy as "the scaffolding that empowers individuals, households, communities or nations to protect diet quality through change and strengthen dietary resilience over time. It is composed of a collection of inter-related knowledge, skills and behaviors required to plan, manage, select, prepare and eat food to meet needs and determine intake" (Vidgen & Gallegos, 2014). Contribution III included an experiential phase of the intervention with athletes making their own plates to apply the knowledge acquired during presentation on the Athlete's Plate. An observational analysis to extract valuable information on athletes' behavior when creating and eating their plates was used. Mix-model research was used, as combining qualitative and quantitative research is considered a valid method to evaluate interventions in practical settings (Creswell & Plano Clark, 2011; Glesne, 2011). The observational analysis of athletes' behaviors identified three themes that, with only the classroom session and survey completion, could have not occurred. The themes will help improve nutrition interventions with athletes when using the Athlete's Plate model. Theme one "personalize your plate" highlights the necessity to adapt nutrition education to the target population. Theme two "navigate the dining hall on the road to success" focuses on the need to familiarize athletes with dining hall settings, food offerings, labels and culturally diverse foods (even when traveling) to provide athletes with all the tools to make appropriate food selections according to training load and food preference. Theme three, "eat more when it matters" underlines the concept of nutrition/training periodization of the Athlete's Plate model and focuses on when to eat more and what to eat more of depending on training load. These three topics, identified through the observational analysis, emphasized how experiential interventions and nutrition education beyond simple sport nutrition and fueling matters. Smell and taste of food, cultural differences and the social environment, among others, also need to be considered when delivering nutrition education programs with athletes and active individuals. Contribution III showed how the Athlete's Plate Education Program could be the perfect platform to integrate not only performance nutrition, but also the value of food linked with sustainable principles. In this sense, including environmental sustainability in the nutrition education of athletes, and specifically for the Athlete's Plate model is of importance, as it considers the necessity of feeding athletes but also teaches them to be mindful about it. Garnett, (2016) addresses the necessity to identify diets that can be sustainable and, at the same time, also benefit health for all rather than just being the diets for the "healthy and the wealthy" (Garnett, 2016). For this reason, integrating sustainability principles that include social justice and ethical eating concepts are no longer a choice. In fact, sustainability integration into sport nutrition is an ethical obligation in the 21st century.

For this reason, Contribution IV is an important addition to the topic and results of this dissertation as it brings the environmental sustainability aspect of diets into the sport nutrition field. To our knowledge this contribution is the first one, to measure the environmental impact of real diets in an athletic setting. Life Cycle Assessment is a suitable and standardized methodology to calculate the EnvI of diets (*ISO 14040:2006*). The results show how the EnvI of the plates varies by expressing them using different functional units, as was previously shown by others (Saarinen, Fogelholm, Tahvonen, & Kurppa, 2017; Stylianou et al., 2016). When the total quantity of food is considered, the environmental impact of the plates increases proportionally with training load due to the greater amount of food consumed. However, when adjusted per kg or per kcal this direct relationship disappears. As shown by others, animal protein and, especially red meat, is the main contributor to the environmental impact of the plates, especially for GWP and exergy (Gerber et al., 2013; Sabaté et al., 2014). However, when considering ecotoxicity, vegetables are the main contributor. When comparing the total amount of food on the plates with others, the results of this study show a higher GWP compared to others (Murakami & Livingstone, 2018; Scarborough et al., 2014; Vieux, Soler, Touazi, & Darmon, 2013). This difference could be because athletes require high energy intakes to match their energy expenditure depending on training load (Thomas, Erdman, & Burke, 2016). However, the protein content for moderate and hard training days above the recommendation found in contribution II and mainly coming from animal proteins could also be the cause of this higher total environmental impact. It is important to note the limitations of LCA (Notarnicola et al., 2016) and difficulty to develop inventories for for all the food analyzed in this study. As a consequence, different assumptions were used as proxies, as recommended by others (Canals et al., 2011). While this study tried to assimilate the most plausible and real case setting, these limitations have to be considered when evaluating the results of this study. The results of this study also analyzed main effects and interactions among RD, training load, meal and sex using different factorial analyses. When evaluating the effects of the different variables, interactions are important as they represent the combined effects of factors in the dependent measure. There was also a significant main effect for meal on all impact categories with lower impact for breakfast compared to lunch and dinner. This result is related to the results found in contribution II where breakfast had a lower total protein content than lunch and dinner. Moreover, the analysis shows that there is a significant interaction between RD and meal. This interaction indicates that RDs differ in the environmental impact of the Athlete's Plate when creating plates by meal type (B, L, D). Some of the RDs where very consistent creating plates with lower environmental impact, while some had higher coefficients of variation. This highlights the importance of training RDs on food and environment and how to make and recommend environmentally friendly meals, as well as nutritionally adequate meals. Integrating environmental sustainability into the Athlete's Plate will help lower the environmental impact of the Athlete's Plate and develop more consistency among professionals and athletes when making their plates. Moreover, RDs were consistent making nutritionally adequate plates for athletes in contribution II when familiar with the Athlete's Plate model and related sport nutrition recommendations. As a consequence, it should be expected that RDs will be able to create plates with a lower environmental impacts if proper instructions and knowledge were provided to them. Ideally environmental sustainability should already be integrated into nutrition education of RDs in all areas of expertise (clinical, sports, community care, etc.). Unfortunately, the integration of sustainability remains small in health professionals, nutrition professionals (Webber & Sarjahani, 2011), and also sport RDs (Lynch et al., 2018). For this reason, it is recommended that environmental sustainability, but also other aspects of sustainability, that were not considered in dissertation (e.g., social equity), should be integrated in all areas of sport nutrition in the future. Contribution IV proposes figure 3.14 to show environmental hotspots and possible solutions. In the same line Contribution IV includes eight recommendations for athletes and active individuals: (1) adjust energy, carbohydrate, and fat intake to the recommendations according to training loads, (2) reduce protein intake to the recommended level, (3) replace some animal protein with plant protein, (4) within the animal protein fraction, prioritize milk, eggs, poultry and pork over ruminant meat and cheese, (5) use fresh, seasonal, regional, and unprocessed foods and (6) limit frozen and canned products and reconsider protein powders that result in protein surplus, (7) obtain education in environmental issues of food choices when creating plates and (8) consider individual and cultural preferences.

It is important to note that the data collection for part of this research was carried out in the CSOPTC an elite training center for Olympic and Paralympic sports. Conducting research in such a facility is not easy and the researcher should aim for the smallest interference with training and competition. While this research can be seen as very specific, data collection for contribution II and IV was done in the kitchen and dining hall of this facility. However, sport nutrition recommendations are very homogeneous worldwide and commonly, similar foods are used for athletes in periods of training and competition (such as pasta, rice, lean meats, eggs or dairy), and thus, the results herein may be generalized (with its cultural differences and adaptations) to other athletes and active individuals training and competing in other countries. In addition, the AP is known and used internationally, with some countries having developed their own cultural modification following the Athlete's Plate model (e.g., Mexico and Costa Rica). This underlines the generalizability of these results.

While others have included sustainability when developing nutritional guidelines (FAO, 2016), they have not included sustainability into the sport nutrition field. This research proposes a new case of inclusion of sustainability into sport nutrition. Diffusion of Innovation theory is how a new idea is dispersed and adopted by society (Dearing & Cox, 2018). This theory has four constructs 1) the innovation 2) the Channels 3) the time 4) the social system. The innovation of this research is the quantification of the environmental impact of a nutritional educational tool for athletes using data of real diets and aiming to give recommendations on how to reduce environmental impact, without compromising nutritional quality. The Athlete's Plate is recognized and used internationally, with easy access to transfer the updated modifications to the target population. Moreover, athletes are, in many occasions, an inspirational icon for society. Including sustainability guidelines in this specific tool could have a higher diffusion in other sections of the population. Furthermore, there is already a social system, internationally, using these plates and adapting the model initially developed at UCCS to a country's specific food culture (i.e., Mexico). Thus, the Athlete's Plate tool can have an additional diffusion to other cultures. For this reason, including sustainability guidelines into this tool will have a bigger impact, as it will be transferred to athletes and their practitioners of various countries around the world who already know about the AP. As sustainability in diets might vary upon country, developing specific regional food culture recommendations might be a suitable supplement when implementing sustainability into this nutrition education tool. In addition, the result of this study might encourage others to also measure the environmental impact of their national nutritional guidelines and expand this work beyond athletes and active individuals.

4.2 limitations

One of the limitations of this study, and specifically from contribution II and IV, is the inability to account for snacks ingested throughout the day. The purpose of this study was to validate the Athlete's Plate against daily sport nutrition recommendations but without the inclusion of snacks. The snack portion of an athlete varies depending on the training session, the goal of the session, travel constrains, and recovery strategies, to name a few. Several studies have shown that snacking in athletes makes up between 23-25% of daily EI (Burke et al., 2003; Erdman, Tunnicliffe, Lun, & Reimer, 2013). Thus, 23% of EI was added to the three meals by training load and sex with the same macronutrient distribution to maintain variability. Considering that contribution II found higher protein content on the plates than recommended for moderate and hard training loads and contribution IV found higher environmental impact values of the plates than other studies that were based on general population, this study most likely underestimates the protein content and the environmental impact of the Athlete's Plate. If snacks had been considered, higher values could have been expected.

Another limitation of this study is that the data analyzed regarding the composition of the AP was based on the AP made in the dining hall of the CSOPTC. While this presents a major limitation of the study, dining halls, catering kitchens, and food service facilities (such as in schools, hospitals, or training centers) have many similarities. Also, sport nutrition recommendations are similar around the world with staple foods recommended worldwide for athletes (e.g., pasta, rice, chicken or yogurt among others), while different serving dishes might be used (e.g. bowls) and cultural adaptations might need to happen. Moreover, for LCA, data collected in the US was considered but inventories were developed according to Switzerland. While this is a big limitation of the environmental study it was done due to access and consistent data of detailed inventories for a Swiss case. However, it could be speculated that some impacts on the results of this study would have been higher or lower had US LCI data been used. First, the list of ingredients considered for this study was very broad and different assumptions were made (table 3.13A and 3.14A). For the analysis we needed a large number of inventories, covering a wide range of different food products and sufficiently detailed, specific and consistent to represent the environmental impact in the best possible way. Such a comprehensive dataset was not available for the US case, corresponding to our list of ingredients, so we decided to adapt the study to Switzerland because Swiss data, which fulfilled these criteria, were available and could be used instead US data.

The main limitation of Contribution III is the small sample size and minimal variety in the type of athletes who participated. This is due to the difficulty of athlete recruitment to participate in research at an elite athlete training center. Moreover, this study evaluated athletes' knowledge after an in-class presentation, followed by behavior observations to study athletes' understanding of using the plates in a real-life setting. However, these plates were subsequently not analyzed for energy or nutritional content to ensure they truly met the respective recommendation according to training load.

This study did not quantify different farming systems such as, organic vs conventional farming systems. As underlined in contribution IV this could change the results of vegetable contribution in the total ecotoxicity of the plates but also other environmental impact categories such as eutrophication.

These limitations occurred because of the difficulty of doing research and LCA in real case scenarios, where all data might not be so detailed and/or available. Moreover, doing research in elite Olimpic and Paralympic training centers and with elite athletes is not always easy, as lower interference in their training and competition is demanded from the team. For this reason, this study is important and significant as it allowed, despite its limitations, to carry out a study in one of the highest performance centers for training and competition worldwide.

4.3 Revising the Athlete's Plate: Sustainability Integration

The overall goal of this dissertation was to develop sustainability principles applicable to athletes that may be integrated into practical guidelines aligned with periodized sport nutrition concepts using the Athlete's Plate Education Tool.

For this reason, as a way to summarize all the results of this dissertation in a practical way, the different findings highlighted by the results of each of the contributions of this dissertation are summarized and included into the Proposed Sustainable Athlete's Plate (figure 4.1 & figure 4.2). However, this dissertation didn't analyze the social and economical aspects of sustainability but its integration should also be considered. For this reason, two ideas of sustainable AP are proposed as a starting point and will be developed in the future. Figure 4.1 includes two main themes that arised during this PhD research: 1) your food and 2) your plate. Theme one, "your food" includes recommendations on sourcing and preparing the food for institutions, food services but also active individuals and athletes. Theme two "your plate" incorporates guidelines on how to create a plate following the Athlete's Plate model but considering both, sports nutrition requirements and environmental sustainability. Both themes have been incorporated as arrows around the plate, as they are concepts that surround the whole plate and create an "atmosphere" of integration. However, because sustainable diets cannot be reduced to such a simplistic definition, some other concepts surrounding sustainability have also been integrated in a second figure which consider a wider perspective of sustainability that should always be integrated (figure 4.2). While figure 4.1 might be more practical, figure 4.2 integrates sustainability as a whole. For this reason, this two figures should be integrated and combined to create a more sustainable AP. While this is a first proposition of some possible changes of the Athlete's Plate model to create the sustainable Athlete's Plate a deeper analysis of this plate and further expert validation will be done.

FIGURE 4.1

The Proposed Sustainable Athlete's Plate (1)

FIGURE 4.2

The Proposed Sustainable Athlete's Plate (2)

4.4 References

Aiking, H. (2014). Protein production: Planet, profit, plus people? *American Journal of Clinical Nutrition*, *100*(SUPPL. 1), 483–489. https://doi.org/10.3945/ajcn.113.071209

Areta, J. L., Burke, L. M., Ross, M. L., Camera, D. M., West, D. W. D., Broad, E. M., ... Coffey, V. G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *The Journal of Physiology*, *591*(9), 2319–2331. https://doi.org/10.1113/jphysiol.2012.244897

Babault, N., Païzis, C., Deley, G., Guérin-Deremaux, L., Saniez, M.-H., Lefranc-Millot, C., & Allaert, F. A. (2015). Pea proteins oral supplementation promotes muscle thickness gains during resistance training: a double-blind, randomized, Placebo-controlled clinical trial vs. Whey protein. *Journal of the International Society of Sports Nutrition*, *12*(1), 3. https://doi.org/10.1186/s12970-014-0064-5

Brown, M. L., & Tenison, E. (2018). Creation of a Dual-Purpose Collegiate Athlete Nutrition Advising Program and Educational Curriculum. *Journal of Nutrition Education and Behavior*, *50*(10), 1046–1052. https://doi.org/10.1016/j.jneb.2018.07.004

Burd, N. A., Gorissen, S. H., van Vliet, S., Snijders, T., & van Loon, L. J. (2015). Differences in postprandial protein handling after beef compared with milk ingestion during postexercise recovery: a randomized controlled trial. *American Journal of Clinical Nutrition*, *102*(4), 828–836. https://doi.org/10.3945/ajcn.114.103184

Burke, L. M., Slater, G., Broad, E. M., Haukka, J., Modulon, S., & Hopkins, W. G. (2003). Eating patterns and meal frequency of elite Australian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*(4), 521–538. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14967874

Canals, L. M. I., Azapagic, A., Doka, G., Jefferies, D., King, H., Mutel, C., ... Williams, A. (2011). Approaches for addressing life cycle assessment data gaps for bio-based products. *Journal of Industrial Ecology*, *15*(5), 707–725. https://doi.org/10.1111/j.1530-9290.2011.00369.x

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*. Los Angeles: SAGE Publications.

Dearing, J. W., & Cox, J. G. (2018). Diffusion Of Innovations Theory, Principles, And Practice. *Health Affairs*, *37*(2), 183–190. https://doi.org/10.1377/hlthaff.2017.1104

Diker, A., Cunningham-Sabo, L., Bachman, K., Stacey, J. E., Walters, L. M., & Wells, L. (2013). Nutrition Educator Adoption and Implementation of an Experiential Foods Curriculum. *Journal of Nutrition Education and Behavior*, *45*(6), 499–509. https://doi.org/10.1016/j.jneb.2013.07.001

Erdman, K. A., Tunnicliffe, J., Lun, V. M., & Reimer, R. A. (2013). Eating patterns and composition of meals and snacks in elite Canadian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *23*(3), 210–219. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23114732

FAO. (2016). *Plates, pyramids, planets. Developments in national healthy and sustainable dietary guidelines: a state of play assessment*. Food and Agriculture Organisation of the United Nations (FAO) and the Food Climate Research Network at The University of Oxford (FCRN).

Garnett, T. (2016). Plating up solutions. *Science*, *353*(6305).

Gerber, P. J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., ... Tempio, G. (2013). *Tackling Climate Change Through Livestock-A global assessment of emissions and mitigation opportunities*. *FAO, Rome*. Rome.

Gillen, J. B., Trommelen, J., Wardenaar, F. C., Brinkmans, N. Y. ., Versteegen, J. J., Jonvik, K. L., ... van Loon, L. J. C. (2017). Dietary protein intake and distribution patterns of well-trained Dutch athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *27*(2), 105–114. https://doi.org/10.1123/ijsnem.2016-0154

Glesne, C. (2011). *Becoming Qualitative Researchers: An Introduction*. (Pearson, Ed.) (4th ed.). Boston.

Heim, S., Stang, J., & Ireland, M. (2009). A Garden Pilot Project Enhances Fruit and Vegetable Consumption among Children. *Journal of the American Dietetic Association*, *109*(7), 1220–1226. https://doi.org/10.1016/j.jada.2009.04.009

ISO 14040:2006. Environmental management - Life Cycle Assessment - Principles and Framework. (2006).

Kanda, A., Nakayama, K., Sanbongi, C., Nagata, M., Ikegami, S., & Itoh, H. (2016). Effects of Whey, Caseinate, or Milk Protein Ingestion on Muscle Protein Synthesis after Exercise. *Nutrients*, *8*(6), 339. https://doi.org/10.3390/nu8060339

Lunn, W. R., Pasikos, S. M., Colletto, M. R., Karfonta, K. E., Carbone, J. W., Anderson, J. M., & Rodriguez, N. R. (2012). Chocolate Milk and Endurance Exercise Recovery. *Medicine & Science in Sports & Exercise*, 44(4), 682–691. https://doi.org/10.1249/MSS.0b013e3182364162

Lynch, H., Johnston, C., & Wharton, C. (2018). Plant-based diets: Considerations for environmental impact, protein quality, and exercise performance. *Nutrients*, *10*(12). https://doi.org/10.3390/nu10121841

Mettler, S., Mannhart, C., & Colombani, P. C. (2009). Development and validation of a food pyramid for Swiss athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *19*(5), 504–518. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19910652

Moore, D. R., Camera, D. M., Areta, J. L., & Hawley, J. A. (2014). Beyond muscle hypertrophy: why dietary protein is important for endurance athletes. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition et Metabolisme*, *39*(9), 987–997. https://doi.org/10.1139/apnm-2013-0591

Murakami, K., & Livingstone, M. B. E. (2018). Greenhouse gas emissions of self-selected diets in the UK and their association with diet quality: is energy under-reporting a problem? *Nutrition Journal*, *17*(1), 27. https://doi.org/10.1186/s12937-018-0338-x

Notarnicola, B., Sala, S., Anton, A. O., Mclaren, S. J., Saouter, E., & Sonesson, U. (2016). The role of life cycle assessment in supporting sustainable agri-food systems: A review of the challenges. *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.06.071

Parnell, J. A., Wiens, K. P., & Erdman, K. A. (2016). Dietary intakes and supplement use in pre-adolescent and adolescent Canadian athletes. *Nutrients*, *8*(9), 1–13. https://doi.org/10.3390/nu8090526

Phillips, S. M., Tang, J. E., & Moore, D. R. (2009). The role of milk- and soy-based protein in support of muscle protein synthesis and muscle protein accretion in young and elderly persons. *Journal of the American College of Nutrition*, *28*(4), 343–354. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/20368372

Saarinen, M., Fogelholm, M., Tahvonen, R., & Kurppa, S. (2017). Taking nutrition into account within the life cycle assessment of food products. *Journal of Cleaner Production*, *149*, 828–844. https://doi.org/10.1016/j.jclepro.2017.02.062

Sabaté, J., Sranacharoenpong, K., Harwatt, H., Wien, M., & Soret, S. (2014). The environmental cost of protein food choices. *Public Health Nutrition*, *18*(11), 1–7. https://doi.org/10.1017/S1368980014002377

Scarborough, P., Appleby, P. N., Mizdrak, A., Briggs, A. D. M., Travis, R. C., Bradbury, K. E., & Key, T. J. (2014). Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. *Climatic Change*, *125*(2), 179–192. https://doi.org/10.1007/s10584-014-1169-1

Skouteris, H., Cox, R., Huang, T., Rutherford, L., Edwards, S., & Cutter-Mackenzie, A. (2013). Promoting obesity prevention together with environmental sustainability. *Health Promotion International*, *29*(3), 1–9. https://doi.org/10.1093/heapro/dat007

Spendlove, J., Mitchell, L., Gifford, J., Hackett, D., Slater, G., Cobley, S., & O'Connor, H. (2015). Dietary Intake of Competitive Bodybuilders. *Sports Medicine (Auckland, N.Z.)*, *45*(7), 1041–1063. https://doi.org/10.1007/s40279-015-0329-4

Stylianou, K. S., Heller, M. C., Fulgoni III, V. L., Ernstoff, A. S., Keoleian, G. A., & Jolliet, O. (2016). A life cycle assessment framework combining nutritional and environmental health impacts of diet: a case study on milk. *International Journal of Life Cycle Assessment*, *21*(5), 734–746. https://doi.org/10.1007/s11367-015-0961-0

Thomas, D. T., Erdman, K. A., & Burke, L. M. (2016). Nutrition and Athletic Performance. *Medicine & Science in Sports & Exercise*, *48*(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

Vidgen, H. A., & Gallegos, D. (2014). Defining food literacy and its components. *Appetite*, *76*, 50–59. https://doi.org/10.1016/j.appet.2014.01.010

Vieux, F., Soler, L.-G., Touazi, D., & Darmon, N. (2013). High nutritional quality is not associated with low greenhouse gas emissions in self-selected diets of French adults. *The American Journal of Clinical Nutrition*, (9), ajcn.035105. https://doi.org/10.3945/ajcn.112.035105

Webber, C. B., & Sarjahani, A. (2011). Fitting Sustainable Food Systems Into Dietetic Internships—A Growing Trend. *Journal of Hunger & Environmental Nutrition*, *6*(4), 477–489. https://doi.org/10.1080/19320248.2011.627304

CHAPTER

5

CONCLUSIONS

“La primera tasca de l’educació és agitar la vida, però deixar-la lliure perquè es desenvolupi”

Maria Montessori

5.1 Conclusions

This dissertation aimed to validate the Athlete's Plate educational tool and its use by athletes and to evaluate its environmental impact. The dissertation offers an overview of the importance of validating nutrition education tools as well as the importance of educating target populations how to use such tools, especially focusing on the integration of environmental sustainability into sport nutrition and, specifically the Athlete's Plate nutrition education tool. This topic was addressed from four angles as represented in the four main research questions of this dissertation. A proposed hypothesis was developed for each research question described in chapter 2 and transcribed below. Each one of these research questions was evaluated and tested against the corresponding hypothesis with one of the four contributions of this dissertation. The main conclusions of each and their relationships are described below.

RESEARCH QUESTION 1: What is the current state of inclusion of sustainability considerations in sport nutrition recommendations pertaining to active and athletic individuals?

HYPOTHESIS 1: It was hypothesized that sustainability concepts are currently not integrated into nutrition guidelines and educational tools targeting active and athletic groups.

The first objective of this PhD was established through a literature review by contribution I which confirmed hypothesis one, that environmental sustainability is currently not integrated into nutrition guidelines and educational tools targeting active and athletic groups. Contribution I underlined how the interest about the integration of sustainability into sport nutrition is rising, and while it is still in an early phase, some efforts have been made recently in this direction. First, there is a growing interest from organizations and institutions working in sports to incorporate sustainability and environmental sustainability in their work. Second, scientific research is increasing, examining plant-based protein sources with adequate amino acid profiles to optimize muscle growth and muscle recovery. Third, there is a rising interest from health professionals and sport dietitians, in topics of environmental sustainability.

While there are some areas in sport nutrition where integration of environmental sustainability is commencing, contribution I highlighted the need for a boarder and deeper focus in this field. Athletes have the potential to be an inspiration to society. Thus, sustainability in sport nutrition is the perfect platform to promote both a healthy and fit body, while also addressing planetary boundaries and environmental sustainability.

RESEARCH QUESTION 2: Does the AP meet current sport nutrition recommendations?

HYPOTHESIS 2: It was hypothesized that the AP is a valid sport nutrition tool for athletes to meet sport nutrition guidelines for energy and macronutrients at variable training loads.

Contribution II confirmed that the AP is a valid sport nutrition tool for athletes to meet sport nutrition guidelines for energy, carbohydrates and fat at different variable training loads. However, it did not comply with the international recommendation for protein, as protein content was higher than recommended for moderate and hard training days. While sport dietitians created the plates for hypothetical athletes, sport nutrition recommendations emphasize the importance of quantity and quality of proteins to optimize muscle training adaptation and recovery. Research has been mainly focused on animal proteins such as dairy (milk and yogurt) relative to post-exercise muscle protein balance muscle protein balance and very few research has been done in the role of plant-based protein. Moreover, the distribution of protein was not homogeneous through all meals of the day, highlighting the need for both reduced quantity and better distribution throughout the day. The results of the validation of the athlete's plate nutrition education tool are a good example of the need to integrate environmental sustainability into sport nutrition and specifcially nutrition education tools to help athletes meet sport nutrition recommendations while also integrating contemporary sustainability recommendations.

RESEARCH QUESTION 3: Do athletes understand how to use the AP?

HYPOTHESIS 3: It was hypothesized that the AP can be used by athletes in practical settings.

While contribution II analyzed if the AP meets sport nutrition guidelines for energy and macro-nutrients at variable training loads, contribution III confirmed hypothesis three establishing that athletes can use the AP in a practical setting. Contribution III is a good addition to the conclusions of this dissertation as nutritional education tools are only useful if the target population understands and knows how to use them. Moreover, the findings of contribution III suggest that experiential learning should be included in nutrition education strategies for athletes and active populations. However, more studies are needed to account for different setting and athletic/active populations. Contribution III underlined the need to adjust nutrition education tools to different populations so they are more inclusive and integrate teaching strategies for athletes with disabilities (e.g., visually impaired).

RESEARCH QUESTION 4: What is the environmental impact of the AP?

HYPOTHESIS 4: It was hypothesized that animal protein content of the AP generates the greatest environmental impact, although that this would not be the only environmental concern of the AP.

Contribution IV of this dissertation validates hypothesis four, confirming that animal protein highly contributes to the total environmental impact of the AP although it is not the only environmental concern of the AP. While animal proteins are the main contributor for GWP, exergy and eutrophication, vegetables generated the highest environmental impact related to ecotoxicity. Processed food (such as frozen and canned) also increased considerably the total environmental impact of the plates analyzed. Also, contribution IV underlined how animal protein sources have a higher environmental impact than plant-based protein sources. Contribution IV results suggest a reduction in protein to meet recommendations, reduce total animal protein and when included, reduce ruminant meat and choose from a sustainable source. Moreover, reducing processed foods and choosing organically grown, local and fresh foods would help reduce the environmental impact of the plates. These recommendations highlight again, the importance of integrating environmental sustainability into sport nutrition and the necessity of not only considering nutrition for health and performance but also include environmental considerations of diets when using the AP model.

All four contributions of this dissertation highlighted the need for a better integration of environmental sustainability into sport nutrition, from food sourcing to the kitchen, and helped understand how environmental sustainability could be integrated into sport nutrition education and nutrition education tools. As a general conclusion, the AP needs to include aspects of environmental sustainability as well as further constructs of sustainability in general, as proposed by the overall discussion of this dissertation as well as, to integrate sustainability in the education of health professionals and sport dietitians. Moreover, as athletes and sports are an inspiration to society the findings of this research can be transferred to other areas of health sciences as well as other countries and cultures.

5.2 Future research

This section identifies main future research lines around the topics analyzed through this dissertation.

First, it is necessary to integrate sustainability into the educational curriculum of health professionals and sport dietitians but also taught in food service, food supply managers, and food companies to ensure all the food supply chain meet sustainable principles. Moreover, nutrition education should integrate topics of sustainability, cultural variability, and diversity.

Second, more research is needed on combinations of plant-based protein sources and their effects to optimize recovery and muscle anabolism to training. Future research should focus not only on plant-based protein sources but also on more sustainable animal protein sources such as insects.

Third, while the plates analyzed in this study were created by sport dietitians for hypothetical athletes, future research could evaluate the nutritional content and the environmental impact of plates created by athletes themselves to evaluate possible differences and improvement areas.

Fourth, life cycle assessment is a suitable methodology to evaluate the environmental impact of foods. However, it is a complex methodology and more studies are needed to evaluate the environmental impact of diets in real settings and specifically the settings for athletes and active individuals. Further studies should evaluate different funtional units to evaluate and interpret health, performance and environmental impact of diets. Thus, this dissertation is unique, as it proves that it is possible to evaluate real plates in athletes' real-life settings. Including a more consumer-friendly and efficient output of the results of LCA could help integrate the environmental impact of diets when educating athletes or delivering training to food service personnel.

Fifth, athletes should not only focus on performance (similar to the concept of diets for the healthy and the wealthy), but also integrate other aspects of nutrition such as environmental sustainability. More research should focus on experiential learning opportunities that incorporate aspects of sustainability such as the ethics of food, growing food or cooking skills, among others. Also, educating athletes to be more actively engaged in the community when at home through community service projects, helping on a local farm, in an institutional kitchen or cooking school could provide meaningful learning environments.

APPENDIX

0.1 Other relevant contributions

Reguant-Closa, A.; Harris, M.; Meyer, N. Validation of the athlete's plate quantitative analysis (Phase 1). *International Journal of Sports Nutrition and Exercise Metabolism*. 2016, 26, S1–S15.

Reguant-Closa, A.; Judson, A.; Harris, M.; Moreman, T.; Meyer, N.L. Including sustainability principles into the Athlete's Plate Nutritional Educational Tool. In Proceedings of the Oral Communication presented at the International Confederation of Dietetics 17th Conference in September 2016, Granada, Spain, September 7-10, 2016.

Reguant-Closa A; Lansche, J; Nemecek, T; Roesch, A; Meyer, NL. Including Environmental Impact Principles into Sports Nutrition. Case Study: the Athlete's Plate in Switzerland. *International Journal of Sports Nutrition and Exercise Metabolism*. 2019, 29, S1-S16.

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LLAURADOR

Dibuixo un solc
amb el dit
gairebé solc infinit
de pit a pit arribava
transparent
fil de llum
hi sembrava un somni bell
i en despertar
hi floria una rialla

Joan Reguant Aleix
Del llibre: *Terra segellada*