Utilitat de la dinamometria en la rehabilitació de patologia musculoesquelètica en pacients laborals

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Tesi presentada per optar al grau de
Doctor per la Universitat de Barcelona

Director de tesi:
Dr. Casimiro Javierre

A la Blanca
A l'Emma, en Pere i en Quimi
Als meus pares Joaquim i Lluïsa
A la Laura

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Abreviatures

DEC: Diferencia excèntric-concèntric.
Paràmetre resultant de substraure el rati excèntric/concèntric a velocitat baixa del rati a velocitat baixa

RE/C: Rati excèntric/concèntric.
Paràmetre resultant del cocient entre el registre de moment màxim de força excèntric i el concèntric a la mateixa velocitat

MM: Moment màxim.
Paràmetre principal de valoració de la força muscular mitançant dinamometria isocinètica.

CV: Coeficient de variació.
Mesura de la variabilitat d'un paràmetre que es calcula dividint la desviació estàndard pel promig

VPP: Variancia promig puntual.
Paràmetre de variabilitat de mesures isocinètiques que es calcula restant el promig de quatre repeticions de força isocinètica del registre màxim de les quatre

EMG: Electromiografia

Agraïments

Aquesta tesi es la conseqüència de la passió per la feina de metge, la rehabilitació, la biomecànica i, més concretament, l'avaluació de la força muscular. Es el fruit de molt esforç i dedicació. Tanmateix mai hagués estat possible sense el suport, l'ajut i la participació de moltes persones a qui vull mostrar el meu agraïment:

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A la família Roman Viñas, per haver-me acollit amb amor com un fill i germà més.

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Als amics de MAZ Zaragoza, especialment a l'Andrés Alcázar, per creure des de fa molt temps en les meves habilitats avaluadores.

A tots els meus ex-companys de residència i de l'Hospital Universitari Germans Trias i Pujol. Allí i amb ells vaig començar el camí dins la rehabilitació i l'avaluació funcional.

A tots i cadascun dels 151 voluntaris que han participat desinteressadament als estudis. Realment son crucials per fer avançar la ciència.

A tots i cadascun dels 107 pacients avaluats en els diferents estudis, i també als no inclosos en els estudis i que he tingut l'oportunitat d'avaluar i ajudar a rehabilitar. Ells son els que donen el sentit més profund a tota la meva feina.

A totes les persones de qui he après alguna cosa.

A tots, un agraïment sincer.

Capítol 1

Pròleg

Few things are impossible to diligence and skill.
Great Works are performed not by strength, but perseverance.

Samuel Johnson
Autor anglès, crític i lexicògraf (1709 – 1784)

Ara fa més de 17 anys, quan em vaig incorporar, a la primavera de l'any 1995, a treballar com a metge adjunt al servei de rehabilitació de l'Hospital Mútua de Terrassa (ara Hospital Universitari Mútua de Terrassa) i, uns mesos més tard, a Mútua Egara (tal com s'anomenava Egarsat aleshores), va començar el llarg camí que ha cristal·litzat en el present treball. De fet, ja durant la residència al servei de rehabilitació de l'Hospital Universitari Germans Trias i Pujol (Can Ruti), on ja s'havia desenvolupat un laboratori de proves funcionals, vaig viure una primerenca necessitat imperiosa de mesurar els aspectes que es treballen a la pràctica de la rehabilitació. Ja a Terrassa, amb tota la il·lusió que es pot tenir amb 28 anys per créixer professionalment, em vaig trobar com a cap de servei a la Roser Garreta. La Dra. Garreta estava fermament decidida a implementar l'organització d'un laboratori de biomecànica. L'agulla es degué enfilar bé doncs el somni d'aleshores s'ha acomplert amb escreix; hores d'ara, a Egarsat disposem d'un laboratori de biomecànica dels més complets del nostre entorn.

Pel que fa a la meva implicació en la valoració de la força muscular mitjançant dinamometria isocinètica tot va començar a Mútua Egara-Egarsat, on, a finals del 1997, es va decidir comprar un dinamòmetre isocinètic (el Cybex Norm) per mesurar la força muscular. A mi em va tocar posar-lo en marxa, fet que ha marcat profundament la meva carrera des d'aleshores. Ràpidament vaig poder comprovar la gran utilitat i validesa de la dinamometria isocinètica en el dia a dia de la pràctica clínica de la rehabilitació. No endebades, en l'àmbit de la rehabilitació musculoesquelètica el treball de la força muscular sempre és un aspecte fonamental, per tant, la mesura de la mateixa també ho és. L'ús clínic de la dinamometria ràpidament em va donar, i em continua donant, immenses satisfaccions com a metge rehabilitador. No obstant, de seguida, i donat l'entorn médico-legal en que es treballa en la medicina laboral, es va començar a generar una demanda de proves per avaluar dèficits en relació a la capacitat laboral. En altres paraules, inexorablement, va sorgir la necessitat de donar resposta a situacions mèdico-legals. La implicació en aquesta tasca va suposar un salt qualitatiu important durant la realització de les proves, doncs aparegué la qüestió, gens menor, de la estimació de la col·laboració dels pacients durant la realització de les mateixes per tal d'assegurar la seva validesa. En aquesta tessitura em vaig haver d'espavilar i buscar referències d'autors que haguessin treballat aquest tema. Es així com vaig trobar una monografía i els primers articles del professor Zeevi Dvir, on propugnava l'anàlisi del contrast entre les contraccions concèntriques i excèntriques per valorar la sinceritat de l'esforç i descrivia un paràmetre, la diferència excèntric concèntric (el DEC), eficient per avaluar el nivell de col·laboració dels subjectes mentre realitzen una prova isocinètica. En aquell moment (finals del segle passat) només s'havia demostrat la seva utilitat en flexo-extensors de genoll i colze. La Roser Garreta i jo ens vam assabentar que, a inicis del 2000, hi havia un congrés de la societat europea d'isocinètics (EIS) a Bruges on anava el professor Dvir. Allí vam anar i el vam conèixer. Aquell va ser un altre moment clau de la meva carrera professional doncs es va iniciar una relació altament fructífera que ha esdevingut d'amistat. En aquella trobada ja vam parlar de la necessitat d'avaluar la sinceritat de l'esforç en l'espatlla, probablement aquella conversa va ser l'inici de tot plegat. A més, el vam convidar a unes jornades que vam organitzar, a finals d'aquell any 2000 a Terrassa, per celebrar la inauguració del nostre laboratori de biomecànica i el centenari de la institució on vam acabar de afiançar la nostra relació. Des d'aquell moment i amb la incorporació inicial de l'Angels Abril, la Carme Unyó i l'Eduard Pujol i, posterior, del Valentín Freijo, la Mónica García, la Natàlia Ridao, la Dores Sánchez, l'Olga Kharseeva i el Jesús Carnicer vam començar a utilitzar intensivament i extensiva la dinamometria isocinètica en la pràctica diària de la rehabilitació i en la definició de seqüeles o situacions mèdico-legals. Així, actualment, la utilització de la dinamometria isocinètica ha esdevingut quotidiana en la pràctica de la rehabilitació a Egarsat. Sens dubte, aquest ha estat el repte més important que hem assolit com a grup. D'altra banda, al mateix temps vam posar en marxa treballs de recerca dirigits a estudiar aspectes de col·laboració i, en definitiva, la validesa de la dinamometria isocinètica en diferents aspectes. La majoria dels treballs son inclosos en el present document. Cal remarcar que en el present document es plasma una petita part del resultat d'una quantitat ingent de feina, clínica i de recerca, realitzada durant els darrers anys per molta gent, a qui estic profundament agraït.

Els diferents estudis recollits en el present document expliquen diferents aspectes de la valoració de la força muscular que hem investigat i que espero puguin ajudar a establir la validesa de la dinamometria en la pràctica de la rehabilitació musculoesquelètica en el entorn laboral. La pràctica de la rehabilitació en aquest entorn té unes singularitats que han condicionat la tasca de recerca aquí desenvolupada. El neguit més important a l'hora dur a terme proves funcionals amb utilitat clínica en els pacients laborals és determinar la seva fiabilitat. Per això es molt important, tal com s'ha comentat més amunt, intentar establir paràmetres que indiquin el nivell de col·laboració per dues raons: assegurar la rellevancia clínica de les proves i recolzar el seu eventual ús medico-legal. Per tant, el tema central de recerca de la present tesi és l'avaluació del nivell de col·laboració durant la realització d'una prova isocinètica (concretament amb el DEC). En estreta col·laboració amb el professor Dvir, hem estudiat aquest paràmetre, aprofundint en l'avaluació dinamomètrica isocinètica de la musculatura rotadora externa del muscle. Es per això que dels dos articles centrals de la tesi, el primer (publicat a la revista *Clin Rehabil el 2007*) descriu la utilitat del DEC en la valoració del nivell d'esforç realitzat per voluntaris sans durant una prova isocinètica de rotadors externs i, el segon, la seva aplicació pràctica en una població de 74 pacients laborals reals amb patologia d'espatlla. De fet, aquest darrer estudi, acceptat al *J Eletromyogr Kinesiol*, i actualment en premsa, per les seves implicacions clíniques, és el que em va empényer a decidir a fer una tesi doctoral i amb aquest objectiu vaig contactar amb el Dr.

Javierre qui m'ha guiat amb encert fins aquí. Prèviament a aquests dos articles ja hi va haver un treball preliminar (publicat a la revista *Rehabilitación (Madr)* el 2002) en que s'utilitzaven paràmetres basats en el contrast entre les contraccions concèntriques i excèntriques (el rati excèntric/concèntric) per estimar el nivell de col·laboració durant la realització de proves dinamomètriques en pacients laborals i que s'inclou a mode d'introducció al tema. Posteriorment, la recerca s'ha continuat assajant el protocol de valoració de rotadors externs en un dispositiu isocinètic d'una altra marca i en un recorregut articular curt amb resultats que perfilen les troballes prèvies (enviat a publicar a la revista *Disability & Rehabilitation*). Per tant, aquests dos treballs es comenten a continuació. Paral·lelament als estudis realitzats centrats en l'articulació de l'espatlla es varen realitzar treballs focalitzats en l'avaluació de diferents aspectes de la força muscular i la seva avaluació a l'avantbraç i la seva relació amb l'epicondilitis, patologia molt freqüent en l'entorn laboral. En aquest cas també s'ha aconseguit demostrar la utilitat del DEC en l'estimació del nivell de col·laboració durant la realització d'una prova isocinètica de flexors dorsals i palmars del canell (s'afegeix el treball que s'ha enviat a la revista *Eur J Phys Rehabil Med*). Iguament es van dur a terme dos estudis, publicats al *Conf Proc IEEE Eng Med Biol Soc* (del 2005 i el 2007), que mostren la potencialitat de l'ús conjunt de la EMG de superfície i la dinamometria isomètrica en l'avaluació funcional de la musculatura de l'avantbraç. Aquests mostraren unes troballes interessants pel que fa a l'activació muscular que podrien ser específiques de pacients amb epicondilitis. Per acabar, pel que fa al canell, també s'ha afegit un estudi publicat recentment (novembre del 2012) al *Eur J Phys Rehabil Med*, identificant un perfil de força muscular dinàmica en expacients amb epicondilitis que pot indicar un desequilibri de força muscular. El genoll també ha cridat la nostra atenció pel que fa a la recerca i hem participat en un estudi, publicat el 2010, també al *Eur J Phys Rehabil Med*, de fiabilitat d'un protocol de fatiga dinàmica així com en la presentació dels resultats de l'aplicació d'un protocol accelerat de rehabilitació de les plàsties de lligament encreuat anterior mitjançant un protocol accelerat en pacients laborals en què la força muscular es monitoritzava mitjançant dinamometria isocinètica, publicat el 2001 en la revista *Rehabilitación (Madr)*. En definitiva, el present document representa un compendi de 10 treballs que tenen l'avaluació de la força muscular com a denominador comú. Tots plegats penso que reflexen be la realitat de la rehabilitació laboral (predominància com a focus d'interès de la extremitat superior sobre la inferior, és a dir 8 treballs centrats en la primera contra 2 en la segona) i toquen temes com la fiabilitat, el nivell de col·laboració, la validesa, i, per tant, la utilitat clínica de la dinamometria isocinètica en la rehabilitació musculo-esquelètica en la població de pacients amb lesions laborals.

Com a mena d'epíleg, s'adjunta una editorial, publicada el 2010 en la revista *Rehabilitación (Madr)*, en la que es fa una reflexió de la importància de les proves biomecàniques en general i de la dinamometria isocinètica en particular en la pràctica de la disciplina de la rehabilitació. Espero i esperem que pugui ser d'utilitat a professionals implicats en la rehabilitació i avaluació de pacients laborals o musculo esquelètics en la seva pràctica habitual.

Barcelona, desembre 2012

Capítol 2

Introducció General. Força muscular, la dinamometria isocinètica, la fiabilitat de les mesures, la validesa clínica de les proves isocinètiques, l'avaluació del nivell de col·laboració i aspectes mèdicolegals en la pràctica de la rehabilitació musculoesquelètica

<<οὐ γὰρ ἐμὴ ἲς ἔσθ› οἵη πάρος ἔσκεν ἐνὶ γναμπτοῖσι μέλεσσιν.εἴθ›
ὣς ἡβώοιμι βίη τέ μοι ἔμπεδος εἴηώς ὁπότ› Ἠλείοισι>>

"Yo ya no poseo el vigor que solía albergar en mis flexibles músculos"
(Comentari que fa el vell Néstor, àvid per lluitar contra els ciutadans de Troia,
quan s'assabenta que Aquiles es nega a lluitar contra els troians)

Ilíada. Homer. Cant XI. Versicle 669
Traducció d'Oscar Martínez García
Alianza Editorial, 2010

La frase en boca de l'heroi Néstor, de la Ilíada, mostra fins a quin punt és d'antiga la preocupació per la força muscular. El vigor o la força muscular, objectiu central i ben actual dels que ens dediquem a ajudar als que l'han perdut per la vellesa o altres raons, era en aquelles èpoques remotes la condició fonamental per dur a terme accions bèl·liques. Per tant, els que patien mancança de força eren en una situació de desavantatge. De fet, en aquell moment, probablement, el mètode principal que tenien de mesurar la força muscular era batre's en el camp de batalla. Hores d'ara, afortunadament, la força ja no es mesura en el camp de batalla. No obstant, la força muscular continua essent essencial per dur a terme qualsevol activitat (tant laboral com quotidiana o del lleure) i, per tant, en situacions d'incapacitat esdevé un dels objectius centrals de la rehabilitació; fet que fa que la seva mesura sigui indispensable. Actualment, disposem de sistemes menys perillosos per mesurar-la, entre ells la dinamometria isocinètica. En efecte, l'ús d'aquesta en la mesura de la força muscular de pacients musculo-esquelètics en l'entorn laboral és el principal tema del present treball. En ell s'aprofondirà en aspectes de la utilitat de la mesura de la força muscular en la rehabilitació musculoesquelètica en general i en l'entorn laboral en particular.

2.1. Importancia de la força muscular en rehabilitació

El darrer Informe mundial sobre discapacitat de la OMS (2011) (*World report on disability* 2011) defineix la rehabilitació com "un conjunt de mesures que ajuden a les persones que tenen o, probablement, tindran una discapacitat a aconseguir i mantenir el funcionament òptim en la interacció amb el seu ambient". Des del punt de vista funcional la força muscular es crucial. Aquesta importància es reflexa en el fet que, per segona vegada, en la darrera edició de manual de rehabilitació de referencia internacional *DeLisa's Physical Medicine and Rehabilitation* (Frontera, DeLisa, Gans, Walsh, & Robinson L.R., 2010) s'inclou un capítol sencer dedicat a l'avaluació de la funció del múscul en humans. La primera frase d'aquest capítol es molt indicativa i podria representar el mandat que ha guiat tot el present treball: *"la rellevància de la musculatura estriada en la realització de tot tipus d'activitats físiques (p.e. terapèutiques, recreacionals, ocupacionals i altres) i la participació adecuada en les activitats de la vida diària i obligacions socials hauria de ser ben apreciada per tots aquells que treballen en la rehabilitació"* (Frontera & Lexel, 2010). En rehabilitació, la seva importància ve donada perquè des del punt de vista funcional, en general, la força muscular s'ha associat a unes velocitats de marxa confortable i màxima més grans (Buchner, Larson, Wagner, Koepsell, & de Lateur, 1996; Rantanen, Guralnik, Izmirlian et al., 1998), la incidència i prevalència de discapacitat (Rantanen, Guralnik, Leveille et al., 1998; Rantanen, Guralnik, Ferrucci, Leveille, & Fried, 1999; Rantanen et al., 1999), l'equilibri (Rantanen, Guralnik, Ferrucci, Leveille, & Fried, 1999), el temps per aixecar-se d'una cadira (Millington, Myklebust, & Shambes, 1992; Wretenberg & Arborelius, 1994), la capacitat de pujar escales (Schroll, Avlund, & Davidsen, 1997), incidència de caigudes(Lipsitz et al., 1994) i el percentatge de supervivència en gent gran(Katzmarzyk & Craig, 2002; Laukkanen, Heikkinen, & Kauppinen, 1995). D'altra banda, la potència o la velocitat amb que es pot produir força, també mostra una associació positiva i significant amb el nivell funcional(Bean et al., 2002; Brill, Macera, Davis, Blair, & Gordon, 2000). Així, en general, totes aquestes evidencies reforcen la conclusió de que augmentant i mantenint la força i resistència muscular al llarg de la vida, ja sigui des del punt de vista de la prevenció com del de la rehabilitació, pot reduir la prevalència de limitacions en les activitats recreacionals, domèstiques, quotidianes i de cura personal, tant en situació de salut preservada com en la malaltia.

En la rehabilitació musculoesquelètica, òbviament, la força muscular es clau. De fet, la força muscular (junt amb la flexibilitat, l'equilibri i la coordinació) es un dels components claus sistema neuro-muscular(Gotlin & Huie, 2000) que s'han definit com objectius clars dels programes de rehabilitació. L'entrenament de la força muscular s'ha mostrat eficaç com a part fonamental de protocols de rehabilitació de nombroses patologies musculoesquelètiques, tant freqüents i amb un impacte sanitari i econòmic tan important com la patologia de manegot (Ellenbecker & Cools, 2010; Littlewood, Ashton, Chance-Larsen, May, & Sturrock, 2012), el dolor lumbar (Kristensen & Franklyn-Miller, 2012; Rainville et al., 2004), l'epicondilitis (Kristensen & Franklyn-Miller, 2012; Trudel et al., 2004) i l'artropatia degenerativa de genoll (Kristensen & Franklyn-Miller, 2012; K. R. Vincent & Vincent, 2012).

En definitiva, en el tractament i monitorització de l'evolució dels pacients de rehabilitació en general i els musculoesquelètics en particular, l'avaluació de la força muscular esdevé crucial. A la fi de registrar la força muscular disposem de diferents mètodes(Frontera & Lexel, 2010): el balanç muscular manual, els tests isomètrics (dinamòmetre d'urpa jamar, dinamòmetres manuals ("hand held")), el mètode de una repetició màxima (1RM) i la dinamometria isocinètica. Aquest darrer mètode, basat en el principi d'avaluar la força muscular durant la realització d'un moviment angular o linear a velocitat constant, es considerat el "gold standard" per avaluar la capacitat de força muscular(Jarvela, Kannus, Latvala, & Jarvinen, 2002; Stark, Walker, Phillips, Fejer, & Beck, 2011)

2.2. Mesura de la força muscular mitjançant dinamometria isocinètica: fiabilitat i validesa

Els tests isocinètics han demostrat avantatges rellevants respecte a les altres mesures de força muscular (balanç muscular manual, tests isomètrics amb dinamòmetres manuals, tensiometria per cable i resistència basada en sistemes hidràulics) doncs la dinamometria isocinètica es la única capaç de detectar diferències bilaterals inferiors al 20-25%(H. Hartsell, Hubbard, & Van Os, 1995; Mathur, Makrides, & Hernandez, 2004). Aquest fet explica que hagin estat el "gold standard" per avaluar la capacitat de força muscular (Jarvela, Kannus, Latvala, & Jarvinen, 2002; Stark, Walker, Phillips, Fejer, & Beck, 2011).

La dinamometria isocinètica va ser possible a partir de l'aparició del Cybex I a finals dels anys 60 (Malone, 1998). Probablement l'atribut fonamental dels dinamòmetres es la capacitat de fer que els pacients/subjectes duguin a terme un exercici amb una resistència variable que s'acomoda, mantenint la velocitat constant, a la força que realitzen en cada moment del recorregut articular (Dvir, 2003; Walmsley & Pentland, 1993). Ja fa molts anys, es va demostrar que els exercicis isocinètics augmentaven el volum de treball fet per repetició en comparar-ho amb un exercici isotònic (Moffroid, Whipple, Hofkosh, Lowman, & Thistle, 1969), per tant, els dispositius isocinètics poden fer generar als usuàris el màxim esforç durant tot el rang articular en que es realitza l'exercici. Aquest fet fa que les mesures isocinètiques suposin una mesura molt mes exhaustiva de la força muscular dinàmica en un determinat rang articular quan es compara amb altres sistemes de mesura. Els dinamòmetres isocinètics consisteixen, bàsicament, en un dinamòmetre connectat a un ordinador que processa les dades i que es pot aliniar amb l'articulació a mesurar mitjançant diferents adaptadors i ajustos (veure figura 1).

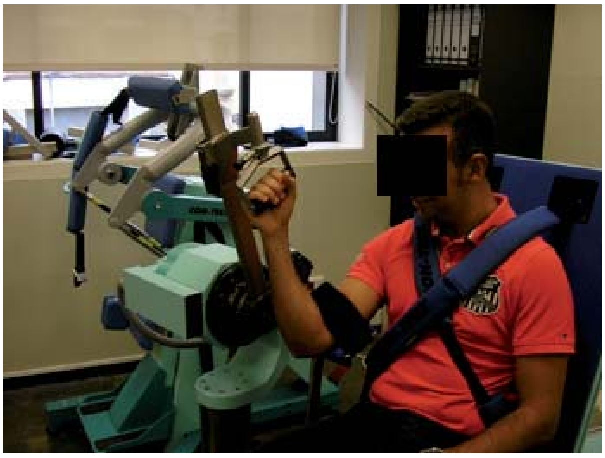


Figura 1. Pacient posicionat a un dinamòmetre isocinètic duent a terme una prova de flexo-extensors de colze.

Amb ells es poden obtenir tot un seguit de variables de rendiment muscular. Entre elles destaquem el moment màxim (MM), moment de força angle específic, el treball i la potència. Cal destacar que aquestes variables es poden obtenir tant en contracció concèntrica com excèntrica. Indubtablement el MM es el paràmetre central en l'ús clínic de la dinamometria isocinètica (veure figura 2).

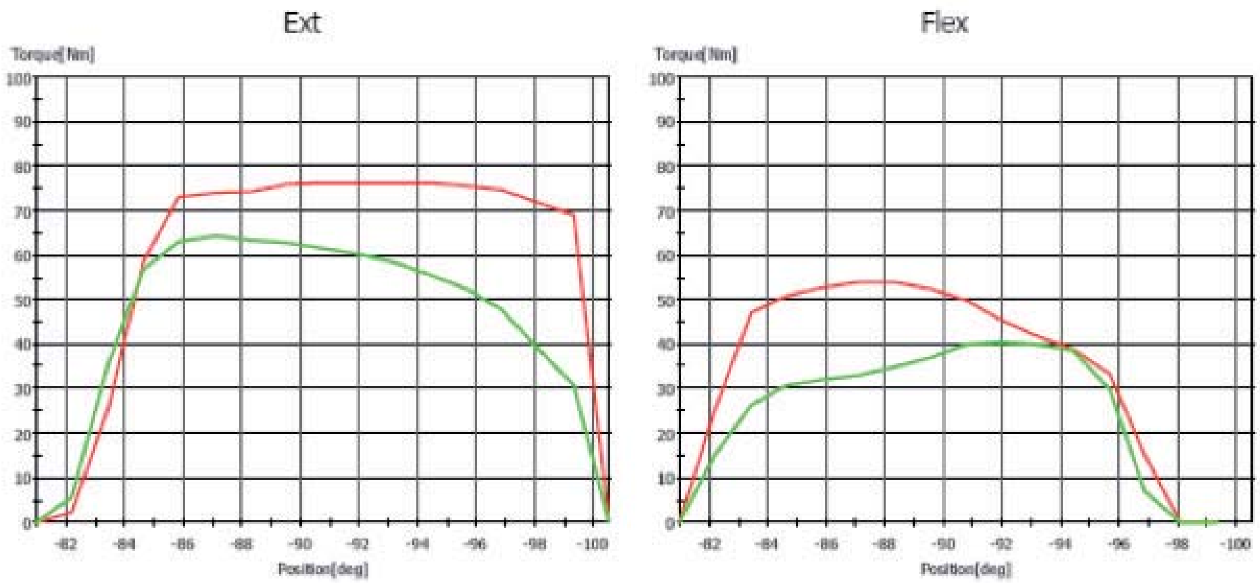


Figura 2. Gràfica moment de força (Moment)-recorregut articular dels m. flexoextensors de la espatlla en un pacient afecte de resecció de l'extrem distal de clavícula dreta. En vermell cantó sa (esquerre) i en verd el cantó afecte (dret). El MM es el punt culminant de les gràfiques.

Així, en la pràctica habitual, quan s'avalua la força al voltant d'una articulació, es registren els MM de cada cantó i aplicant la formula:

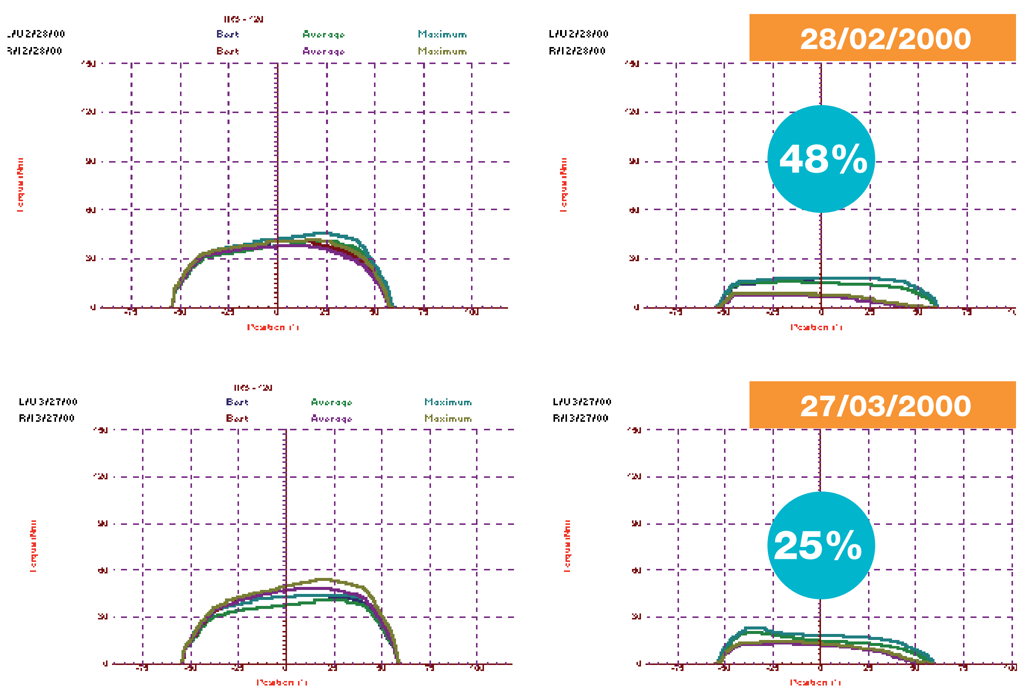
$$\text{Dèficit} = 1 - \frac{\text{MM afecta}}{\text{MM sana}} \times 100;$$

en general , es poden obtenir dèficits que podem graduar com rellevants a partir d'un 20% (Sapega, 1990). Igualment, podem definir els dèficits com lleus (20-50%), moderats (51-75%) o severs (>76%) (Dvir, 2004).

En alguns casos, especialment en l'entorn de l'esport, per avaluar desequilibris musculars, es calculen ratis de MM agonista/antagonista (per exemple rotadors exters/rotadors interns i flexors/extensors per espatlla i genoll, respectivament). Pel que fa als ratis, molt especialment en l'esport, s'ha definit el rati dinàmic que barreja contraccions excèntriques amb concèntriques. Així, pel que fa al genoll, es calcula fent el quocient entre els flexors a modalitat excèntrica i els extensors a modalitat concèntrica (Hole et al., 2000). A l'espatlla el rati dinàmic més definit es el resultant del quocient entre les mesures de rotadors externs en modalitat excèntrica i les de rotadors interns en concèntrica (Noffal, 2003).

Un punt fonamental en la utilitat clínica de les proves isocinètiques es la seva fiabilitat. En els tests isocinètics quan es parla de fiabilitat, normalment, es refereix a la reproductibilitat o fiabilitat test-retest. Es a dir, en una situació d'estabilitat, dues mesures seguides han de produir resultats similars. Si aquesta premissa no es dóna, ens podem trobar que diferencies en mesures successives siguin degudes a errors en la mesura. En aquest sentit es molt important remarcar que la precisió (derivada de la seva qualitat intrínseca) dels dispositiu isocinètics no assegura la fiabilitat. És a dir, amb un dispositiu molt precís es poden dur a terme proves poc fiables. De fet, la fiabilitat, que és a la base de la validesa, es un tema major i complex en les proves isocinètiques. Un test isocinètic és una experiència singular en que un o varis examinadors avaluen mitjançant un dinamòmetre isocinètic un subjecte o pacient que realitza una acció voluntària. Per tant, es poden identificar múltiples factors que incideixen en la fiabilitat (Dvir, 1995). En primer lloc, els derivats del dispositiu com la calibració o el processament de les dades. En segon lloc, els relacionats amb el procediment (posicionament, fixació, etc.) i protocol de valoració (número de tests, períodes de repòs, estímuls verbals, etc.). Finalment, els factors més lligats als observadors (explicació al pacient, interpretació de dades, etc.) i, molt especialment, al pacient o subjecte en sí (motivació, col·laboració, comprensió, etc.). Com molt be resumeix Dvir (Dvir, 2004) en la seva darrera monografia sobre isocinètics, les mesures derivades d'aquests incorporen múltiples fonts de variació, des de aspectes purament tècnics (aparentment controlables) fins aspectes neuro-conductuals tan complexos com la motivació del subjecte o pacient durant la realització de la prova (probablement molt menys controlables). No obstant, malgrat les dificultats, la fiabilitat dels dinamòmetres isocinètics ha estat ampliament estudiada i, en gran mesura,s'ha demostrat alta o molt alta en l'avaluació de la força muscular del genoll (L. E. Brown, Whitehurst, & Bryant, 1992; L. E. Brown, Whitehurst, Bryant, & Buchalter, 1993; Callaghan, McCarthy, Al-Omar, & Oldham, 2000; Caruso, Brown, & Tufano, 2012; Carvalho et al., 2011; Greenblatt, Diesel, & Noakes, 1997; Hartmann, Knols, Murer, & de Bruin, 2009; Maffiuletti, Bizzini, Desbrosses, Babault, & Munzinger, 2007; Wilson, Walshe, & Fisher, 1997), articulació de l'espatlla (L. E. Brown, Whitehurst, Findley, Gilbert, & Buchalter, 1995; Caruso, Brown, & Tufano, 2012; A. M. Cools, Erik E. Witvrouw, E. E., Danneels, Vanderstraeten, & Cambier, 2002; Dauty et al., 2003; Durall et al., 2000; Ellenbecker & Davies, 2000; Forthomme, Dvir, Crielaard, & Croisier, 2011; Frisiello, Gazaille, O'Halloran, Palmer, & Waugh, 1994; Hill, Pramanik, & McGregor, 2005; Ly & Handelsman, 2002; Mandalidis, Donne, O'Regan, & O'Brien, 2001; L. A. May, Burnham, & Steadward, 1997; F. Mayer, Horstmann, Kranenberg, Rocker, & Dickhuth, 1994; Montgomery, Douglass, & Deuster, 1989; Mueller, Mayer, Baur, & Mayer, 2011; Orri & Darden, 2008; W. E. Pentland, Kai Lo, & Strauss, 1993; Perrin, 1986; Plotnikoff & MacIntyre, 2002; Siston & Dyson-Hudson, 2007), l'anca (Callaghan, McCarthy, Al-Omar, & Oldham, 2000; Caruso, Brown, & Tufano, 2012; Claiborne, Timmons, & Pincivero, 2009), el turmell (E. Aydog, Aydog, Cakci, & Doral, 2004; Caruso, Brown, & Tufano, 2012; De Noronha & Júnior, 2004; Hartmann, Knols, Murer, & de Bruin, 2009), el canell (Caruso, Brown, & Tufano, 2012; H. D. Hartsell, Hubbard, & Van Os, 1995; S. Poulis, Rapanakis, Pastra, Poulis, & Soames, 2003), el colze (Deighan, De Ste Croix, & Armstrong, 2003; Demura, Miyaguchi, & Aoki, 2010; Griffin, 1987; Howatson & van Someren, 2005; Kakebeeke, Lechner, & Handschin, 2005) i la columna lumbar i cervical (Byl & Sadowsky, 1993; Caruso, Brown, & Tufano, 2012; Delitto, Rose, Crandell, & Strube, 1991; Timm, Gennrick, Burns, & Fyke, 1992).

Respecte a la validesa dels isocinètics podríem diferenciar la concurrent (capacitat de mesurar la força muscular i la seva relació amb la situació real del subjecte o pacient) i la predictiva (capacitat de predir events en relació a uns resultats actuals). Quant a la primera, ja l'any 1994, en Kannus (Kannus, 1994) afirmava que no hi havia dubte de la utilitat dels isocinètics en la monitorització del guany de força muscular en rehabilitació i, per tant, de la seva correlació amb la situació muscular dels pacients de rehabilitació. Pel que fa al genoll, la seva validesa en la avaluació de la força muscular en pacients operats de plàstia de lligament encreuat anterior s'ha evidenciat en una recent revisió (Pua, Bryant, Steele, Newton, & Wrigley, 2008), en que es destaca la correlació entre els resultats dels tests isocinètics i els de les escales funcionals autoaplicades pels pacients. Pel que fa a l'espatlla, també s'ha constatat la seva validesa en la monitorització clínica, especialment amb la utilització de ratis agonistes/antagonistes (Codine, Bernard, Pocholle, & Herisson, 2005). En la figura 3 es mostra un exemple de monitorització de la força muscular de rotadors externs d'espatlla en un pacient intervingut de la ruptura de manegot



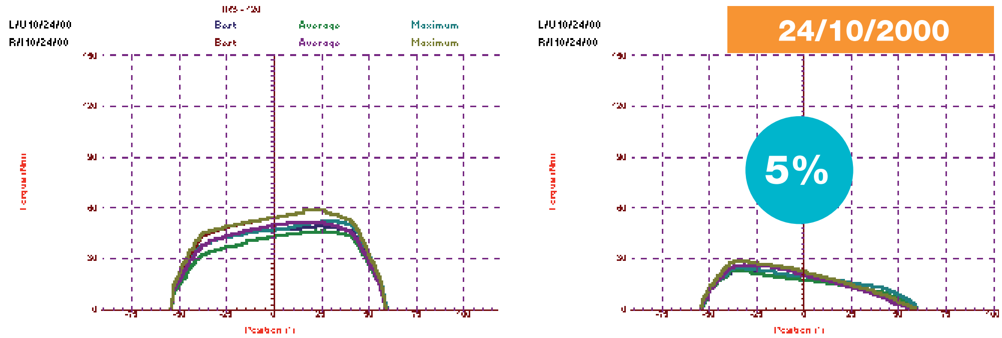


Figura 3. Monitorització de la força muscular dels rotadors d'un pacient afecte de la ruptura de manegot intervinguda. Les gràfiques de la dreta mostren les curves força-velocitat dels rotadors externs on es veu la progressiva millora al llarg del temps de seguiment dels registres del cantó afecte (marró) fins pràcticament superposar-se amb els del cantó sa (verd).

Al canell es destacable un recent treball on es mostra la validesa, diferenciant pacients afectes de síndrome de tunnel carpià de un grup de voluntaris sans (Reichard, Katz-Leurer, Rubinstein, Croisier, & Dvir, 2010), de manera que els primers tenien una debilitat significativa al comparar-los amb els segons.

Pel que fa a la validesa predictiva dels tests isocinètics destaca molt l'estudi realitzat per Croisier i col·laboradors (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008) en que demostrà que un rati dinàmic (flexors eccentric/extensors concèntric) disminuït en futbolistes correlacionava amb una incidència posterior augmentada de lesions de isquiotibials.

En definitiva, es pot afirmar que, hores d'ara, la dinamometria isocinètica es un mètode fiable i vàlid en la pràctica de la rehabilitació per monitoritzar la força muscular i, en alguns casos, per prevenir lesions. No obstant, la seva utilitat clínica radica en la fiabilitat de la prova. Com hem comentat més amunt, aquesta depèn en gran part de la motivació del subjecte/pacient. Normalment, aquesta es dona per segura, sobretot en pacients de l'ambit de l'esport. Per contra, hi ha poblacions, com per exemple els pacients laborals, en que la col·laboració no es pot assegurar d'entrada donades les connotacions medico-legals. De fet, la revisió de la literatura específica de pacients laborals avaluats mitjançant dinamometria isocinètica només mostra un article antic (Bray, Roth, & Jacobsen, 1987) en que s'avaluaven després de una intervenció quirúrgica de dolor anterior de genoll. Curiosament, en aquell estudi els resultats pel que fa a força muscular eren similars al comparar pacients laborals amb pacients no laborals. En tot cas, en pacients laborals, el paper de la dinamometria isocinètica pot ser en entredit si s'hi barreja una situació mèdico-legal. Per això, en aquests pacients en particular, caldria revisar el tema de la col·laboració durant la realització de les proves per poder utilitzar una eina tant potent des del punt de vista clínic.

2.3. Avaluació de la sinceritat de l'esforç o del nivell de col·laboració durant la realització d'una prova dinamo-mètrica.

El tema de la "motivació" dels pacients mereix una atenció a part perquè el establiment de laboratoris de biomecànica, que està experimentant una important crescuda en el nostre entorn, sobretot en centres de rehabilitació laboral i en centres independents dedicats a la valoració de seqüeles, té molt a dir amb l'avaluació d'aquest aspecte particular. Això entronca directament amb l'ús médico-legal dels sistemes d'avaluació biomecánics (entre ells els dinamòmetres isocinètics). Com s'ha comentat més amunt, la motivació o col·laboració del pacient es fonamental per assegurar la fiabilitat i, al mateix temps, la validesa de la prova. Per això, sempre es desitjable tenir alguna dada que ens indiqui el nivell de col·laboració en la realització de la prova, sobretot si el resultat s'ha d'usar en la determinació de seqüeles i/o incapacitats (es a dir, situacions medico-legals). El fet de detectar signes de manca de col·laboració implica una conseqüència crucial: la prova no és fiable i, per tant, la valoració del pacient no és vàlida. Pel que fa a la valoració del nivell de col·laboració durant la realització de tests isocinètics, s'han avaluat diferents mètodes que es poden agrupar en *paràmetres de consistència* (el coeficient de variació (CV) (Birmingham, Kramer, Speechley, Chesworth, & MacDermid, 1998; Hazard, Reid, Fenwick, & Reeves, 1988; Luoto, Hupli, Alaranta, & Hurri, 1996), la variància promig puntual (VPP) (M. Newton & Waddell, 1993), la observació de les gràfiques (Ayalon, Rubinstein, Barak, Dunsky, & Ben-Sira, 2001; Reid, Hazard, & Fenwick, 1991) i mesures de la similaritat de gràfiques (Almosnino et al., 2012)) i index basats en la fisiologia (la diferència isocinètic- isomètric (Birmingham & Kramer, 1998) i la diferència excèntric-concèntric (DEC) (Dvir, 2004)). Pel que fa als paràmetres de consistència i a la diferència isocinètic-isomètric presenten limitacions que els fan inacceptables com a paràmetre principal en el entorn mèdico-legal. Malgrat tot, poden usar-se com paràmetres secundaris. Per contra, el DEC, definit per primera vegada el 1996 i fermament impulsat pels treballs inicials del professor Dvir (figura 4), ha estat ampliament estudiat.

Es remarcable que els paràmetres de col·laboració basats en la fisiologia permeten raonaments més determinants que els basats en la consistència de mesures. Aquests darrers depenen a parts iguals del subjecte observat i de l'habilitat del observador mentre que els primers descriuen un fet fisiològic que que si es compleix en un moment donat assegura la bona realització de la prova per part del subjecte i implícitament l'habilitat de l'observador. Podriem dir que es un nivell d'avaluació jeràrquicament superior.

Figura 4. Professor Zeevi Dvir

La solidesa del raonament fisiològic en que es basa aquesta aproximació, probablement, explica la utilitat demostrada en múltiples accions detallades més a baix. Es basa en la diferencia de producció de força en situació concèntrica i excèntrica, especialment en situacions de contracció submàxima. Així, quan es produeix un esforç màxim la força muscular es governada per la funció moment de força-velocitat angular (M-ω) o "força velocitat". D'acord amb aquesta funció, que ha estat demostrada en tots els grups musculars, quan es fa un esforç concèntric la força es redueix al mateix temps que s'augmenta la velocitat. D'altra banda, la força produïda en contraccions excèntriques varia poc amb la velocitat i, en la majoria d'estudis, augmenta (Dvir, 2004). La figura 5 es extreta del treball en que es va demostrar la utilitat del DEC en la detecció d'esforços isocinètics submàxims de rotadors externs d'espatlla (Chaler et al., 2007). En ella es representa la gràfica força-velocitat (concèntrica i excèntrica) de rotadors externs en una situació de contracció màxima (línies contínues) i submàxima (línies discontinues). Es constata, efectivament, que en les contraccions màximes la força concèntrica disminueix amb la velocitat i l'excèntrica varia molt poc. Per contra, en situació submàxima, mentre la contracció concèntria segueix un patró similar (encara que més pronunciat) la contracció excèntrica augmenta d'una manera sensible.

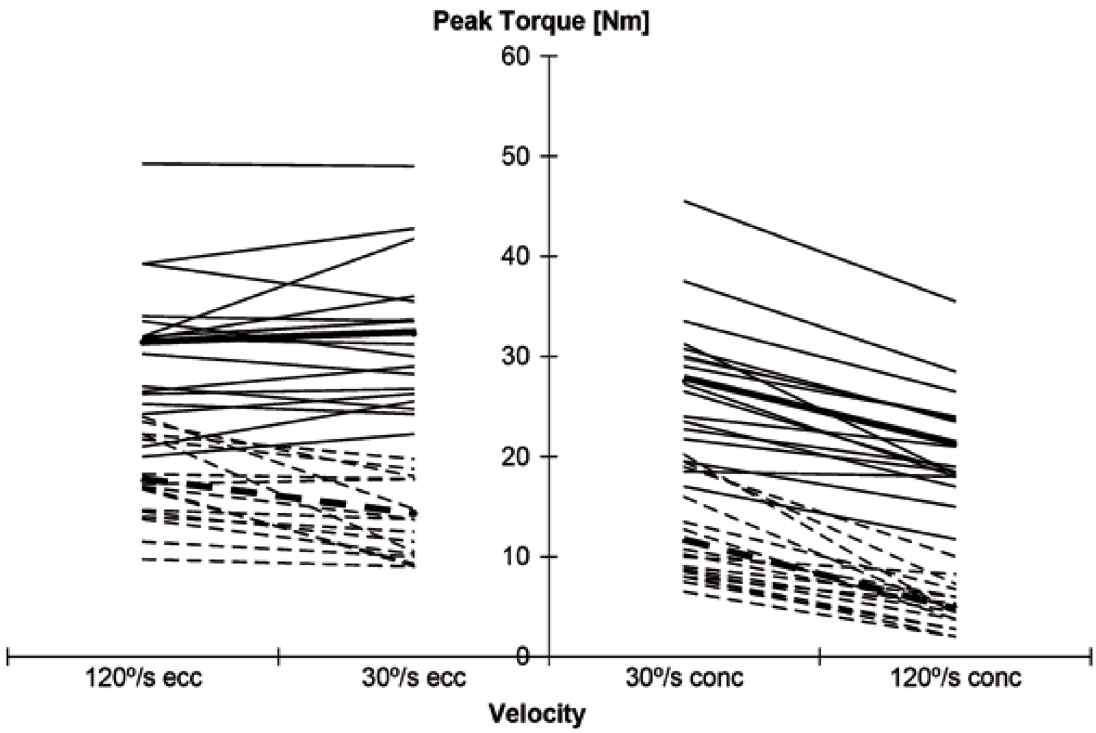


Figura 5. Gràfiques moment de força-velocitat angular (M-ω) dels rotadors externs de 17 voluntaris en situació màxima (línies contínues) i submàxima (línies discontínues). Veure comentari al text.

En situació màxima, en principi, tots els ratis excèntric/concèntric (RE/C) seran superiors a 1 però no molt superiors a 2. Quan més baixa es la velocitat probablement més s'acostaran a 1 o, fins i tot, poden baixar una mica. Quan a un subjecte se l'instrueix en produir un esforç isocinètic submàxim, els contrastos entre les contraccions concèntriques i excèntriques s'accentuen independentment del tipus d'instrucció donada. Efectivament, sembla que la capacitat de controlar la tensió muscular per part del subjecte difereix molt entre les contraccions concèntriques i les excèntriques, fet que, molt probablement, reflexa unes demandes neurofisiològiques diferents per cada tipus de contracció. Mentre que les contraccions concèntriques es dirigeixen a produir moviment, les excèntriques tenen una funció inhibitòria o de frenar el moviment amb un objectiu defensiu o protector moltes vegades (p.e. el fet de mantenir-se d'empeus quan es rep una empenta es deu a tot un seguit de contraccions excèntriques que es produeixen immediatament). Aquesta funció específica de les contraccions excèntriques, que requereix una extrema urgència, fa que la precisió en la producció de tensió sigui molt disminuïda en comparació a la que s'assoleix quan es produeix una contracció concèntrica. A més a més, si per produir una contracció excèntrica s'augmenta la velocitat angular probablement s'interpreta com una situació d'amenaça que genera un reclutament major d'unitats motores amb la generació de tensió muscular més alta corresponent (Dvir, 2004). De fet, estudis neurofisiològics indiquen que l'activitat excèntrica es modulada per estructures diferents que la concèntrica (Enoka, 1996).

Aquestes particularitats del control motor de les contraccions concèntriques i les excèntriques fa que, en situacions de contracció submàxima a velocitats altes de contracció, els registres concèntrics baixin molt mentre que els excèntrics ho facin més suaument. A la figura 6 es mostren les gràfiques de força-recorregut articular de rotadors externs i interns d'un pacient intervingut de ruptura de manegot en que aquest fenòmen es donava d'una manera extrema. Així, si ens fixem en les gràfiques de la dreta, veiem que mentre els registres de rotadors externs concèntrics del cantó afecte (blau) eren extremadament baixos en comparació als contra laterals (vermell), en situació excèntrica, pràcticament es superposen i, inclús, els del cantó afecte superen lleugerament els del cantó sa. Aquesta troballa òbviament contravé qualsevol llei de la fisiologia de la contracció muscular màxima i, per tant, indicaria que l'esforç realitzat pel subjecte en aquella prova hauria estat "no màxim".

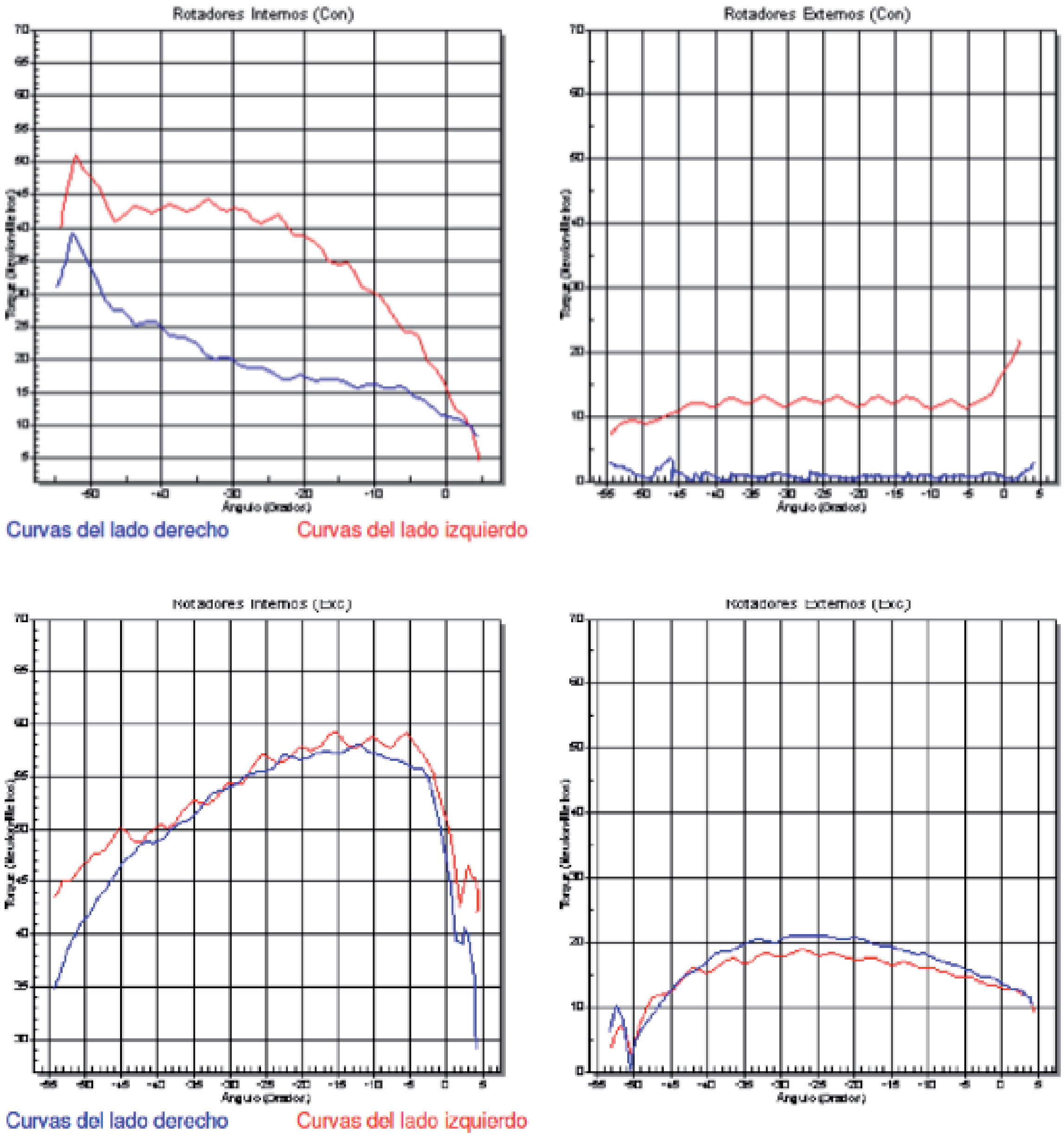


Figura 6. Curves força-recorregut articular (120ºs-1) de test isocinètic de rotadors externs realitzat al final de procés de rehabilitació d'pacient intervingut de ruptura de manegot dret (gràfiques de color blau pel cantó l'afecte i vermell pel cantó sa). Amunt es mostra el registre concèntric de rotadors interns (esquerra) i externs (dreta). A vall, hi ha els corresponents registres excèntrics. Veure comentari al text.

Les gràfiques força-velocitat que podem registrar en situacions màximes i submàximes també mostren variacions en relació a aquest diferent comportament en situacions màximes i submàximes, de manera que en les darreres s'observa un allunyament dels extrems. Es a dir, els registres concèntrics baixen més intensament amb la velocitat de contracció mentre que els excèntric menys o, fins i tot , augmentar discretament amb la velocitat. Aquest fenòmen queda clarament representat en la figura 5.

Basant-se en aquestes observacions, Dvir i els seus col·laboradors (Dvir, 2004) van suggerir que comparant REC a diferents velocitats amb un gradient suficientment gran es podria diferenciar un esforç màxim d'un submàxim. Com a resultat de les seves investigacions es va definir un paràmetre, el DEC que es el resultat de la següent fórmula:

$DEC = REC_{vel\ alta} - REC_{vel\ baixa}$

El gradient de velocitat que s'usa habitualment es 1:4 i no es arbitrari doncs correspon exactament (en $^{o}\cdot s^{-1}$) a la meitat (la baixa) del recorregut articular i al doble (l'alta), respectivament. Així, si per exemple es fa un test amb un recorregut articular de 60º, la velocitat baixa seria de $30^{o}\cdot s^{-1}$ i l'alta de $120^{o}\cdot s^{-1}$.

La capacitat del DEC per diferenciar un esforç màxim d'un de submàxim s'ha explorat en una sèrie d'estudis (Dvir & David, 1996; Dvir, 1997; Dvir, 1999; Dvir & Keating, 2001; Dvir, Steinfeld-Cohen, & Peretz, 2002; Olmo, Jato, Benito, Martin, & Dvir, 2009) en que a grups de subjectes sans se'ls feia realitzar una prova isocinètica màxima i, a continuació, repetir-la demanant-los que fessin un esforç submàxim amb diferents instruccions (que fessin la meitat de força o que fingissin debilitat per lesió). En tots els estudis, com era d'esperar, en situació màxima es varen registrar uns MM significativament superiors als registrats en situació submàxima. Però, el que es més important, els DEC en situació submàxima també eren en tots els casos significativament superiors als registrats en situació màxima. Així utilitzant el càlcul d'intervals de tolerància, l'eina estadística que permet establir punts de tall, es va fer possible definir un esforç com màxim o submàxim amb un donat nivell de confiança. En la taula 1 es resumeixen tots els treballs, fora dels presentats en el present compendi, que demostraren l'efectivitat del DEC per la detecció d'esforços submàxims en diferents accions (extensió de genoll, flexió de colze, prensió d'urpa, extensió de tronc, flexió d'espatlla, flexió dorsal i plantar de turmell). En ella es representen les característiques de la mostra de subjectes (n, sexe i edat), l'acció mesurada, la marca de dispositiu utilitzada, el recorregut articular i les velocitats corresponents del protocol i, finalment, els punts de tall del valor del DEC a partir dels quals un esforç isocinètic es pot considerar submàxim amb un nivell de confiança del 95% i del 99%. Així, per exemple, si es fa una prova a un pacient i el DEC registrat és per sota el nivell de tall, l'esforç es pot considerar màxim amb el nivell de confiança que haguem escollit. Per tant, i el que es més important, automàticament atorgaria més validesa clínica a la prova i implícitament també validesa medico-legal. La qüestió de quin nivell de confiança es recomanable escollir depèn de la "rigidesa" amb que es vulgui avaluar els tests. De tal manera, si el posem més alt (99%) serem més permissius i tindrem mes probabilitat de resultats falsos negatius, mentre que si el posem al 90% fora possible que augmentessin els falsos positius. En tot cas, donat que l'estandard biomèdic de que l'α=0.05 es universalment acceptat, un nivell de confiança del 95% es més que raonable.

	Subjectes			**Acció avaluada-Aparell-Protocol**					**Punts de tall DEC**	
Cita	N	Sexe	Edat(± DE)	Acció	Aparell	Rang articular	Velocitats		95%	99%
Dvir et al, 1996	16	homes	21-30*	Extensió de genoll	KinCom	80°	30°s^{-1}-180°s^{-1}		1.02	1.14
Dvir et al, 1997	15	homes	21-55*	Flexió de colze	KinCom	30° (20°F-50°F)	20°s^{-1}-60°s^{-1}		1.11	1.29
						60° (20°F-80°F)	20°s^{-1}-60°s^{-1}		1.23	1.47
Dvir, 1999	17	dones	20-25*	Prensió d'urpa	KinCom	8°(4cm)	4°s^{-1}-16°s^{-1}		2.12	3.27
Dvir et al, 2001	18	homes	38.5 ± 12.2	Extensió de tronc	KinCom	20° (10°F-10°E)	10°s^{-1}-40°s^{-1}		0.69	0.95
	17	dones	28.3 ± 11.4	Extensió de tronc	KinCom	20° (10°F-10°E)	10°s^{-1}-40°s^{-1}		0.75	1.02
Dvir et al, 2002	17	homes	29.1 ± 2.4	Flexió d'espatlla	KinCom	16° (82°F-98°F)	8°s^{-1}-32°s^{-1}		0.36	0.41
						16° (82°F-98°F)	8°s^{-1}-64°s^{-1}		0.55	0.61
						80° (50°F-130°F)	40°s^{-1}-160°s^{-1}		0.99	1.09
Olmo et al, 2009	20	homes	30.9 ± 13.2§	FD/FPI de turmell	Biodex SII	60°	30°s^{-1}-120°s^{-1}	FPI:	1.9§	2.34§
	18	dones						FD:	2.2§	2.71§

DE: desviació estàndard; **DEC:** diferència excèntric-concèntric; *DE no proporcionada a l'article, es reflexa el rang d'edats; **FD:** flexió dorsal; **FPI:** flexió plantar; **F:** flexió; **E:** extensió; § El promig d'edat i els resultats d'homes i dones es mostren barrejats en aquest estudi; **n.c.:** no calculable

Taula 1. Estudis on s'ha demostrat la utilitat del DEC en la detecció d'esforços submàxims: característiques dels subjectes, acció avaluada, dispositiu utilitzat, rang articular, velocitats, punts de tall als nivells de confiança del 95% i del 99% i, finalment, límit inferior de valor de DEC acceptable calculat restant dues DE del promig del DEC màxim.

L'eficiència del DEC en la detecció dels esforços submàxims al llarg del temps s'ha demostrat en els extensors de tronc (Dvir & Keating, 2001), de manera que, en dues avaluacions distanciades en el temps, ni el DEC màxim ni el submaxim diferien significativament. Així, en els homes, el DEC detectava el 100% dels esforços submàxims en la primera prova i el 93% en la segona. En les dones es passava del 82% al 70%. Es conclogué, per tant, que, sobretot en homes, el DEC era un paràmetre molt potent per detectar esforços submàxims i mantenia la potencia al llarg de diferents avaluacions separades en el temps.

Prèviament al present treball, l'aplicabilitat del DEC en grups clínics havia estat analitzada en dos estudis. En el primer, 44 pacients recuperats de una lumbàlgia crònica varen ser avaluats mitjançant el protocol prèviament definit d'avaluació d'extensors de columna lumbar (un rang de 20° amb velocitats de contracció de $10°·s^{-1}$ i $40°·s^{-1}$) en que es van establir uns punts de tall reflexats a la taula 1(Dvir & Keating, 2003). A un nivell de confiança del 99% el 89% dels pacients varen registrar un DEC de bona col·laboració, quan es baixava el nivell de confiança a un 95%, el percentatge de pacients als que llur efort va ser etiquetat de màxim va baixar al 84%. En aquest cas es va recomanar un nivell de confiança del 99% donada la complexitat dels factors que influeixen en l'avaluació del tronc i la cura extrema que s'ha de tenir a l'hora d'interpretar els resultats. En el segon estudi, es van analitzar 34 pacients afectes de patologia d'espatlla (amb test isocinètic de flexors d'espatlla), ma (amb test d'urpa) i genoll (amb test isocinètic d'extensors) i, també, es van utilitzar punts de tall del DEC de subjectes normals a un nivell de confiança del 95% (veure taula 1). Els pacients portaven tots més d'un any d'evolució i tots reclamaven compensacions. En aquella sèrie només va haver un cas en que l'esforç es va titllar de probablement submaxim basat en el DEC (Dvir, 2002).

En aquest punt, cal remarcar que la realització de proves concèntriques i excèntriques mitjançant dinamòmetres isocinètics no suposa cap inconvenient a l'actualitat, el càlcul del DEC es molt fàcil i ràpidament interpretable, fet que reforça la seva aplicabilitat clínica quotidiana.

No obstant, tal com puntualitzava Dvir en la seva darrera monografia (Dvir, 2004), el DEC no es lliure de limitacions:

1. La majoria de les dades es basen en el KinCom, per tant, la utilitat dels nivell de tall obtinguts amb aquest dispositiu per d'altres requereix més recerca.
2. El gènere te un efecte en el DEC i no en tots els protocols s'han valorat ambdós sexes.
3. El paper de l'edat en els ratis excèntric/concèntric no es clar i, per tant, tampoc en el valor numèric del DEC.

Totes aquestes limitacions son en part adreçades en el present treball.

2.4. Aplicacions mèdico-legals de la dinamometria isocinètica

El paper de la dinamometria en l'entorn mèdico-legal te moltes vessants però, fonamentalment, es tracta de determinar graus de disfunció muscular que es puguin relacionar amb discapacitats. En aquests darrers anys, en el nostre entorn disposem de dades que mostren que la seva utilització no fa més que augmentar. En efecte, segons dades del Institut Català d'Avaluacions Mèdiques i Sanitàries (ICAMS) entre els anys 2007 i 2008 el nombre de proves biomecàniques realitzades per prendre determinacions quant al destí de pacients va augmentar quasi un 25% (Jardí & Manzanera, 2012). La majoria de les proves eren proves dinamomètriques.

En tot cas, en l'us de la dinamometria isocinètica en l'entorn mèdico legal cal tenir en compte una sèrie de qüestions que enumera Dvir (Dvir, 2004):

1. La debilitat muscular es el resultat de la reducció de capacitat de produir tensió muscular en una o vàries repeticions. La debilitat muscular no s'hauria de confondre amb disminució de la potència (velocitat amb la que es capaç de produir la força) o be la disminució de la resistència muscular o augment de fatigabilitat.

2. La força muscular es el paràmetre "sine qua non" per determinar la debilitat muscular. La utilització de la força muscular com criteri es correcte no sols perquè es la més tangible i fàcilment mesurable de tots els paràmetres (p.e. el treball), sino, també, perquè esta forta i linealment correlacionada amb la resta de paràmetres de força.

3. Des del punt de vista purament clínic, cal remarcar que la debilitat muscular es un dèficit. No obstant, aquest dèficit no necessàriament ha de significar que el pacient tingui una discapacitat. Massa sovint però, el fet que un pacient no mostri una discapacitat evident porta a la conclusió de que, si presenta un dèficit de força, està fent un esforç submàxim. Això pot constituir una estigmatització dels pacients que s'hauria d'evitar doncs es ben sabut que una debilitat muscular pot ser molt ben compensada en molts casos i aquesta capacitat no hauria de privar els pacients de compensar-los si la debilitat ve donada per una lesió laboral o per accident.

4. Alguns autors o sistemes d'avaluació del dany corporal no reconeixen la debilitat muscular com una disfunció.

5. No hi ha un acord general sobre quin tipus de sistema d'avaluació de la força muscular hauria de ser el de referència (o "criterion") (isomètric, concèntric o excèntric). En tot cas, les accions musculars són en la majoria de les situacions dinàmiques, per tant una prova dinàmica s'acosta més a la realitat. Pel que fa a incloure test excèntrics, a part de donar

la possibilitat d'avaluar el nivell de col·laboració mitjançant el DEC, afegeixen una avaluació més exhaustiva de la força muscular. S'ha comprovat que els dèficits excèntrics son sempre inferiors als concèntrics (Reinking et al., 1996) i la pràctica diària també ho mostra. Per tant, el dèficit isocinètic excèntric, potser, ens apropa més al dèficit real dels pacients o subjectes.

6. Igualment, no hi ha un acord general sobre els protocols, el temps apropiat per realitzar les proves i les mesures de la maximalitat de l'esforç a aplicar per assegurar la validesa de les proves. Generalment, pel que fa al temps de realització d'una prova en un entorn medico-legal es recomana un any d'evolució per estar segur de ser en una situació estabilitzada. No obstant, caldria remarcar la "bondat" de realitzar aquest tipus de proves abans, ja durant les fases finals del procés de rehabilitació, en que s'acaba de treballar la força muscular. En aquests casos una sèrie de proves congruents te moltíssim valor per prendre decisions clíniques i mèdico-legals

7. No hi ha un acord general pel que fa a la graduació del dèficit, en altres paraules, a partir de quin valor es pot considerar un dèficit rellevant. Malgrat tot en la practica clínica, normalment es subscriu plenament la guia de Sapega:tot dèficit entre el 10 i 20% es possiblement anormal i qualsevol diferència del 20% o més hauria de ser considerada, pràcticament amb total seguretat, patològica (Sapega, 1990). A partir d'aquí sorgeix la qüestió de graduar el dèficit i aquí hi ha diversitat d'opcions que es mostren a continuació:

   - Qualsevol diferencia inferior al 20% no s'hauria de considerar d'entrada com un dèficit en població normal (es a dir no esportistes).
   - El 80% restant pot dividir-se en dos meitats: del 20-60% i del 60-100%. Un subjecte que té un dèficit del 100% tindria un balanç muscular manual de 3.
   - Un dèficit entre el 20 i 60% es podria considerar moderat i a partir de 60% sever.
   - Una subdivisió més fina podria ser: de 20-50% lleu, de 51-75% moderat i >75% sever.

8. Malgrat que la comparació bilateral està ja molt establerta i acceptada com a criteri, no hi ha un mecanisme, hores d'ara, per correlacionar la severitat de la diferencia bilateral amb el grau de disfunció.

9. Finalment, malgrat els dinamòmetres isocinètics son ampliament utilitzats en diferents especialitats mèdiques (rehabilitació, ortopèdia, neurologia i medicina de l'esport) a més de en la fisioteràpia, fisiologia de l'exercici i ergonomia, i que ja es considera un "gold standard", encara no està establert universalment com la mesura de la força muscular.

En tot cas, la dinamometria isocinètica es una prova fiable, factible i, molt probablement, vàlida i l'autor del present document pensa que aporta, i pot aportar en el futur, dades clau en l'entorn de la rehabilitació laboral (i també no laboral) i l'eventual us medico-legal.

Un dels punts claus seria la inclusió d'aquesta tècnica en la monitorització del procés de rehabilitació, en altres paraules, inserir les proves dinamomètriques en un pla i/o raonament clínic. Això li dona una robustesa enorme com a prova complementaria i, eventualment, medico-legal.

Per acabar s'enumeren un seguit de recomanacions pràctiques a l'hora d'aplicar proves isocinètiques en un entorn laboral i/o medico-legal (adaptat i ampliat de Dvir (Dvir, 2004)):

1. Tenir una història clínica complerta del pacient així com el registre del procés patològic pel que es remés (incloent exploracions complementàries).

2. Realitzar una exploració física convencional del pacient.

3. Confirmar, abans de començar, amb les dades dels punts 1 i 2, que el pacient pot tenir una disfunció muscular.

4. Confirmar que la situació està mínimament estabilitzada si es vol obtenir una dada per suportar una seqüela.

5. Repassar contraindicacions del test (bàsicament malalties cardiovasculars). En aquest punt, el dolor es una contraindicació relativa i, per tant, el coneixement de la patologia del pacient i la fase en que està es crucial per decidir la indicació o no del test.

6. Explicar, el més detalladament possible, al pacient els objectius del test, assegurar-se que ho entén i insistir molt en que el test es molt sensible i que cal fer el màxim possible. També es recomana recollir totes les explicacions en un full de consentiment informat i donar-li al pacient perquè el signi.

7. Pel que fa al protocol i interpretació, qualsevol fet rigorosament serveix sempre que es compleixin certs requeriments:

   - S'ha d'assegurar la maximalitat del esforç, evidentment la opció del present autor es el DEC.

   - Si no hi ha signes de bona col·laboració el test no es vàlid i, per tant, no útil per determinar cap dèficit.

   - Si el test mostra signes de bona col·laboració es pot procedir a calcular els dèficits amb la fórmula esmentada més a munt. En cas d'afectació bilateral o avaluacions de tronc, s'hauria de comparar amb taules de normalitat, cosa que dóna en alguns casos menys potència a la prova

8. A l'hora de realitzar l'informe es recomana

   - Reflexar les dades clíniques i d'exploració convencional rellevants juntament amb les dinamomètriques per elaborar la conclusió.

- Afegir tots els paràmetres de força registrats (MM) en cada segment explorat, així com els dèficits i els paràmetres per valorar la maximalitat de l'esforç (DEC).
- Inclure una breu descripció de la metodologia
- Afegir els fulls impresos del registre del dispositiu.
- Afegir les dades actualitzades de la calibració de l'aparell.
- Incloure el full de consentiment informat signat pel pacient.

9. Finalment, es important tenir en compte que, si els paràmetres per valorar la maximalitat de l'esforç indiquen que la prova ha estat submàxima, mai es pot etiquetar, en altres mots estigmatitzar, d'entrada el pacient com simulador o magnificador. De fet, s'ha indentificat múltiples causes de mala de col·laboració en la realització d'una prova (D. E. Lechner, Bradbury, & Bradley, 1998): Dolor, por al dolor, por a la lesió, ansietat, depressió, falta de comprensió, falta de comprensió de la importància del test i, també, la simulació. Per tant, sempre que aquesta situació es doni es recomana tornar a fer la prova per confirmar.

   Diferents qüestions apuntades en aquesta introducció s'aprofondiran en aquest treball. Es passa així a definir la hipòtesi i els objectius del present treball en relació a l'estudi de l'ús de la dinamometria isocinètica en l'entorn de la rehabilitació laboral.

Capítol 3

Hipòtesi

La hipòtesi general del present treball es:

En l'entorn de la rehabilitació musculoesquelètica laboral la dinamometria (isocinètica i/o isomètrica) es una mesura vàlida.

La hipòtesi general es desplega en diverses hipòtesis de treball concretes que s'enumeren a continuació:

1. El paràmetre DEC es una mesura útil d'estimació del nivell de col·laboració durant la realització d'una prova isocinètica de rotadors externs de muscle en voluntaris sans i en pacients laborals reals afectes de patologia musculoesquelètica de l'articulació de l'espatlla.
2. L'avaluació de la força muscular de rotadors externs mitjançant dinamometria isocinètica es factible i útil per prendre decisions en pacients laborals afectes de lesions del muscle.
3. El paràmetre DEC es una mesura útil d'estimació del nivell de col·laboració durant la realització d'una prova isocinètica de flexors dorsals i palmars de canell en voluntaris sans.
4. En l'epicondilitis d'origen laboral hi ha desequilibris i patrons d'activació alterats de la musculatura de l'avantbraç subjacents.
5. L'avaluació de la fatigabilitat isocinètica en la musculatura de flexo-extensors de genoll es fiable.
6. L'avaluació mitjançant dinamometria isocinètica de la força muscular de flexo-extensors de genoll en pacients laborals intervinguts de ruptura de lligament encreuat amb plàstia os-tendó-os es util per monitoritzar el programa de rehabilitació.

Capítol 4

Objectius

Objectius primaris

1. Analitzar l'eficiència del DEC i/o paràmetres basants en la discrepància de les contraccions concèntriques i excèntriques en la detecció d'un esforç submàxim de rotadors externs de espatlla.

2. Analitzar l'utilitat del DEC en la detecció de esforços submàxims de rotadors externs d'espatlla en pacients reals afectes de patologia del muscle.

3. Descriure l'utilitat clínica i en la determinació de seqüeles de la dinamometria isocinètica en pacients laborals afectes patologia de l'espatlla.

Objectius secondaris

4. Analitzar l'eficiència del DEC en la detecció d'un esforç submàxim de músculs flexors dorsals i palmars de canell.

5. Identificar, mitjançant electromiografia (EMG) de superfície, patrons de l'activació de la musculatura de l'avantbraç en pacients afectes d'epi- condilitis durant la realització d'un esforç isomètric

6. Identificar, mitjançant dinamometria isocinètica, el perfil de força muscular de l'avantbraç en pacients afectes d'epicondilitis recuperada.

7. Avaluar la fiabilitat d'un protocol de fatigabilitat isocinètica de flexoextensors de genoll.

8. Avaluar l'efectivitat d'un protocol accelerat de rehabilitació després d'una plàstia de lligament encreuat anterior de pacients laborals en la recuperació de la funció, així com l'utilitat de la dinamometria isocinètica en la monitorització del protocol.

Capítol 5

Articles

Capítol 5.1

Identificació d'esforç màxim fingit de rotació externa de muscle

Identification of feigned maximal shoulder external rotation effort

Clin Rehabil 2007; 21; 241

Identification of feigned maximal shoulder external rotation effort

Joaquim Chaler, Zeevi Dvir, Urko Díaz, Salvador Quintana, Àngels Abril, Carme Unyó, Roser Garreta

Clin Rehabil 2007; 21; 241

Objectiu

Estudis previs han indicat que la diferencia dels ratis de força excèntrica/concèntrica a velocitats alta i baixa (DEC) es un paràmetre amb alta potència per identificar esforços submàxims, en altres paraules identifica subjectes que fingeixen fer un esforç màxim. No obstant, la seva utilitat no havia estat investigada en l'avaluació mitjançant dinamometria isocinètica de rotadors externs. Per la importància de la patologia de espatlla, la avaluació de la força muscular i el nivell de col·laboració en fer el test dels músculs de l'espatlla es d'alt interès. Per tant l'objectiu del present estudi es examinar l'eficiència del DEC en la identificació d'esforços submàxims deliberats en subjectes normals.

Per analitzar això es van seleccionar disset voluntaris sans homes entre 20 i 40 anys, als que se'ls va realitzar dues proves isocinètiques de rotadors externs a 30ºs^{-1} i 120ºs^{-1} en modalitat concèntrica i excèntrica. La primera prova la van realitzar fent esforç màxim i a la segona se'ls va demanar que simulessin esforç màxim sense en realitat dur-lo a terme. Es van calcular els moments màxims de força i els ratis excèntric/concèntric. Amb aquests últims es va calcular el DEC.

Resultats principals

L'anàlisi detallat dels resultats va mostrar que els DEC registrats en la situació d'esforç submàxim eren significativament més alts que els registrats en situació d'esforç màxim. Per tant es va poder establir un punt de tall (0.81) de valor de DEC que podria distingir entre esforç submàxim i submàxim.

Conclusió

Les troballes de l'estudi van indicar que el DEC es molt efectiu en la identificació de un esforç màxim fingit en subjectes sans.

Clinical Rehabilitation 2007; **21:** 241–247

Identification of feigned maximal shoulder external rotation effort

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Objective: To examine the efficiency of the difference between the isokinetic eccentric to concentric strength ratios at high and low velocities (DEC) for identifying feigned maximal shoulder external rotation effort.
Background: Previous studies have indicated that the DEC is a powerful identifier of feigned maximal effort. However comparison of maximal versus feigned maximal shoulder external rotation effort has not been undertaken. Due to the high prevalence of rotational shoulder disorders and their chronic ramifications in terms of occupational disability such a study is of specific interest.
Design: Maximal and feigned maximal shoulder external rotation isokinetic efforts were compared.
Setting: Functional evaluation unit at an occupational rehabilitation centre.
Subjects: Seventeen healthy male volunteers aged between 20 and 40 years old.
Main measure: Concentric and eccentric isokinetic tests at 30°/s and 120°/s in maximal and feigned maximal experimental conditions. DEC was calculated by subtracting the 30°/s eccentric/concentric peak torque ratios from the 120°/s ones for both experimental conditions.
Results: A case-by-case analysis revealed that the DEC scores derived from the feigned effort were significantly greater than their maximal counterparts in all cases, leading to a cut-off value (0.81) which could distinguish between maximal and feigned performances.
Conclusions: The findings indicate that the DEC is highly effective in identifying feigned shoulder external rotation effort in normal subjects.

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Introduction

Shoulder injuries are a major management problem in musculoskeletal rehabilitation and occupational medicine settings. A one-year prevalence study of shoulder pain interfering with occupational activities indicated a rate of 9%.[1] Most patients require extensive treatment with medication and physical therapy and, in some cases, surgery is indicated. Following treatment, return to work may be difficult. Due to their high prevalence, the economic consequences of shoulder pain are therefore not negligible. In fact, shoulder, back, wrist, knee and neck injuries are the five most costly work-related injured body parts.[2] Moreover, objective and precise evaluation of the deficits and determination of the degree of possible permanent impairment are necessary in order to deal fairly with the situation.

One of the major manifestations of shoulder injury, specially rotator cuff pathology, is muscle weakness and/or imbalance.[3,4] Objective evaluation of shoulder muscles performance is therefore of a significant value as it provides information essential for treatment or rehabilitation planning and monitoring, as well as assessment of clinical outcomes and permanent impairment. Isokinetic dynamometry enables accurate and reproducible measurement of shoulder muscle strength.[5,6] However, the patient's collaboration is crucial in order to produce meaningful results. Indeed for both clinical and medicolegal decisions, estimation of the patient's collaboration is crucial. It has been demonstrated that a powerful tool to assess such collaboration is the difference between the isokinetic eccentric to concentric strength ratios at high and low velocities (DEC), an index derived from isokinetic testing and referring to the numeric difference between the eccentric/concentric strength ratios at relatively high and low test velocities. Specifically, the DEC was highly effective in identifying feigned maximal muscular effort in normal subjects[7–12] as well as patients.[13] Among these studies only one focused on shoulder muscles assessing maximal effort in shoulder flexion.[12] However although shoulder rotational strength evaluation is of a particular interest, no parallel analysis has been carried out with respect to the muscles generating this motion.

The objective of the present study was therefore to examine the efficiency of the DEC in identifying suboptimal effort in shoulder rotators, specifically those that effect external rotation.

Material and methods

Subjects

Seventeen healthy male volunteers aged 20–40 years (27.7 ± 6,09) with no history of shoulder, elbow, wrist or hand pathology took part in the study. This study was approved by the Ethical Review Board of Hospital Mútua de Terrassa. All subjects signed an informed consent form.

Testing protocol

A Cybex Norm isokinetic dynamometer (Ronkonkoma, New York, USA) was used. The device was fully calibrated before every test. Warm-up and testing was conducted with the subject seated on an adjustable seat and proximally stabilized using cross chest straps. The arm was positioned in the scapular plane, between 30 and 45° anterior to the frontal plane and elevated approximately 45°. Elbow was maintained at 90° flexion and supported by a standard shoulder rotation attachment. A forearm strap helped in positioning the elbow. The forearm remained neutral during the testing protocol while the hand grasped a handle connected distally to the lever arm. The mechanical axis of the lever arm was aligned with the humeral shaft.

The test protocol started with familiarization and warm-up. It consisted of one set of 10 increasing submaximal concentric contractions, one set of 10 increasing submaximal eccentric contractions, a 2-min rest period and two short (3 or 4 contractions) sets of maximal concentric and eccentric contraction respectively. After a 3-min rest the actual test started.

Testing was performed unilaterally on the dominant side. The test range of motion (RoM) was 60°, starting from about 50° internal to 10° external rotation. This RoM was selected according to the excellent tolerance reported by shoulder patients in previous tests. The protocol consisted of two experimental conditions. During maximal effort, subjects were asked to exert maximal effort against the lever arm whose angular speed was first set at

30°/s. The test consisted of four pairs of intermittent, reciprocal, concentric-eccentric contractions with a 5-second inter-contraction pause and a 25-second inter-pair pause. Following a 5-min pause, speed was then raised to 120°/s and the same protocol applied again. Following a 10-min pause, testing of feigned external rotation weakness was then conducted. Subjects were given spoken instructions as follows:

> Imagine that one year ago you suffered a shoulder injury. Although now completely recovered, you are suing your insurer or employer for shoulder weakness. The dynamometric test is crucial for the final decision, so you must try to convince me that you really have weakness while performing the shoulder movements.

After instructions were given the protocol was repeated in full.

Data reduction and statistical analysis

Peak torque of each contraction measured was individually recorded by using the Cybex Norm software. Eccentric/concentric ratios were calculated for each speed and test conditions (maximal and feigned maximal). Finally the DEC, defined as the difference in the eccentric/concentric, was calculated:

$$\text{DEC} = (\text{Ecc}/\text{Con})_{120} - (\text{Ecc}/\text{Con})_{30}$$

The DEC was calculated for both the maximal and feigned maximal conditions. The findings were analyzed using multiple analyses of variance (MANOVA) with repeated measurements with the DEC as the dependent variable and effort level as the fixed factor.

Concentric and eccentric data were then analysed separately. A bifactorial analysis (Velocity [120, 30], effort [maximal, feigned maximal]) was performed for each condition (concentric and eccentric) in order to assess differences in force velocity curve behaviours.

Finally, the maximal effort DEC tolerance interval was calculated.

Results

Table 1 outlines the mean peak torque values in the two experimental conditions. A three-factor MANOVA (velocity × contraction mode × level of effort) indicated a highly significant interaction ($F = 15.343$, $P = 0.001$). As expected, the mean peak torques in maximal performance were significantly higher than those registered for the feigned maximal counterpart ($P < 0.001$).

The torque–velocity curves (Figure 1) indicate that in both maximal and feigned maximal conditions the concentric strength declined with a rise in the test speed. However, there was a notable difference with respect to the eccentric strength. Whereas in the maximal effort the high speed mean eccentric peak torque was smaller than its lower speed counterpart, the reverse was true for the feigned weakness condition. In order to assess this difference, the interaction between the curves (maximal and feigned maximal) was analysed by using two separate bifactorial variance analyses. These analyses indicated no difference in terms of the concentric torque fall-off ($P = 0.83$) but a highly significant difference in the eccentric branch ($P < 0.001$). In other words, feigned maximal eccentric contractions lead to a highly significant

Table 1 Strength of external rotators by effort level: means and standard deviations in Nm

Effort level	Contraction speed (°/s)	Contraction type	Mean peak torque (Nm)	SD
Maximal	30	Concentric	27.5	7.2
	30	Eccentric	32.3	7.2
	120	Concentric	21.2	5.6
	120	Eccentric	31.4	6.8
Submaximal	30	Concentric	11.5	4.5
	30	Eccentric	14.2	4.7
	120	Concentric	5.0	2.2
	120	Eccentric	17.6	4.3

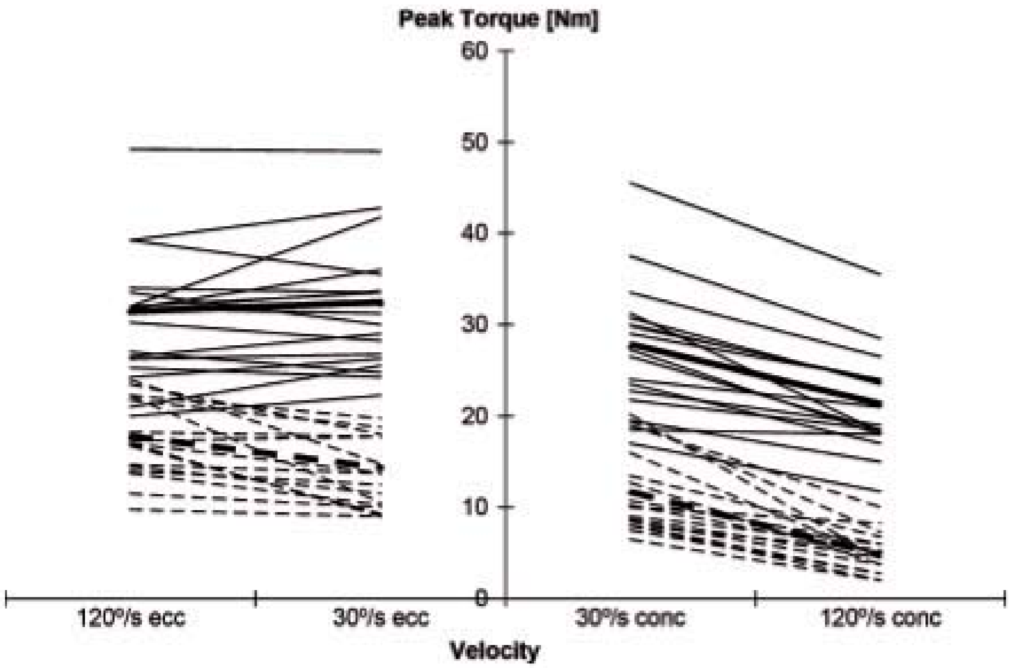

Figure 1 Peak torque–velocity curves of the 17 subjects: Eccentric effort (left half of the figure) and concentric effort (right half of the figure). Continuous lines depict maximal effort, discontinuous lines depict the submaximal effort. Bold lines depict the mean value curve. ecc, eccentric or negative velocity; conc, concentric or positive velocity.

different behaviour of the force–velocity curve eccentric branch.

Table 2 outlines the mean (SD) of the eccentric/concentric ratios. The most conspicuous finding is the relatively high eccentric/concentric ratio obtained for the feigned maximal contraction at 120°/s. This finding is intimately related to the results of the DEC calculations as well as to the feigned maximal strength velocity curve behaviour described above. Table 3 presents the resulting DECs which in the case of the feigned effort were significantly higher ($P < 0.001$) than those obtained from the maximal effort. Figure 2, which depicts the individual DEC values according to subject number, demonstrates that in all cases the DEC in the feigned maximal effort was greater than its maximal counterpart.

Using these scores cut-off values were calculated allowing the identification of feigned maximal effort level in case these values were exceeded. Cut-off level derived from the calculation of tolerance intervals for a normal distribution.[14] For instance, if a statement is to be made at 95% level of confidence, the DEC relating to external rotation must be higher than 0.81 in order to label the effort as feigned maximal. Obviously, a higher level of confidence is associated with a higher cut-off. Thus, for a 99% level of confidence the cut-off value is 1.079 whereas if 90% is sufficient the cut-off value drops to 0.658 (Table 3).

Table 2 Mean eccentric/concentric (E/C) ratios

Effort level	Contraction speed	E/C ratios	SD
Maximal	30	1.172	0.995
	120	1.480	1.211
Submaximal	30	1.232	1.041
	120	3.527	1.942

Discussion

Isokinetic evaluation of shoulder rotation is a valuable tool in shoulder injury assessment. Since it is a dynamic test which requires a maximal effort of the subject being tested, collaboration during test performance is a major issue. This study

Table 3 Mean DEC and SD obtained in both experimental conditions: maximal and submaximal effort. Calculated tolerance or cut-off levels are depicted relative to the different options of confidence level

Maximal effort		Confidence level (%)	Tolerance or cut-off level	Submaximal effort	
Mean DEC	SD			Mean DEC	SD
0.311	0.175			2.925	1.945
		90	>0.658		
		95	>0.810		
		99	>1.079		

indicates that suboptimal shoulder external rotation effort (i.e. feigned shoulder external rotators weakness) can be effectively identified using the DEC. A DEC score of 0.81 and above has been calculated to signal feigned maximal effort at a level of confidence of 95%. In the present study, all feigned maximal efforts could indeed be positively identified as feigned maximal at this level of confidence, thus demonstrating the power of the DEC as an evaluation tool (Figure 2).

This power arises from the different behaviour of the force–velocity curve in maximal compared to feigned maximal conditions namely the difficulty associated with voluntary controlling the magnitude of the feigned maximal eccentric effort. A divided central control of concentric and eccentric contractions has been indicated,[15] which could account for the differences in modulating the concentric versus the eccentric efforts. This distinct phenomenon has been highlighted by Dvir *et al.* in their series of studies[7–13] relating to the uniform capacity of the DEC in all tested muscle groups.

In the present study, maximal effort average DEC value (0.311) was well within the range reported in previous studies performed in different muscle groups: 0.007–0.68.[7–12] Regarding the feigned effort, average DEC (2.925) is lower than the one obtained in the study performed on shoulder long ROM flexion (5.35).[12] The difference between the feigned maximal DEC average value and the maximal average was 2.614 and 4.87 respectively. The latter high value has been explained by the specific performance profile of shoulder flexor muscles.[12] Shoulder flexor muscles are poorly trained in eccentric contraction since this particular action is rare. At this point, care must be taken to interpret these data. Two major issues must be highlighted. First, it is the first time that a Cybex Norm isokinetic device has been used to assess DEC. The incompatibility between

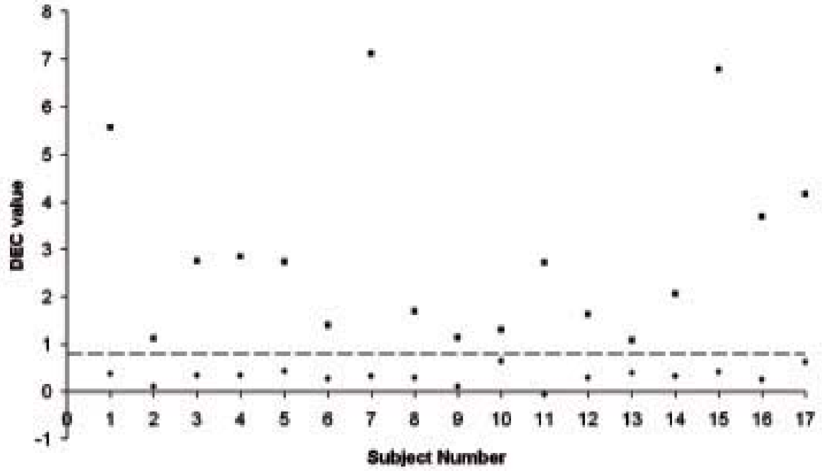

Figure 2 Case by case DEC values for the maximal (DECm) and submaximal (DECsm) efforts. Dotted line depicts the cut-off level (0.81) at a 95% level of confidence. Squares represent DECsm; diamonds represent DECm.

Clinical messages

- The DEC is a powerful tool for evaluating full collaboration in performing shoulder external rotators effort in normal subjects.
- In medicolegal situations, the DEC can be a valuable tool to detect feigned weakness, especially in subjects without evident injury.
- Further research is needed to establish the usefulness of the DEC in shoulder injury patients.

isokinetic dynamometers is well established and this could significantly contribute to the disparity. Besides, the study on shoulder flexor muscles long RoM DEC calculation used a much steeper gradient (40:160). This could also explain the long RoM shoulder flexion feigned strength DEC higher scores. Lower feigned DEC of external rotator muscles, if eventually confirmed, could describe the shoulder external rotators better eccentric activity fine tune. In fact, eccentric contraction of external rotators is not a rare action. Specific shoulder actions, such as throwing, require a highly modulated external rotator eccentric contraction in order to counteract a sudden and forceful internal rotation concentric action.[16]

Regarding the protocol applied, convenience and feasibility must be emphasized. In our facility, testing of shoulder external rotation using isokinetic dynamometry is next only to the testing of knee extensor strength. A humeral axis positioned in the scapular plane has been highly recommended in the literature and is regularly well tolerated by patients.[5,17] The test range of movement (60°) and velocities (30°/s and 120°/s) selected are broadly used and regularly recommended for rotators evaluation.[17] They can be attained by most patients in the chronic phase of shoulder injury, including the eccentric modality. Thus, protocol application in a common clinical setting is not complicated.

Although DEC-based sincerity of effort evaluation offers an attractive option, its application should be conducted with extreme care, especially in medicolegal situations. It is well known that collaboration can be affected by a variety of reasons[18] (pain, fear of pain, fear of re-injury, anxiety, depression, lack of understanding of instructions, lack of understanding of the importance of the test, and secondary, i.e. financial, gains). In this context, careful clinical evaluation of the patients or subjects being tested is recommended. Moreover, incongruence indicated by clinical evaluation can help in interpreting the isokinetic findings. In addition complementary tests such as magnetic resonance imaging, computerized tomography scans, electromyography and plain X-rays showing a mild or absence of structural injury are also crucial to fully assess the collaboration of the patient. Thus isokinetic evaluation and use of DEC should be viewed just as another diagnostic tool. Its weight depends to a great extent on the results of the other tests. In any case, in situations where muscle performance is thought to have reached a stable level, when pain is no longer present and assuming the patient understands the test procedure, failure to stay within the 95% level of confidence-based acceptance zone should give serious ground to suspected lack of co-operation in performing the test.[13]

In conclusion, the DEC is a valuable and powerful tool for evaluating full collaboration in performing shoulder external rotators effort in normal subjects. Based on this finding further research should focus on its application in patients with chronic shoulder rotational strength insufficiency, both for medicolegal situations and in the general musculoskeletal rehabilitation practice.

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Competing interests

None declared.

Contributors

All authors provided concept/idea/research design. JC and ZD provided writing. UD provided data collection, and SQ provided data analysis. JC is the guarantor.

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Capítol 5.2

Maximalitat de l'esforç de rotació externa de muscle en pacients amb lesions laborals: Aplicabilitat clínica del paràmetre DEC

Maximality of shoulder external rotation effort in patients presenting with work related injury: The clinical applicability of the DEC parameter

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Maximality of shoulder external rotation effort in patients presenting with work related injury: The clinical applicability of the DEC parameter

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J Electromyogr Kinesiology, en premsa

Objectiu

El DEC es un paràmetre molt útil en la identificació d'esforços submàxims de rotadors externs en subjectes sans. L'objectiu d'aquest treball fou examinar l'aplicabilitat del paràmetre isocinètic DEC en la identificació d'un esforç submàxim en pacients reals afectes d'una lesió de muscle amb possible debilitat muscular de rotadors. Amb aquest objectiu es van analitzar retrospectivament 74 pacients (33 dones i 41 homes) amb lesions al voltant de l'articulació del muscle avaluats mitjançant el protocol descrit en el estudi previ.

Resultats principals

Utilitzant el nivell de tall de DEC marcat per l'estudi previ en subjectes sans(0.81) la proporció de pacients etiquetats de no col·laboradors, especialment dones, era enorme. Per tant es va decidir usar els valors de l'extremitat sana per avaluar l'afecta. Aplicant aquest criteri, cinquanta dos pacients van mostrar al cantó afecte uns valors de DEC dins els rangs considerats com normals i, per tant, es van etiquetar de col·laboradors. Deu tenien uns DEC superiors al límit superior i es van considerar no col·laboradors. Finalment hi havia 12 pacients amb uns valors de DEC extremadament baixos que es van considerar com no col·laboradors.

La comparació entre sexes va mostrar una gran diferència significativa de proporció de col-laboradors a favor dels homes. En els col·laboradors els dèficits registrats mostraven una correlació molt important pel que fa a la capacitat laboral al final del procés.

Conclusió

Els resultats del present estudi van recolzar la utilització dels tests isocinètics en pacients afectes de lesions de l'articulació del muscle, tan des del punt de vista clínic com mèdico-legal.

No obstant, calgué remarcar que els criteris derivats de subjectes sans s'haurien d'aplicar amb molta precaució en pacients, sobretot si són dones. En aquest grup es requereix més recerca.

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Maximality of shoulder external rotation effort in patients presenting with work related injury: The clinical applicability of the DEC parameter

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ABSTRACT

The aim of the present study is to examine the applicability of the isokinetic DEC parameter for identifying submaximal effort in workers with potential weakness of the shoulder external rotators. A previous study indicated that the DEC was a powerful identifier of submaximal effort of shoulder external rotation in normal volunteers. Its applicability in shoulder injury patients is of specific interest. Thus, a retrospective study of 74 (33 female and 41 male) patients who claimed compensation for work-related shoulder injury was designed. 52 patients had their injured side DEC values within the normal range and were thus labeled as maximal performers. Ten patients had higher than cutoff DEC values, indicating submaximal effort whereas 12 patients had exceedingly low DEC values. Gender comparison showed a significantly different proportion of maximal performers. Strength deficits registered in patients demonstrating maximal performance correlated with the final outcome. The findings support the application of the DEC for determination of the extent of weakness of shoulder external rotators in male patients. In terms of shoulder external rotators status in male worker injury, the results support the application of isokinetic tests both in the clinical and medicolegal sense. However, the gender discrepancy warrants further research.

1. Introduction

Shoulder injuries are a major management problem in musculoskeletal rehabilitation and occupational medicine settings. A 1-year prevalence study of shoulder pain interfering with occupational activities indicated a rate of 9% (Palmer et al., 2001). Most patients require extensive treatment with drugs, physical therapy and in some cases, surgery. Following treatment return to work may be difficult. Due to their high prevalence, the economic consequences of shoulder pain are enormous (Waehrer et al., 2005). Regarding workers' compensation patients, it has been well documented that work injury is associated with poorer outcomes, especially following surgery (Koljonen et al., 2009; Viola et al., 2000; Sallay et al., 2005). It has been postulated that this phenomenon was caused by the fact that most commonly adopted shoulder-specific functional outcome measurement tools are subjective in nature (Koljonen et al., 2009). Thus, objective and precise evaluation of the deficits and determination of the degree of potentially permanent impairment are highly desirable in order to facilitate decision making in worker compensation shoulder injury patients.

One of the major manifestations of shoulder injury causing dysfunction is muscle weakness. Objective evaluation of shoulder muscles performance is therefore of a significant value. It provides information essential for treatment or rehabilitation, as well as assessment of clinical outcomes and permanent impairment which might interfere with work ability. Isokinetic dynamometry enables accurate and reproducible measurement of muscle strength (Greenfield et al., 1990; Plotnikoff and McIntyre, 2002). However, patient maximal effort is crucial in order to produce meaningful results. Indeed for both clinical and medico-legal decisions, estimation of the patient maximal effort is crucial. It has been demonstrated that a powerful tool for assessing maximallity of effort is the DEC, a parameter that derived from the numeric difference between the eccentric/concentric strength ratios at relatively high and low test velocities. Specifically, the DEC was highly effective in identifying submaximal muscular effort in normal subjects (David et al., 1996; Dvir and David, 1996; Dvir, 1997a,b; Dvir,

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1999; Dvir and Keating, 2001; Dvir et al., 2002; Chaler et al., 2007; Olmo et al., 2009) as well as in patients (Dvir, 2002). The physiological rationale for the method derives from the different mechanical output of eccentric and concentric contractions, especially when performed at a submaximal level. In submaximal contractions the ability to control muscle tension differs significantly between the two contraction modes. Thus, as far as concentric activity is concerned, when subjects are asked to perform submaximally the difference between their strength output at low and high velocities is quite considerable. In contrast, the drop in eccentric output is rather moderate. Based on these variations it was suggested that by comparing Ecc/Con Rations related to velocities that are set a sufficiently large gradient, one could potentially differentiate between maximal and submaximal effort (Dvir, 2004). The efficiency of the DEC in identifying maximality of shoulder external rotation effort has been demonstrated in a group of male volunteers (Chaler et al., 2007) but not in patients.

Therefore, the objective of the present study was threefold: 1. to examine the use of the DEC in identifying suboptimal effort in patients suffering from work related injury to the shoulder external rotators, 2. to assess the significance of gender in DEC-based evaluation, 3. to analyze the usefulness of isokinetic testing of shoulder external rotation strength for evaluating long term patients with shoulder injuries who seek compensation.

2. Material and methods

2.1. Subjects

74 unilateral shoulder injury patients (33 women and 41 men), aged 18–65 years (48.1 ± 10.2) participated in the study (Table 1). All participants were seeking compensation for work-related injuries affecting shoulder external rotation function. In all patients this dysfunction had a potential medico-legal context in terms of various secondary gains such as avoiding onerous work duties and/or seeking economic benefits. The objective of the test was to help decision making regarding return to work planning and/or compensation allocation. All subjects received a talk from the testers before the actual test. They were instructed about test protocol and aim. The importance to perform a maximal effort during the test in order to obtain meaningful results was highlighted during the talk. They also signed an informed consent form before the test was performed. The study design was approved by the local IRB.

Table 1
Baseline demographics diagnosis and work related outcomes. Comparison between genders. Note that, as expected, the only significant difference among groups is found in weight (*). Diagnosis proportion differences were not significant between genders.

	Female	Male
No. of worker compensation patients included	33	41
Mean age (yr ± SD)	48.48 ± 9.6	47.78 ± 10.84
Mean weight (kg ± SD)	67.97 ± 10.74	80.34 ± 11.67*
Mean process duration (days ± SD)	271.24 ± 168.99	306.49 ± 242.54
Diagnosis		
Impingement/rotator cuff tendinosis	12	15
Arthroscopic surgery	10	4
Rotator cuff surgical reconstruction	7	8
Instability	1	7
Other	3	7
Outcomes (work related)		
Complete healing	20	22
Impairment, no disability	5	4
Impairment, partial disability	1	2
Impairment, total disability	7	13

2.2. Testing protocol

The testing protocol for isokinetic shoulder external rotation strength has been previously described (Chaler et al., 2007). A Cybex Norm® isokinetic dynamometer (Rokonkoma, New York) was used. The device was fully calibrated before every test. Warm up and testing was conducted with the subject seated on an adjustable seat and proximally stabilized using cross chest straps. The arm was positioned in the scapular plane, between 30° and 45° anterior to the frontal plane and elevated 45°. Goniometry was used to check positioning. Elbow was maintained at 90° flexion and supported by a standard shoulder rotation attachment. A forearm strap helped positioning the elbow. The forearm remained neutral during the testing protocol while the hand grasped a handle connected distally to the lever arm. The mechanical axis of the lever arm was aligned with the humeral shaft (see Fig. 1).

The test protocol started with familiarization and warm up. It consisted of one set of 10 increasing submaximal concentric contractions, one set of 10 increasing submaximal eccentric contractions, a 2 min rest period and two short (3 or 4 contraction) set of maximal concentric and eccentric contraction respectively. After 3 min rest the actual test started. Testing was performed bilaterally starting on the injured side. The test range of motion (RoM) was 60°, starting from 55° internal to 5° external rotation. During the test performance, subjects were asked to exert maximal effort against the lever arm whose angular speed was first set at 30°/s. The test consisted on four pairs of intermittent, reciprocal, concentric-eccentric contractions with a 5 s inter-contraction pause and a 25 s interpair pause. Following a 5 min pause, speed was then raised to 120°/s and the same protocol was applied again. Allowing a 5 min pause, testing of the uninjured side was then conducted applying the same protocol.

2.3. Data reduction and statistical analysis

Demographic (weight, age), injury (diagnosis and process duration in days) and outcome data were registered for each patient.

Fig. 1. Patient positioning: humeral shaft is in the scapular plane and, at the same time, aligned to the dynamometer rotation axis.

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Process duration was defined as the time between injury date and follow-up discharge and/or return to work. Diagnoses comprised (1) impingement/rotator cuff tendinosis, (2) arthroscopic decompression surgery, (3) rotator cuff reconstruction, (4) instability and (5) other (fractures and nerve injury). Four functional outcome levels were defined according to the local working compensation system related to the injury: (1) complete healing (patient does not deserve compensation), (2) impairment without work disability (namely, patient fully returns to previous work and deserves compensation), (3) impairment and partial work disability (namely, patient returns to previous work with work adaptations and deserves a higher compensation) and, (4) impairment leading to total work disability (namely, patient does not return to previous work and deserves a lifetime compensation, however the patient may be employed in a less demanding job).

The strength of the shoulder external rotators was defined by the maximum point of the muscle's torque vs. angular position curve (the peak torque – PT, expressed in Nm) of each contraction and the criterion strength was the mean value of the four individual contractions. To assess effort maximality, the eccentric/concentric ratios (ECRs) were calculated for each speed and side (injured and uninjured). The DEC was defined as the difference in the ECRs:

$$\mathrm{DEC} = (\mathrm{Ecc/Con})_{120} - (\mathrm{Ecc/Con})_{30},$$

Two methods of interpretation were used. Using the first, the DEC scores obtained from normal subjects (Chaler et al., 2007) were applied and thus any DEC score above 0.81 was considered as indicative of submaximal effort at the 95% level of confidence. According to the second, the DEC values derived from the apparently patient's uninvolved side served for assessing the admissibility of the involved side providing the latter stayed within the mean DEC value ± 2SD of the uninvolved side. Thus DEC values above 2.25 and 1.6 or below −0.83 and −0.6, for women and men respectively were labeled "outside the normal range".

The deficits for each velocity and contraction modality (i.e. concentric and eccentric) were calculated in those patients showing maximal effort parameters and expressed in percentage by applying the following formula:

$$\mathrm{Deficit} = 100 - (\text{injured side PT/uninjured side PT}) \times 100.$$

PT: peak torque.

Patient deficits were labeled relevant when bilateral difference was above 20%(1).

Demographic, diagnostic and outcome data and isokinetic parameters results were compared separately for women and men (Tables 1 and 2) due to the significant differences in the PT. Pearson's χ^2 (chi-square) test was applied to compare qualitative data sets. Unpaired *t*-tests and ANOVA were performed to compare quantitative data whose normality had been previously evaluated using the Kolmogorov–Smirnov test. Mann–Whitney test was used to compare quantitative variables which were not normally distributed. Finally, the uninvolved side's DEC tolerance interval was calculated.

Table 2
Shoulder external rotators isokinetic test mean variables (PT) and parameters (ECR and DEC): comparison between genders and sides.

	Women	Men
PT		
30°/s concentric		
Involved side	5.01 ± 3.29	12.73 ± 7.20[a]
Uninvolved side	9.96 ± 4.03[b]	22.45 ± 8.40[a,b]
30°/s eccentric		
Involved side	14.31 ± 5.25	23.02 ± 8.99[a]
Uninvolved side	15.85 ± 4.84	30.18 ± 9.08[a,b]
120°/s concentric		
Involved side	3.95 ± 3.002	10.23 ± 5.57[a]
Uninvolved side	7.28 ± 3.10[b]	16.87 ± 7.56[a,b]
120°/s eccentric		
Involved side	13.21 ± 5.02	22.93 ± 8.81[a]
Uninvolved side	15.67 ± 4.32[b]	25.90 ± 8.63[a,b]
ECR		
30°/s		
Involved side	4.28 ± 3.72	2.48 ± 2.65[c]
Uninvolved side	1.77 ± 0.67[d]	1.40 ± 0.24[c,d]
120°/s		
Involved side	4.97 ± 3.83	3.11 ± 3.22[c]
Uninvolved side	2.48 ± 1.13[d]	1.90 ± 0.67[c,d]
DEC		
Involved side	0.69 ± 3.89	0.62 ± 2.78
Uninvolved side	0.71 ± 0.77	0.50 ± 0.55

PT: peak torque.
ECR: Eccentric to concentric ratio.
DEC: Difference of eccentric/concentric ratio at high and low velocities.
[a] Male PT values significantly higher than female ones.
[b] Uninvolved side PT values significantly higher than involved side ones.
[c] Male ECR values significantly lower than female ones.
[d] Uninvolved side ECR values significantly lower than involved side ones.

3. Results

Except for weight, inter-gender differences were unremarkable (Table 1). The most frequent diagnostic group was impingement/rotator cuff tendinosis in both men and women, followed by rotator cuff reconstruction in men and arthroscopic surgery (decompression) in women. As for the functional level, the most frequent in both groups was complete healing but this was followed by total work disability. Peak torque inter-gender comparison showed that, in all cases, men were significantly stronger than women whereas in terms of uninvolved vs. involved side, the former was significantly associated with higher PT. (Table 2). Peak torque analysis relating to the eccentric to concentric ratios (the ECR) indicated that in all cases the values associated with the uninvolved side were significantly lower than those in the involved side and those derived from the higher speed test higher than their low speed counterparts (Table 2). Of particular note were the disproportionately high SDs in the involved side. The women's ECRs were significantly larger than the men's whereas the DEC scores were gender independent although in this case as well, the involved side SDs were at least 4 times higher than those of the uninvolved side.

A case by case comparison of the individual DEC values to previously calculated (Chaler et al., 2007) normal subjects-based maximal effort mean DEC ± 2SD (−.039 to .611) permitted the classification of the present cohort into three sub-groups: less than −.039, between −.039 and .661 and greater than .661 (Table 3). This resulted in 82% (27/33) of the women and 39% (16/41) of the men falling outside the normal range of the DEC. This inter-gender proportion was significantly different ($\chi^2 = 14.2$; $p < 0.001$). Significantly, 14/27 of the women and 10/16 of the men had DEC values above the normal range resulting in their classification as submaximal performers, using the comparison to normal DEC approach. On the other hand the DEC scores of 13/27 (women) and 6/16 (men) fell below the range. Analysis of the DEC scores of the uninvolved side revealed that in most (namely 57.57% and 75.6% of women and men respectively) cases they were within normal limits and indicating no gender differences ($\chi^2 = 3.4$; $p = 0.178$). Most (namely 39.4% and 24.4% of women and men respectively) of uninvolved side DEC outside limits were above the normal DEC + 2SD. Of note, only one female subject registered a negative DEC. Comparison with involved sides showed significant differences both for women and men.

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Table 3
Patient distribution related to DEC value compared to normative DEC value ± 2SD in involved and uninvolved sides. Note that the proportion of females showing a DEC outside the range in the involved side is higher than the number of men. The difference is highly significant. Comparison between sides in each gender also shows highly significant differences.

	Involved side		Uninvolved side	
	Female	Male	Female	Male
DEC value above normative DEC + 2SD[a]	14	10	13	10
DEC value within normative DEC ± 2SD	6	25	19	31
DEC value below normative DEC − 2SD[b]	13	6	1	0

[a] Above 0.661 both for women and men.
[b] Below −0.039 both for women and men.

Table 4
Patient distribution related to involved side DEC value compared to uninvolved DEC value ± 2SD. Comparison between genders shows significant proportion differences (namely, only 54.54% of women rated DEC within limits whilst 82.92% of men did).

	Female	Male
DEC value above uninvolved side DEC + 2SD[a]	7	3
DEC value within uninvolved side DEC ± 2SD	18	34
DEC value below uninvolved side DEC − 2SD[b]	8	4

[a] Above 2.25 and 1.6 for women and men respectively.
[b] Below −0.83 and −0.6 for women and men respectively.

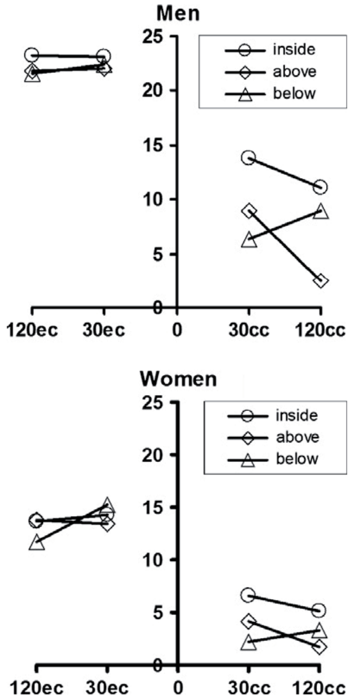

Fig. 2. Torque–velocity graphs of involved side mean PT records (Nm) for patients (men and women) inside, below and above uninvolved side DEC ± 2SD. 120ec: 120°/s eccentric contraction. 30ec: 30°/s eccentric contraction. 30 cc: 30°/s concentric contraction. 120ec: 120°/s concentric contraction. Inside: graph of patients whose injured side DEC was within range (uninvolved side DEC ± 2SD). Above: graph of patients whose injured side DEC was above upper limit (>uninvolved side DEC + 2SD). Below: graph of patients whose injured side DEC was below lower limit (<uninvolved side DEC − 2SD).

To further assess DEC compatibility the alternative approach in which the gender-based range of DEC values of the uninvolved side (mean ± 2SD) namely −0.83–2.25 and −0.6–1.6, for women and men, respectively, was applied. Thus, patients whose DEC value was inside those limits were labeled as maximal performers. This resulted in classifying 18/33 (55%) of the women and 34/41 of the men (83%) as maximal effort performers in terms of DEC value (Table 4). Thus, the proportions of maximal performers rose significantly for women ($\chi^2 = 8.3$; $p = 0.016$) but not for men ($\chi^2 = 5.54$; $p = 0.063$, Tables 3 and 4). Similar to the outcome of the first approach the proportion of male patients with involved side DEC within the limits was significantly higher than that of the females' ($\chi^2 = 8.42$; $p = 0.015$). In 7 (21%) women and 3 (7%) men, the DEC score was above the upper bound of the DEC indicating a strong (95%) likelihood of submaximal effort. On the other hand, in 8 women and 4 men, the involved side DEC was below the lower bound of the DEC (i.e. negative DEC). To assess the meaning of the negative DEC, Fig. 2 shows the force–velocity curves for each patient group. Both female and male patients whose involved side DEC was below the lower bound had a rise of the concentric PT in the higher velocity (120°/s), a finding that runs opposite to the common physiological behavior of the muscle. On the other hand, in women, the eccentric branch of curve demonstrated a sharp decline with velocity rise. This finding is partly in variance to the normal muscle physiology which indicates either a rise or levelling off of the eccentric strength.

In order to assess this difference in both men and women, the interaction between the curves (inside, above and below) was analyzed by using two separate bifactorial variance analyses. These analyses indicated, both for woman and men, no difference in terms of the eccentric torque fall-off ($p = 0.96$ and $p = 0.95$ for woman and men respectively). The concentric branch analysis showed that "below lower bound" DEC group curve behavior was significantly different from those of other patient groups ($p = 0.01$) in women. However, such a difference could not be demonstrated ($p = 0.07$) in men.

The relationships between the DEC and gender and the most frequent diagnostic group (impingement/rotator cuff tendinosis, arthroscopic surgery and rotator cuff reconstruction) were assessed by a bifactorial ANOVA (gender × main diagnostic group) were unremarkable. The other bifactorial ANOVA (gender × outcome) regarding the relationship between the DEC and functional outcome (complete healing, impairment without work disability, partial work disability, total work disability) yielded the same result.

Finally, the strength findings of the 25 male patients whose DEC indicated maximal effort according to the first approach (normal subjects'-based DEC) were analyzed in order to assess clinical relevance of shoulder external rotator isokinetic strength measurements in real worker compensation patients (Table 5,). The only significant difference was revealed between patients who demonstrated "complete healing" and those with any degree of "impairment".

4. Discussion

To the best of our best knowledge this may be the first study relating to maximality of effort among patients seeking compensation for chronic shoulder joint injury. The findings of the present study indicate that the DEC is a potentially useful tool for assessing maximality of effort in worker compensation claims relating to weakness of the shoulder external rotators. Remarkably, most of the patients met the criteria of full collaboration according to the second approach i.e. when the DEC of the uninvolved side served as the cutoff score. In the medicolegal context as well as in the clinical setting, confirmation of full effort is a sine qua non condition

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Table 5
Male Maximal effort group external rotator deficits (in %) related to main diagnostic groups (impingement/rotator cuff tendinosis and surgically treated rotator cuff patients) and main final work related outcomes (total healing and some degree of impairment) are shown. Note that patients whose final outcome indicated impairment, showed significantly higher deficits in all isokinetic records when compared to completely healed patients. Surgically treated patients rated highest deficits than impingement/rotator cuff tendinosis ones; however significant differences could not be demonstrated.

	30°/s conc	30°/s ecc	120°/s conc	120°/s ecc
Diagnostic groups				
Impingement/rotator cuff tendinosis ($n = 9$)	26.60 ± 38.35	16.43 ± 21.41	30.12 ± 33.58	13.51 ± 24.97
Surgically treated patients (decompression and Rotator cuff reconstruction ($n = 7$)	47.98 ± 37.34	31.60 ± 23.32	41.16 ± 29.61	27.39 ± 23.52
Outcomes (work related)				
Complete healing ($n = 15$)	19.22 ± 34.77	9.88 ± 18.24	19.62 ± 31.99	8.96 ± 20.89
Impairment (any degree) ($n = 10$)	58.86 ± 17.65[a]	38.38 ± 21.31[a]	50.89 ± 15.82[a]	32.52 ± 19.75[a]

Conc: concentric contraction.
Ecc: eccentric contraction.
[a] Impaired shoulder patient deficits significantly higher than "complete healing" patient ones.

for decision making. Once maximal muscular effort is assured, the relative strength deficiency of the involved side can serve as a crucial factor in decisions relating to return to work and/or degree of disability (compensation allocation).

Analysis of demographic, diagnostic group and outcome data highlights, beyond the obvious significantly higher male weight, that the patients are middle aged (i.e. active workers) and the process length indicates an extremely long duration. This may be due to medico-legal causes, severity of the injury or both. An additional cause might be that in our setting the long or very long duration of processes have been a usual indication of comprehensive isokinetic tests. This fact might have biased the results in the present sample so that most patients could be medically complicated and/or in the process of litigating (i.e. medico-legal patients). However, this is an important group in worker compensation patients and, thus, present study results might be especially helpful in dealing with such particular population. Regarding diagnostic groups, as expected, rotator cuff surgical and non-surgical pathologies predominate. Fortunately, most of patients recorded returned to work with complete healing. However, the percentage of patients with a relevant impairment leading to total work disability at the end of the process is relevant: 31.7 in men and 21.2 in women. The present findings are similar to those of a previous report on shoulder tendinosis related to repetitive work which indicated that 25% of injured workers did not recover after 22 months (Bonde et al., 2003).

As expected, the PT values of shoulder external rotation, both in the concentric and eccentric modes and for the two velocities were significantly higher in men compared to women and in the uninvolved side compared to its involved counterpart (Table 2). On the other hand, the bilateral ECRs in both the uninvolved and involved sides were significantly higher in women than in men, a finding that may reflect a different gender-based muscular behavior and one which, as far as we are aware of, has not been previously reported. In spite of these discrepancies, the DEC scores remained stable irrespective of side and gender (Table 2). However, the dispersion of scores in the involved side as evidenced by the fact that the SDs which were 4 times higher than those calculated for the uninvolved side, indicate a highly different performance of the involved side muscles.

In order to assess the optimality of effort the patients' DECs were individually compared with the cutoff value derived from a previous study of apparently healthy subjects which was based on an identical testing protocol (Chaler et al., 2007). This resulted in an unexpected classification of 61% of the male and 18% of the female patients as optimal performers, namely, their DEC value was lower than 0.661 and higher than −0.039. In addition, women showed a conspicuous proportion of DEC scores that were below the lower bound of the acceptability zone (Table 3). In this context the meaning of DEC scores that were *below* the lower bound mandates a special interpretation. The DEC derives from the substraction of the low velocity ECR from its high velocity counterpart. Normally, the latter is greater then the former as the concentric branch yields lower scores with rise in the velocity whereas the eccentric branch plateaus with velocity increase or may even rise, especially in what is considered as a medium velocity (120°/s). However, this result may change if either the concentric scores increase with the test velocity, the eccentric scores decrease or a combination of both occurs. Indeed, as amply demonstrated in Fig. 2 both have taken place resulting in a situation where $ECR_{120} < ECR_{30}$ leading to negative DEC scores. This situation has been observed on occasion and was related to either pain or apprehension (or both). Inasmuch as pain is concerned, a longer exposure to loads developed by contracting muscle/s, which invariably happens when the test velocity is lower (in this case 30°/s), has been previously associated with much diminished strength score in patello–femoral pain syndrome (Dvir et al., 1990). This mechanism may well operate in patients exerting maximal shoulder external rotation effort where pain where discomfort or apprehension could inhibit full expression of the involved muscles' capacity. While this argument is speculative at the moment, we believe that scores that fall below the lower bound should be classified under the 'optimal' rather than 'suboptimal' performance.

In this respect the high proportion of women and men, 39% and 24%, respectively, whose uninvolved side DEC indicated insincere effort became a concern since a submaximal effort in the uninvolved side is difficult to explain, even in the present cohort. Collectively put, these findings render the application of a cutoff score that is based on the DEC derived from apparently healthy subjects untenable. We attribute this conclusion to a combination of factors consisting of the fact that the DEC is derived from ratios and not from absolute values, the chronicity of the pathology which may affect the uninvolved side as well and to the age of the subjects in the present compared to the previous study. In brief, probably DEC derived from young healthy subjects may not be a good reference for real patients. In real patients a number of factors may influence DEC, among them gender, age, physical condition, level of procedure comprehension and others. Thus we adopted an alternative, more clinically plausible cutoff value based on the patients' uninvolved side DEC, 2.64 and 1.84 for women and men respectively. This approach resulted in a dramatic change in those patients who were classified as sub-optimal performers. As stated above, in this case proportion of women whose DEC indicated maximal effort trebled from 18% to 55%. The parallel rise in men was less dramatic although the rise from 61% to 83% is quite impressive. However, the difference in the proportion of maximal

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performers between genders persisted supporting the impression that women performed somewhat differently in the sense of higher ECRs, particularly considering that inter-gender demographic, diagnostic and outcome differences were unremarkable. The behavior of the DEC as it relates to gender, has been studied in few volunteer studies (Dvir and Keating, 2001), which indicated that women tended to register a higher DEC in trunk extensor muscle tests. Regarding women with pathology only a single previous study (Dvir, 2002) included four women and did not mention any influence. However, at the present stage we cannot offer an explanation for the different concentric-eccentric relationships between women and men.

The bifactorial ANOVA (gender × diagnostic group) failed to reveal a specific influence of diagnosis on the DEC. This permits the conclusion that shoulder pathology may not directly influence the DEC score. Furthermore given the relatively high proportion of surgically treated patients, 17 out of 33 in women and 12 out of 41 in men, the apparent stability of the DEC when comparing results in different diagnostic groups supports its value in clinical decision making.

Analysis of the strength deficits found in 25 male patients labeled as maximal performers revealed some interesting findings. Patients with impairment had significantly higher deficits than patients whose final outcome was complete healing where the latter refers to deficits that were all less than 20% (Sapega, 1990). This finding highlights the applicability of isokinetic analysis in facilitating a decision pertaining to return to work planning and follow-up discharge in these patients. Moreover, since all patients presenting with impairments received compensation, the extent of strength deficit was crucial for the allocation of resources to those patients.

Several limitations are associated with the present study results clinical applicability. First, until the DEC is accepted as a standard for maximality of effort, the lack of an alternative parameter somewhat diminishes the power of the former. Second, the lack of uniformity in diagnosis (i.e. the patient group consisted of rotator cuff disorders, fractures and instability surgically or nonsurgically treated) in present sample may confuse the picture. Therefore narrowing of the diagnostic range in further studies would be highly desirable. Third, the application of tolerance intervals enabled rigorous cutoffs but these should be used with extreme caution until further support is derived from other studies, both in men and, specially, in women. Finally, where primary and/or secondary gains are involved, making a decision is even more challenging. Specifically, it is well known that collaboration can be affected by a variety of reasons (Lechner et al., 1998) such as pain, fear of pain, fear of re-injury, anxiety, depression, lack of understanding of instructions and lack of understanding of the importance of the test. In other words, submaximal effort does not necessarily mean that the patient is intentionally producing a misrepresentation. In any case, repetition of the test as many times as it might be needed is highly recommended when any doubt about maximallity of effort arises.

Further studies would be desirable to complete present one. For instance, as far as the present cohort is considered, since all the patients were employees who sought compensation, information regarding parallel claims that were not related to worker compensation scheme would add significant information.

In conclusion, isokinetic tests are highly useful in evaluating strength deficiencies associated with shoulder external rotator strength, in clinical decision making, discharge planning, and disability evaluation. They may also be a crucial tool for yielding medico-legal decisions where the muscular deficiency accounts for all or part of the damage. In this regard the judicious use of the DEC has been shown to be reasonably effective in the screening of male patients seeking compensation associated with work related injury. However, its adequacy in women requires further research. Thus although DEC-based sincerity of effort evaluation offers an attractive option for detecting submaximal collaboration, its application should be conducted with the implied degree of care.

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Capítol 5.3

Avaluació de la sinceritat de l’esforç en el muscle mitjançant dinamometria isocinètica

Evaluación de la sinceridad del esfuerzo en el hombro mediante dinamometria isocinética

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Objectiu

L’objectiu d’aquest treball va ser analitzar la experiència en una sèrie de casos en que es va avaluar la força i la sinceritat de l’esforç de la musculatura de l’espatlla mitjançant dinamometria isocinètica.

Els pacients van ser avaluats mitjançant dinamometria isocinètica. 14 pacients (13 homes i una dona; edat mitjana 46 anys; la majoria treballadors manuals) remesos a la unitat de isocinesia d’una mútua laboral per avaluació de la força muscular de l’espatlla. La patologia més freqüent va ser la ruptura de manegot dels rotadors intervinguda. El protocol comprenia la determinació dels moments de força màxims d’ambdós espatlles en rotacions, abducció i flexoextensió a diferents velocitats (60º·-1, 120º·-1 i 180º·-1) i dues modalitats de contracció (concèntrica i excèntrica). A continuació, es van calcular els dèficits de força i les ràtios contracció excèntrica/concèntrica (REC). Un dèficit major al 20% es considerà rellevant i un REC superior al 2,05 suggestiu de poca col·laboració.

Resultats principals

Dotze pacients van mostrar dèficit rellevants de força muscular, dels quals cinc van presentar indicis de poca col·laboració. Tres van acceptar la proposta d'alta basada en els resultats, un continuava de baixa en el moment de l'anàlisi i en un cas va ser utilitzada com a prova en magistratura per desestimar la petició d'incapacitat del pacient.

Conclusió

L'aproximació a la mesura de la força muscular de l'espatlla proposada en aquest treball va ser útil per prendre decisions en un entorn laboral. No obstant, l'alta freqüència de indicis de manca de col·laboració fa essencial que la mesura de la força muscular mitjançant dinamometria isocinètica vagi acompanyada sempre d'una valoració del grau de col·laboració del pacient o subjecte durant la realització de la mateixa. Aquesta necessitat es fa més palesa en pacients laborals per les implicacions medico-legals que poden comportar les proves.

ORIGINAL

Evaluación de la sinceridad del esfuerzo en el hombro mediante dinamometría isocinética

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Resumen.—La determinación del déficit de fuerza muscular como secuela es fundamental en la rehabilitación laboral. Para definir un déficit muscular se requiere una colaboración máxima del paciente en la realización del esfuerzo. La valoración de la colaboración de los pacientes en la realización de las pruebas dinamométricas se ha venido realizando mediante el coeficiente de variación, aunque la literatura reciente cuestiona esta aproximación y propone otras basadas en la fisiología de la contracción muscular máxima en modalidades concéntrica y excéntrica.

El objetivo de este trabajo es analizar nuestra experiencia en la evaluación de la fuerza y la sinceridad del esfuerzo de la musculatura del hombro mediante dinamometría isocinética.

Material y métodos: Se aplica el protocolo evaluador a 14 pacientes (13 varones y una mujer; edad media 46 años; la mayoría trabajadores manuales) remitidos a la unidad de isocinesia de una mutua laboral para peritación de la fuerza muscular del hombro. La patología más frecuente fue la ruptura de manguito intervenida. El protocolo comprende la determinación de los momentos de fuerza máximos de ambos hombros en rotaciones, abducción y flexoextensión a diferentes velocidades (60°/s, 120°/s y 180°/s) y dos modalidades de contracción (concéntrica y excéntrica). A continuación, se calculan los déficit de fuerza y los ratios contracción excéntrica/concéntrica (REC). Un déficit mayor al 20% se considera relevante y un REC superior al 2,05 sugestivo de poca colaboración.

Resultados: Doce pacientes mostraron déficit relevantes de fuerza muscular, de los cuales cinco presentaron indicios de poca colaboración. Tres aceptaron la propuesta de alta basada en los resultados, uno continua de baja y en un caso fue utilizada como prueba en magistratura para desestimar la petición de incapacidad del paciente.

Discusión: La medición de la fuerza muscular mediante dinamometría isocinética debería acompañarse siempre de una valoración del grado de colaboración del paciente. La aproximación propuesta en este trabajo nos ha sido útil en un entorno laboral.

Palabras clave: *Isocinéticos. Hombro. Evaluación.*

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EVALUATION OF THE SINCERITY OF THE EFFORTS IN THE SHOULDER BY ISOKINETIC DYNAMOMETRY

Summary.—Determination of muscular strength deficit as a sequel is fundamental in work rehabilitation. To define muscular deficit, maximum collaboration of the patient is necessary in performing the effort. Assessment of the collaboration of the patients in the performance of dynamometric tests has been done by variation coefficient (VC), although recent literature questions this approach and proposes others based on the physiology of maximum muscular contraction in concentric and eccentric modalities.

This study was aimed to analyze our experience in the assessment of strength and the sincerity of the shoulder muscle effort by isokinetic dynamometry.

Material and methods: The evaluation protocol was administered to 14 patients (13 male and one female, mean age 46 years; most manual workers) sent to the isokinesis unit from a work insurance company for evaluation of the muscular strength of the shoulder. The most frequent pathology was rupture of the cuff operated on. The protocol includes determination of the maximum force times of both shoulders in rotations, abduction and flexoextension at different speeds (60°/s, 120°/s and 180°/s) and two modalities of contractions (concentric and eccentric). In the following, the force deficit and concentric and eccentric contraction ratios (CER) were calculated. A deficit greater than 20% is considered relevant and a CER superior to 2.05 suggestive of little collaboration.

Results: 12 patients showed relevant deficits of muscular force, of which 5 presented signs of little collaboration. Three accepted the proposal of discharge based on the results, one continued on sick leave and in one case, it was used as a expectice in the courts to reject the request for work incapacity of the patient.

Discussion: The measure of muscle strength by isokinetic dynamometry should always be accompanied by assessment of the degree of collaboration of the patient. The approach proposed in this study has been useful in the work setting.

Key words: *Isokinetics. Shoulder. Assessment.*

INTRODUCCIÓN

La dinamometría isocinética se ha convertido en los últimos años en una técnica muy extendida en la práctica médica, no en vano carece de las limitaciones de la aproximación manual a la hora de realizar la valoración del balance muscular. Este hecho hace que la evaluación dinamométrica con isocinéticos se utilice cada vez más en el ámbito de la rehabilitación laboral y evaluación del daño corporal o peritaje. En este entorno las secuelas de pacientes con patología del hombro constituyen un nutrido y problemático grupo. Es habitual por parte de pacientes laborales la demanda de más atenciones o compensaciones por pérdida de fuerza en el hombro después de una lesión. No hace falta comentar las grandes implicaciones que puede tener este hecho en los costos de asistencia y retribuciones económicas, de ahí la importancia de disponer de una herramienta que por un lado nos permita determinar un déficit de fuerza y por otro nos indique el índice de colaboración del paciente en la realización de la prueba. En efecto, para que de una medición mediante dinamometría isocinética podamos inferir conclusiones clínicas válidas, los resultados emitidos deben ser veraces, es decir el esfuerzo realizado por el paciente debe ser máximo[1]. Por tanto, la cooperación del paciente en la realización de la prueba es fundamental. En relación a esta premisa, han surgido diferentes aproximaciones a la evaluación de la sinceridad en la realización del esfuerzo mediante dinamometría isocinética. En un inicio, la valoración de la sinceridad del esfuerzo se basó en la determinación del coeficiente de variación (CV) de una serie de mediciones. No obstante, este parámetro se ha mostrado ineficaz en la determinación de la sinceridad o la colaboración en el momento de realizar un esfuerzo muscular[2-6].

Una aproximación alternativa a la evaluación de la fuerza muscular y la sinceridad del esfuerzo estaría basada en la curva fisiológica fuerza-velocidad[7]. En pacientes motivados la fuerza máxima se desarrolla en las contracciones excéntricas, en cuyo caso no varían en gran medida con la velocidad. En cambio, en las contraciones concéntricas la fuerza alcanzada disminuye con el aumento de velocidad. El ratio del pico de fuerza excéntrico/concéntrico (REC) ha sido definido para el hombro entre 1,1 y 1,7[8], o en general entre 0,95 y 2,05[9]. Desviaciones a la baja de dicho ratio indicarían patología dolorosa y desviaciones a la alza pueden ser secundarias a espasticidad o patología intrínseca muscular[9]. En recientes años han aparecido en la literatura protocolos para aproximarse a la valoración de la sinceridad del esfuerzo en diferentes segmentos (rodilla, codo, tronco y garra) basados en la fisiología de la contracción de la musculatura[5, 10-12]. En ellos se propone un ratio, el DEC (diferencia excéntrico-concéntrico), resultante de sustraer el REC a velocidad baja del REC a velocidad alta, que aglutina todos los aspectos de la fisiología de la contracción muscular en relación a la velocidad. Una constante en estos estudios es el aumento importante de los REC cuando se realiza un intento de simular un déficit de fuerza. La utilidad de estos protocolos subrayan la evidencia acumulada que alude a un control motor de la contracción concéntrica diferente al de la contracción excéntrica[13]. Los aumentos de los REC traducirían una capacidad limitada para realizar contracciones submáximas en contracciones excéntricas, al contrario de lo que pasaría en las contraciones concéntricas. Así, si sometemos el paciente a una evaluación a diferentes velocidades y modalidades de contracción y los resultados no se ajustan a lo esperado según la evidencia disponible sobre fisiología de la contracción muscular, podemos afirmar que hay elementos para dudar de la sinceridad del esfuerzo.

El objetivo de este trabajo es evaluar los resultados de una aproximación analítica, basada en la evidencia disponible sobre fisiología muscular expuesta más arriba, a la evaluación mediante dinamometría isocinética de la fuerza muscular y su sinceridad en la musculatura rotadora, flexo-extensora y abducción del hombro en el entorno de una mutua laboral.

SUJETOS Y MÉTODOS

Sujetos

Se evalúan 14 sujetos remitidos a la unidad de valoración isocinética de una mutua de accidentes laborales (tabla 1), para ser sometidos a una evaluación pericial de la fuerza muscular en el hombro. La muestra se recogió por orden de llegada a la unidad. La edad media de los pacientes era de 46,07 años. La mayoría eran hombres 13/14. La intensidad de las actividades laborales en relación al peso levantado era en la mayoría de los casos de carácter alto- muy alto, es decir la mayoría de los pacientes realizaban actividades manuales que suponían levantar frecuentemente más de 20 kg[14]. En cuanto a los diagnósticos etiológicos predominaban las lesiones de partes blandas: la mitad rupturas de manguito, cinco pacientes con lesiones de partes blandas variadas y dos fracturas de húmero. El tiempo de evolución medio fue de 15 meses. Todos menos uno eran accidentes laborales. Todos los pacientes eran diestros y el lado afecto era en la mayoría de los casos el derecho. La gran mayoría de los pacientes fueron sometidos a intervenciones quirúrgicas. Todos realizaron programas de

TABLA 1. Sujetos: Detalle.

N.º	Edad	Sexo	Dominancia	Antecedentes laborales	Diagnóstico	Tipo	Lado afecto	Tratamientos quirúrgicos	Motivo solicitud	Solicitante
1	42	V	D	Mantenimiento mobiliario urbano	Síndrome subacromial	Accidente laboral	D	Acromioplastia por artroscopia; a los 2 m acromioplastia a cielo abierto	discrepancia impresión clínico y paciente	Mutua laboral
2	32	V	D	Construcción	Hombro doloroso	ILT	D	No	discrepancia impresión clínico y paciente	Mutua laboral
3	53	V	D	Chófer	Ruptura tendón de supraespinoso	Accidente laboral	I	Acromioplastia y reparación del manguito	discrepancia impresión clínico y paciente	Mutua laboral
4	46	V	D	Calderero	Ruptura tendón de supraespinoso	Accidente laboral	D	Reparación del manguito	discrepancia impresión clínico y paciente	Mutua laboral
5	35	V	D	Administrativo	Fractura conminuta diafisis húmero derecho, fractura de clavícula y la costilla D	Accidente laboral	D	Osteosíntesis con Kirschner	demostrar pérdida de fuerza	Paciente
6	43	V	D	Montador prefabricados de hormigón	Fractura de húmero D	Accidente laboral	D	Osteosíntesis con placa y tornillos	discrepancia impresión clínico y paciente	Mutua laboral
7	48	M	D	Operaria pastelería industrial	Ruptura tendón de supraespinoso	Accidente laboral	D	1.Reconstrucción del manguito; 2.Sinovectomía, liberación y limpieza del espacio subacromial	discrepancia impresión clínico y paciente	Mutua laboral
8	47	V	D	Tornero	Síndrome subacromial	Accidente laboral	I	Acromioplastia	discrepancia impresión clínico y paciente	Mutua laboral
9	57	V	D	Peón industria química	Ruptura tendón de supraespinoso	Accidente laboral	D	Acromioplastia	demostrar pérdida de fuerza	Paciente
10	37	V	D	Minero	Ruptura tendón de supraespinoso	Accidente laboral	D	Acromioplastia y reparación del manguito	discrepancia impresión clínico y paciente	Mutua laboral
11	39	V	D	Operario factoría automóvil	Síndrome subacromial	Accidente laboral	D	Acromioplastia	demostrar pérdida de fuerza	Paciente
12	61	V	D	Construcción	Ruptura tendón de supraespinoso	Accidente laboral	D	Acromioplastia	discrepancia impresión clínico y paciente	Mutua laboral
13	49	V	D	Peón industria papelera	Tendinitis crónica del manguito	Accidente laboral	D	No	demostrar pérdida de fuerza	Paciente
14	56	V	D	Tornero	Ruptura tendón de supraespinoso	Accidente laboral	D	Acromioplastia y reparación del manguito	discrepancia impresión clínico y paciente	Mutua laboral

rehabilitación específicos. La mayoría de los pacientes fueron remitidos por discrepancia entre el déficit referido por el paciente y el juicio clínico de su médico responsable. El solicitante más frecuente fue la mutua de accidentes de trabajo.

Metodología de evaluación

Se le explica al paciente el cometido de la prueba: analizar la fuerza muscular y sus posibles déficit de una manera objetiva. Igualmente se comenta la posibilidad de detectar la baja colaboración mediante el dinamómetro. A continuación se calibra el dinamómetro isocinético (CybexNorm®) delante del paciente y se realiza una exploración física básica del mismo en la que se incluye goniometría de la elevación y rotación externa y medición de la rotación interna anotando a qué alcanza el pulgar. Se practica una evaluación del balance muscular mediante el test manual de la flexión, la abducción y la rotación externa. Se buscan puntos dolorosos a la palpación.

Dinamometría isocinética

Mediante la dinamometría isocinética se obtiene el «Peak Torque» o momento de fuerza máximo en Newtons × metro (Nm) . La medición se realizó mediante un dinamómetro isocinético CybexNorm®. El posicionamiento del paciente básico es en sedestación y alineación del eje con el plano escapular y el húmero para valorar las rotaciones, en sedestación y alineación del eje sagitalmente con la cabeza del húmero para valorar la abducción/adducción, y finalmente en decúbito supino y con el eje alineado con la cabeza del húmero en el plano frontal para valorar la flexoextensión (fig. 1). Los recorridos articulares a los que se realiza la prueba son fijados por el paciente en la extremidad afecta, de manera que se fijan en un rango no doloroso y que el paciente pueda realizar cómodamente. El mismo rango se aplica a la extremidad no afecta. Los criterios de exclusión para la realización de la prueba son los recogidos en la literatura, a saber, balance articular severamente limitado, dolor severo, derrame articular, esguince muscular o ligamentoso agudos, cicatrices abiertas, fracturas inestables y cardiopatía inestable[15].

Los rutina evaluadora comprende:

– Un período de calentamiento con estiramientos e isotónicos libres.

– Calentamiento en la máquina con un minuto a contracciones concéntricas y un minuto a contracciones excéntricas.

– Protocolo de evaluación recíproco intermitente consistente en cinco pares de contracciones concéntricas/excéntricas a 60°/s y 120°/s para todos los movimientos analizados (rotaciones, flexoextensión y abducción/addución). Entre la contracción concéntrica y la excéntrica hay cinco de descanso y entre los pares de contracciones 25. La prueba finaliza con una evaluación a 180°/s que se realiza sólo en la modalidad concéntrica para evitar eventuales lesiones. Se aplica al hombro afecto y a continuación al hombro sano contralateral para obtener el déficit.

Para analizar los resultados se calcula la media, la desviación típica (DE) y el coeficiente de variación a partir de las cinco peak torque obtenidos en cada serie de contracciones. A continuación se calcula el déficit expresado en % (1 - peak torque extremidad afecta/peak torque extremidad preservada × 100). Finalmente se calculan los REC. Para calcular los déficit y los ratios se emplea la media de peak torque obtenido a partir de las cinco mediciones. Una vez obtenidas todas las mediciones y los cálculos correspondientes se evalúan, con el objeto de emitir un informe, los siguientes índices de «poca colaboración»: proporción de mediciones de peak torque de mediciones excéntricas inferiores a las alcanzadas en contracciones concéntricas, proporción de mediciones de peak torque a velocidades altas que es superior al medido a velocidades bajas y proporción de REC superiores a 2,05. Finalmente, antes de emitir el informe se registran las eventuales complicaciones y si se ha finalizado toda la exploración. A partir de estos datos se emite un informe con dos vertientes: por un lado se definen los déficit registrados y se los cataloga de relevantes (si son mayores a un 20% de una manera consistente) o no relevantes, por otro lado, se emite una impresión de buena colaboración o mala colaboración. Se considera que un paciente ha sido «poco colaborador» o que «hay indicios de poca colaboración» cuando se observan de una manera repetida desviaciones del patrón fisiológico. El criterio para seleccionar que nivel es relevante depende de la situación clínica del paciente y del músculo de mayor interés. Así, en la práctica habitual, que se refleja en el presente trabajo, se consideran fundamentalmente los REC elevados (fig. 2). Con uno sólo, normalmente no se cataloga el paciente como poco colaborador. No obstante si hay más de un REC elevado, correspondiente a acciones más relevantes (flexores, abductores o rotadores externos) y encontramos alguna medición a velocidad alta superior a una realizada a velocidad baja la impresión reflejada en el informe final será, sin duda, de baja colaboración.

La evaluación de la utilidad de la prueba se completó, en los pacientes cuya prueba fue solicitada por la mutua de accidentes de trabajo, registrando la pro-

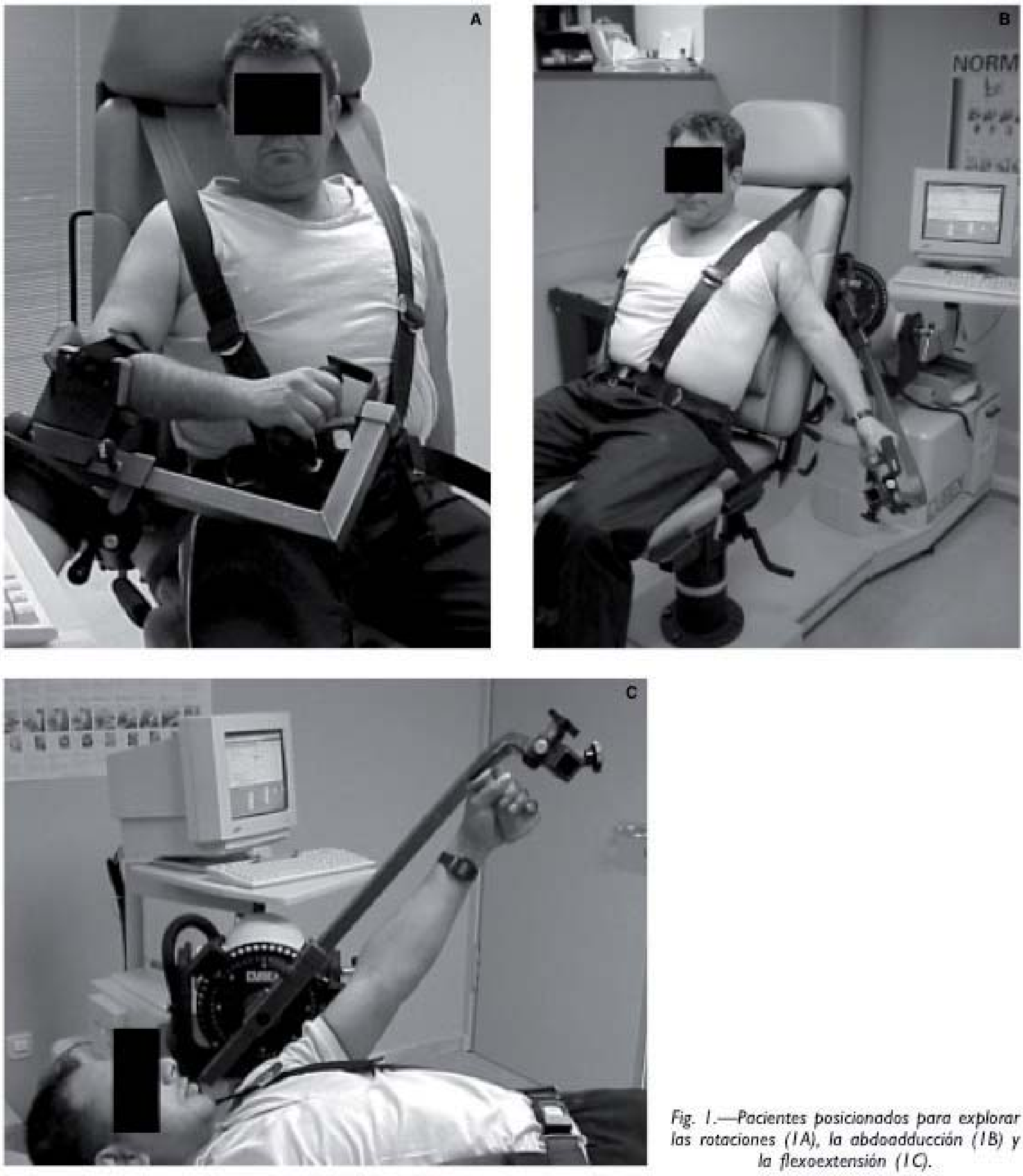

Fig. 1.—Pacientes posicionados para explorar las rotaciones (1A), la abdoadducción (1B) y la flexoextensión (1C).

puesta al alta por parte de la mutua, la aceptación por parte del paciente, el retorno o no a su mismo puesto de trabajo, el tiempo total de baja laboral, la eventual solución del caso en magistratura y la resolución de la misma y la utilización del peritaje como prueba en el juicio.

RESULTADOS

Se ha observado un balance articular relativamente conservado, con una elevación media de 148,21° (DE 29,72), una rotación externa media de 83,64° (DE 16,72) y una rotación interna en un 79%

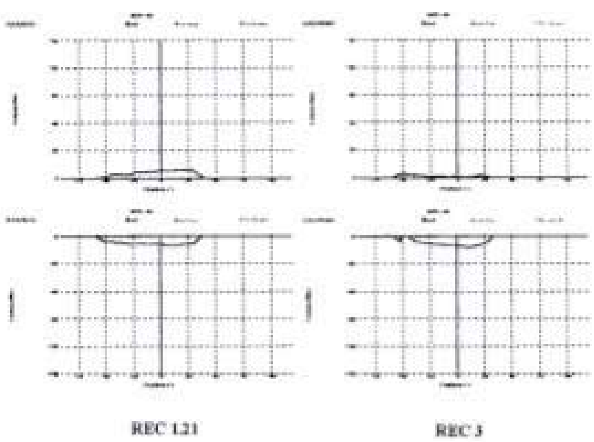

Fig. 2.—Gráficas momento de fuerza/ángulo articular de contracciones concéntrica (arriba) y excéntrica (abajo) a 60°/s en rotación externa. Las gráficas de la derecha correspen a un paciente en que se registró un REC de 1,21, sugestivo de buena colaboración. Las gráficas de la derecha corresponden a un paciente en que se registró un REC de tres, sugestivo de poca colaboración.

de los casos por encima de D10. En cuanto al balance muscular alcanzaban un 4 ó 5 el 71,73% de los pacientes para la abducción, el 64% para la rotación externa y el 83% para la flexión.

Diez pacientes no completaron la dinamometría, la mayoría de ellos por no poder generar fuerza en abducción. Como complicación se registró en un paciente un cuadro vagal al finalizar la exploración, que se autolimitó. No hemos registrado complicaciones musculoesqueléticas.

Al observar los resultados obtenidos en las mediciones de peak torque se han observado muy raramente mediciones de valor inferior en la modalidad de contracción excéntrica que en la modalidad concéntrica. Esta eventualidad sería de esperar con la interferencia del dolor. En cuanto al análisis de las mediciones realizadas a diferentes velocidades se observó que en 10 pacientes se registró al menos una medición a velocidades altas superior a la medida a velocidades bajas (al contrario de lo esperado según la fisiología de la contracción muscular en relación a la velocidad). No obstante, en el momento de realizar la valoración global, en general no se consideró un dato determinante de indicios de poca colaboración.

Los déficit se agruparon en grupos de velocidades y modalidades de contracción (tabla 2). En cuanto a las rotaciones, los déficit más elevados se observaron para la rotación externa, a 180°/s y en modalidad concéntrica (72%; DE 15,56). Los déficit de los rotadores internos son inferiores aunque relevantes en todas las mediciones realizadas en la modalidad de contracción concéntrica. Los déficit medidos en la modalidad de contracción excéntrica para los rotadores externos son sóla y ligeramente superiores a lo que se considera relevante (35,5%; DE 6,36 y 32,5; DE 12,02 para 60°/s y 120°/s respectivamente). Los déficit para los rotadores internos son inexistentes en esta modalidad de contracción. Los déficit de flexión son en general poco relevantes, y, al igual que en el caso de los rotadores, inferiores en la modalidad de contracción excéntrica. El déficit de extensores dio resultados desiguales, probablemente por el posicionamiento específico del paciente que induce a «dejar caer» el brazo a favor de la gravedad en las contracciones concéntricas. Por el contrario, se destaca la ausencia de déficit en extensión en la modalidad de contracción excéntrica. Por último, la media de dos déficit de abducción, en los pocos pacientes donde se ha podido realizar ha sido muy poco relevante. Los altos déficit

TABLA 2. Déficit medio (%). En cursiva se anota la desviación típica.

	Déficit Concéntrico 60°/s	*Déficit Excéntrico 60°/s*	*Déficit Concéntrico 120°/s*	*Déficit Excéntrico 120°/s*	*Déficit Concéntrico 180°/s*
Rotación externa	54,00	35,50	60,00	32,50	72,00
	19,80	*6,36*	*19,80*	*12,02*	*15,56*
Rotación interna	22,50	4,00	35,00	1,50	40,50
	14,85	*24,04*	*1,41*	*26,16*	*0,71*
Flexión	35,50	25,00	48,00	22,50	25,00
	23,33	*22,63*	*24,04*	*17,68*	*50,91*
Extensión	20,00	14,50	50,00	9,50	29,50
	1,41	*14,85*	*9,90*	*13,44*	*44,55*
Abducción	25,20	17,20	9,80	-3,60	15,00
	14,10	*21,18*	*20,75*	*24,66*	*24,71*
Adducción	42,80	41,60	63,75	44,25	71,67
	34,94	*37,75*	*32,97*	*17,21*	*27,10*

TABLA 3. Ratios excéntrico/concéntrico (REC).

	REC RE 60	REC RI 60	REC RE 120	REC RI 120	REC FLEX 60	REC EXT 60	REC FLEX 120	REC EXT 120	REC ABD 60	REC ADD 60	REC ABD 120	REC ADD 120	% con Ratio E/C>2,05
1	21,00	1,61	8,5	1,5	2,65	4,08	3,75	21					75,00%
2	2,80	1,81	2,76	2,17	1,45	1,45	1,73	4,12	1,34	1,32	1,39	4,16	41,67%
3	3,00	1,21	2,6	1,12	1,38	1,19	2,06	1,97					37,50%
4					2,41	2,19	1,99	1,37					50,00%
5	1,94	1,15	1,77	1	1,55	1,84	1,63	1,57					0,00%
6	1,21	1,13	1,93	1,39	1,21	0,9	1,36	1,05	1,14	1,84	1,51	1,87	0,00%
7					1,51	13,4	1,87	15					50,00%
8	1,74	1,37	2,31	1,61	2,24	1,28	2,49	1,5					37,50%
9					1,28	2,12	1,96	2,75	1,23		1,19		33,33%
10	1,61	1,09	1,85	1,17	1,39	1,19	2	1,33					0,00%
11	1,22	1,04	1,33	1,14	1,43	1,35	1,26	1,12	0,97	1,12	1,17	1,08	0,00%
12					1,58	1,5	1,8	2					0,00%
13	2	1,52	1,98	1,92	1,73	1,62	3,11	4,85	1,32	1,22	1,64		18,18%
14	2	1,24	3,25	1,31	1,57	1,31	2,49	2,64					50,00%

en adducción no se consideran en general relevantes por un efecto de «dejar caer». De todas manera se sigue cumpliendo el hecho de que los déficit son mayores a contracción concéntrica que excéntrica.

Se han registrado REC elevados en nueve pacientes (tabla 3).

Una vez calculados y analizados los resultados hasta aquí expuestos, el primer firmante de este trabajo emitió un informe individualizado referente a los déficit hallados y el nivel de colaboración o sinceridad (tabla 4). De los 14 pacientes a 12 se les objetivaron déficit relevantes en las mediciones realizadas. Los pacientes a quienes no se objetivó déficit se les propuso alta por curación que aceptaron. En los pacientes en que se objetivó déficit sin indicios de poca colaboración la prueba sirvió en general para ajustar la propuesta al alta, todos salieron con algún grado de incapacidad o baremo (compensación económica por secuela establecida por la ley y que no implica incapacidad laboral). Finalmente, de los cinco pacientes en que se detectó déficit relevante en un contexto de indicios de poca colaboración, uno impugnó un alta por curación. Su impugnación fue desestimada en magistratura utilizando como prueba el peritaje con isocinéticos. Otro paciente fue reintervenido y continúa de baja. El resto aceptó la propuesta que le hizo la mutua con la prueba pericial en sus manos. Todos los pacientes dados de alta menos uno regresaron a su puesto de trabajo anterior. El tiempo medio de baja laboral fue de 10 meses.

DISCUSIÓN

El balance muscular manual es un instrumento de medición insuficiente para determinar el déficit de fuerza como secuela. De hecho, en esta muestra de pacientes, la mayoría alcanzaban balances musculares manuales entre 4 ó 5, a pesar de que aquejaban pérdida de fuerza. Por tanto creemos de un alto interés, y más en el entorno laboral y de la valoración del daño corporal, el disponer de un método objetivo para medir los déficit musculares de una manera fiable.

La evaluación mediante dinamometría isocinética propuesta en este trabajo es relativamente sencilla de realizar con un entrenamiento adecuado y a pesar de incluir mediciones excéntricas, potencialmente inductoras de lesiones, no ha supuesto complicaciones musculoesqueléticas relevantes. El caso de cuadro vagal al finalizar la prueba que presentó un paciente no requirió ninguna medida especial. La dificultad de muchos pacientes para realizar la prueba en abdoadducción nos hace cuestionar la idoneidad del posicionamiento propuesto para esta acción particular de la articulación del hombro y sería conveniente quizá plantear otras opciones.

En lo que respecta al análisis sistemático de los resultados cabe recalcar que el análisis de las mediciones de peak torque alcanzadas a diferentes velocidades y modalidades de contracción (concéntrica y excéntrica) nos ofrecen poca información sobre la sinceridad del esfuerzo en esta muestra.

Los déficit musculares expresados en % respecto al músculo contralateral ya nos orientan mucho más en la evaluación del paciente. Por un lado nos determinan el grado de déficit y por otro lado podemos intuir «poca colaboración» en el caso de tener una gran discrepancia entre los déficit registrados en las mediciones concéntricas y las mediciones excéntricas. Así, sí observamos una gran discrepancia a favor de las primeras podemos empezar a considerar que probablemente hay indicios de poca colaboración. Finalmente, los déficit más relevantes en esta articulación serían los referidos a la rotación externa, la abducción

TABLA 4. Valoración de la prueba y utilidad posterior.

	Déficits relevantes	Indicios poca colaboración	Solicitante	Propuesta al alta	Aceptación propuesta	Magistratura	Resolución	Utilización del peritaje como prueba	Retorno al mismo puesto de trabajo	Tiempo de baja laboral
1	Sí	Sí	Mutua laboral	Curación	No	Sí	Desestimación de la impugnación del alta realizada por el paciente	Sí	Sí	
2	No	Sí	Mutua laboral	Curación	Sí	No			Sí	8 m
3	Sí	No	Mutua laboral	IPP	Sí	No			Sí	5 m
4	Sí	Sí	Mutua laboral			No				Continua de baja
5	Sí	No	Paciente	IPP		Sí	No concesión IPT solicitada por el paciente	Sí, no demostró suficiente déficit según el juez	Sí	8 m
6	Sí	No	Mutua laboral	IPP	No	Sí	Concesión de IPP solicitada por el paciente	No	Sí	17 m
7	Sí	Sí	Mutua laboral	IPP	Sí	No			Sí	14 m
8	Sí	Sí	Mutua laboral	Baremo	Sí	No			Sí	
9	Sí	No	Paciente	Baremo	No	No			Sí	7 m
10	Sí	No	Mutua laboral	IPP	Sí	No			Sí	16 m
11	No	No	Paciente	Curación					Sí	3 m
12	Sí	No	Mutua laboral	IPT	Sí	No			No	12 m
13	Sí	No	Paciente	–	–	–	–	–	–	–
14	Sí	Sí	Mutua laboral	Baremo	Sí	No			Sí	12 m

IPP: Incapacidad permanente parcial.
IPT: Incapacidad permanente total.
m: meses.

y la flexión. No en vano, son las acciones más comprometidas en la patología tendinosa del hombro.

Una vez establecido el déficit, el REC es el parámetro más útil para hacer una valoración de la sinceridad. En este sentido, observamos por un lado cuantos REC son superiores a los límites establecidos en la literatura en un paciente, y por otro lado tenemos en cuenta la magnitud del ratio. Es decir, a un paciente con más de un REC elevado y valores altos se le atribuirán indicios de poca colaboración y sus eventuales déficit serán cuestionados. En la base de esta aproximación objetiva se encuentra la cada vez mayor evidencia de que el control motor de las contracciones excéntricas es «único» e independiente del control de las contracciones concéntricas[13]. En experimentos realizados con voluntarios a los que se les pidió que realizaran contracciones submáximas para simular pérdida de fuerza, el aumento de los REC era constante[10-13]. En definitiva, se trata de una aproximación objetiva basada en la más reciente evidencia de fisiología de la contracción muscular.

Los resultados del uso de los informes emitidos por el servicio de evaluación isocinética expuestos más arriba ilustran muy bien las dos vertientes de la técnica y protocolo propuestos. Por un lado, permite definir de una manera precisa y exhaustiva los déficit musculares de los pacientes en los que se aprecia buena colaboración, permitiendo tomar decisiones médico-legales más justas y basadas en datos objetivos. Por otro lado, en pacientes con indicios de poca colaboración, puede suponer un argumento objetivo y justo para afrontar peticiones del mismo, y, en casos de resolución en magistratura puede usarse como prueba. Cabe decir que ya es ampliamente aceptada en los juzgados. Consideramos que el instrumento ideal sería la determinación de un DEC para el hombro. En la literatura ya se encuentra un trabajo muy reciente que evalúa la flexión del hombro[16]. Por otro lado el uso del coeficiente de variación debería hacerse con la máxima prudencia en el ámbito médico-legal.

En conclusión, la dinamometría isocinética del hombro con un protocolo que incluya mediciones concéntricas y excéntricas a diferentes velocidades, es un instrumento seguro, objetivo, basado en la evidencia de la fisiología de la contracción muscular, actualmente disponible y factible. Las únicas desventajas son el costo del equipamiento y el requerir un entrenamiento específico. En definitiva, se trata de una aproximación de gran interés en el ámbito laboral y de evaluación del daño corporal por facilitar la toma de decisiones médico-legales justas y equitativas.

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Capítol 5.4

Utilitat de les proves isocinètiques amb recorregut articular curt en la identificació de l'esforç màxim fingit de rotació externa de muscle

Usefulness of short RoM isokinetic dinamometry in feigned maximal shoulder external rotation effort identification

Enviat a publicar a Disability and Rehabilitation

Usefulness of short RoM isokinetic dinamometry in feigned maximal shoulder external rotation effort identification

Eduard Pujol, Joaquim Chaler, Laura Sucarrats, Inés López, Blanca Zeballos, Roser Garreta, Zeevi Dvir

Enviat a publicar a Disability and Rehabilitation

Objectiu

El propòsit d'aquest estudi era examinar l'efectivitat de la diferencia dels ratis excèntric/concèntric a velocitat alta i els registrats a velocitat baixa (DEC) en la diferenciació de un esforç isocinètic màxim i submàxim de rotadors externs en una mostra de subjectes sans. En aquest cas també interessava veure si un test realitzat en un rang articular curt també podia ser útil en aquest propòsit. També, com objectiu secondari, hi havia la observació de la influencia del dispositiu en els resultats del DEC.

Per això es van seleccionar 16 homes voluntaris sans de 20 a 45 anys d'edat. Els subjectes varen fer dos tests: un màxim i un submàxim. Tots dos comprenien contraccions concèntriques i excèntriques. El test es realitzà també amb dos rangs articulars, 20° (curt) i 60° (llarg). El primer es va fer a unes velocitats de $10^{o}s^{-1}$ i $40^{o}s^{-1}$ mentre que el segon a $30^{o}s^{-1}$ and $120^{o}s^{-1}$. Es van calcular els moments de força màxims, els ratis excèntric/concèntric i, finalment, el DEC.

Resultats principals

Els DEC registrats en les situacions submàximes van ser significativament superiors als obtinguts en situacions de esforç màxim de rotadors externs, tant pel que fa al recorregut curt com el llarg. Es van poder determinar uns punts de tall per recorregut curt (0.46) com pel recorregut llarg (0.58) a partir dels quals es pot considerar que el DEC indica esforç submaxim. La especificitat del DEC va ser molt alta en les dues situacions per definir esforç submaxim. La sensibilitat va ser pel recorregut llarg de un 50% mentre que a recorregut curt d'un 18.8%.

Conclusió

El DEC pot ser útil en la detecció de esforços submàxims durant la realització d'un test isocinètic de rotadors en un rang articular curt. No obstant la seva escassa sensibilitat posen en qüestió la seva aplicabilitat pràctica.

El DEC, obtingut en un recorregut llarg aplicant un protocol prèviament definit però amb un dispositiu isocinètic diferent, va ser útil per detectar esforços submàxims amb una sensibilitat acceptable. No obstant el punt de tall obtingut difereix del prèviament fixat amb un altre dispositiu usant el mateix protocol.

Cal més recerca i es continuarà el treball actual per confirmar les troballes preliminars.

Usefulness of long and short RoM isokinetic dinamometry in feigned maximal shoulder external rotation effort identification

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Abstract

The purpose of this study was to examine the effectiveness of a protocol for differentiation of submaximal from maximal effort in shoulder external rotation isokinetic tests. 16 healthy men aged 20 to 45 years took part in the study. In a first test, the subjects were instructed to exert concentric and eccentric external rotator efforts. Then, test was repeated performing submaximal concentric and eccentric effort. The test was performed at two ranges of motion, 20 ° (short) and 60 ° (long). Two angular velocities of 10°/ s and 40°/ s and 30 °/ s and 120°/ s were applied respectively. Peak torques, eccentric/concentric ratios and difference of eccentric to concentric ratios at high and low velocity (DEC) were recorded and compared for maximal and submaximal conditions.

DEC parameter was effective in distinguishing maximal from submaximal isokinetic efforts both in long and short range of motion. Such parameter might be useful in assuring validity of shoulder external rotator isokinetic tests in clinical practice and medico legal situations.

Introduction

Injuries involving the shoulder, especially shoulder impingement, are, together with those involving the elbow, the knees and the back, among the main causes of occupational disease and musculoskeletal disorders[1]

Evaluation of shoulder external rotator muscle strength may be an essential component to assess shoulder injury patients. In fact isokinetic tests have been extensively used in shoulder injury patient assessment[2,3]. Isokinetic dynamometry provides accurate and reproducible measurement of shoulder external rotator dynamic muscle strength[4]. Information yielded by isokinetic tests is generally useful for planning and monitoring strength training programs, as well as establishing permanent impairments. However, patient collaboration is crucial in order to generate reliable results. Thus estimation of the level of collaboration during an isokinetic strength test is of great interest.

A number of parameters, such as coefficient of variation and the difference between isokinetic eccentric and the concentric strength ratios at high and low velocity (DEC) have been advocated to differentiate between maximal and submaximal efforts using isokinetic testing[5-16]. Among them, the DEC appears to be the most widely accepted. Specifically, DEC has been proven to be highly effective at identifying feigned maximal muscular effort in different joints and actions in both healthy subjects and in patients[7-14,16].Different central nervous system pathways of activation and control of concentric contractions as opposed to eccentric contractions have been defined [17,18].It has been postulated that the effectiveness of DEC depends on such differentiated motor control [3]. In other words, eccentric strength is voluntarily less "controllable" than concentric one. Therefore, in feigned maximal efforts, i.e. when individuals try to use less strength than they are capable of, eccentric to concentric ratios (E/CR) increase, especially at high velocities, which in turn increase the value of DEC values. DEC increase in submaximal situations makes it possible to establish, based on studies involving volunteers, cut-off levels to determine whether an isokinetic test hast been submaximal, namely the individual has not used maximum possible strength.

Regarding shoulder external rotator muscles, DEC efficiency has been previously established in normal subject submaximal effort detection[19]. Its usefulness has also been described for shoulder injury patient maximallity of effort detection[20]. However, in these previous studies, isokinetic test was performed in a quite extended range of movement (RoM), namely 60º, which might not be easily attainable for shoulder injury patients. Thus, a shorter test RoM would be desirable in order to assess some cases of shoulder injury patients. DEC efficiency in short isokinetic test RoM has been previously described for shoulder flexors[15], elbow flexors[11] and trunk extensors[10,13,14].To our best knowledge DEC efficiency in maximallity of effort detection in short RoM shoulder external rotator isokinetic tests has not been previously assessed. Therefore, the main goal of the present study is analysing the effectiveness of DEC in identifying suboptimal efforts in a healthy volunteer population performing shoulder external rotation isokinetic tests in both a long (60º) and short (20º) RoM.

Material and Methods

Subjects

Sixteen healthy male volunteers aged 20-40 years (33.63±6.05) without prior history of shoulder pathology took part in this study. All subjects signed an informed consent form, which contained detailed information about the study. The study was reviewed and approved by the local Ethical Review Board.

Protocol

The test was conducted using a CONTREX (CMV AG, Dübendorf/Schweiz) isokinetic dynamometer. The main parameter registered was peak torque (PT).

The testing positioning for isokinetic shoulder external rotation strength has been previously described (**¡Error! Marcador no definido.**). Warm up and testing was conducted with the subject seated on an adjustable seat and proximally stabilized using cross chest straps. The arm was positioned in the scapular plane, between 30 and 45º anterior to the frontal plane and elevated 45º. Elbow was maintained at 90º flexion and supported by a standard shoulder rotation attachment. A forearm strap helped positioning the elbow. The forearm remained neutral during the testing protocol while the hand grasped a handle connected distally to the lever arm. The mechanical axis of the lever arm was aligned with the humeral shaft.

Neutral position (i.e. 0º rotation) was defined locating the forearm in the sagittal plane. Then, two external rotation isokinetic strength test RoM were set: 20º (from 55º to 35º of internal rotation approximately) and 60º (from 55º internal rotation to 5º external rotation) According to previous studies, the test velocities were set at a 1:4 gradient of 10 and 40º/s and 30 and 120º/s for short and long RoM respectively. Once the subject was positioned and the limb strapped to the attachments, gravity correction was performed as indicated by the device manufacturer software.

The test protocol started with a familiarisation and warm-up phase, which consisted of one set of 5 submaximal concentric contractions followed by a 2-minute rest and one set of 5 submaximal eccentric contractions. In the concentric phase, the subject was instructed to push and pull the lever arm throughout the RoM. In the eccentric phase, the subject was instructed to actively resist the lever arm that was moving in both directions. After a 3-minute rest, the actual test started.

In the first part of the experiment (short RoM) subjects were asked to initially exert maximal effort against the lever arm at 10º/s. This effort consisted of 4 pairs of concentric and eccentric contractions, with a 5-second intercontraction pause and a 25-second interpair pause. After a 30-second pause, the velocity was raised to 40º/s and the same protocol was repeated. Following a 3 min pause the protocol was repeated at long RoM (60º) and high velocities (30 and 120º/s respectively)

Following 5-min pause, the second part (submaximal effort) started. During this one, the subject was instructed to apply reduced force during the test, feigning weakness. The subject was told to imagine that one year ago he had an accident and, although he had now recovered, he had to try to convince the doctor that he still had weakness in order to receive compensation. After these instructions the full protocol was repeated.

Data and statistical analysis

Once peak torque of each contraction (concentric-eccentric), velocities (10º/s-40º/s and 30º/s-120º/s), long and short RoM and test conditions (maximal- submaximal effort) were individually recorded, eccentric to concentric ratios (E/CR) were calculated for each velocity and test condition.

From these values, the following parameters were calculated for each test condition:

$DEC_{short\ RoM} = E/CR_{40º/s} - E/CR_{10º/s}$

$DEC_{long\ RoM} = E/CR_{120º/s} - E/CR_{30º/s}$

The findings were analysed using the statistical software SPSS V13. The statistical tests used were t-student for coupled data and analyses of variance (MANOVA) with repeated measurements with DEC as a dependent variable and effort level as a fixed factor. A $p \leq 0.05$ indicated statistical significance. Finally the DEC tolerance interval for maximal effort was calculated, and the cut-off level was calculated from normal distribution tolerance intervals[21].

Results

Table 1 outlines the mean peak torques values and E/CR for shoulder external rotators in the two experimental conditions (short and long ROM). In both conditions, the mean peak torque at maximal performance was significantly higher than those registered for the feigned maximal counterpart ($p \leq 0.001$). Regarding E/CR, both short RoM and long RoM high velocity E/CR registered while performing a feigned maximal effort were significantly higher than their maximal effort counterparts. Such difference was not found in low velocity registers in both conditions.

Feigned effort DEC values (Table 2) were significantly higher than their maximal effort counterparts, both for long RoM ($p=0.049$) and short RoM ($p=0.028$) conditions.

Once proven that submaximal effort DEC were significantly higher than maximal efforts ones, cut-off values were calculated using these DEC scores to allow the identification of feigned maximal efforts in both long and short ROM conditions.

The cut-off level value derives from the calculation of tolerance intervals for normal distribution[21]. Following present study maximal effort DEC , for a 95% confidence level, the value of long ROM and short ROM DEC for shoulder external rotators should exceed 0.58 and 0.46, respectively, to label an effort as submaximal (see table 2). Obviously, the higher the level of confidence is set, the higher the cut-off level. Therefore, for a confidence level of 99% the cut-off value would rise to 0.646 and 0.54 respectively, whereas for 90% the cut-off value would drop to 0.552 and 0.426 for long and short ROM respectively. The cut-off values would drop to 0.483 and 0.342 respectively for a confidence level of 85% and to 0.454 and 0.306 respectively for an 80% confidence level (see Table 2).

For each of these cut-off values, the table 3 outlines the corresponding figures for sensitivity and specificity. The latter was 100% in this sample for all levels of confidence both at short and long RoM. Sensitivity was much lower, especially for short RoM measurements. Depending on the level on confidence selected, DEC showed a sensitivity ranging from 43.75% to 56.25% in detecting submaximal performers when using a long RoM in present sample. Short RoM measurement based DEC sensitivity in submaximal effort detection ranged from 12.5% to 25%.

Discussion

The results of this study indicate that, in healthy male volunteers, a feigned maximal effort of shoulder external rotators can be identified using the DEC in both long and short RoM protocols. However, in the latter condition, sensitivity of DEC dramatically lowers. On the other hand, a DEC shows a very high specificity in both long and short RoM conditions, thus indicating that the likelihood of false positives (namely, labelling a real maximal performer as submaximal) is negligible.

PT values, as expected, were significantly higher in maximal condition than in submaximal condition in both long and short RoM tests (see table 1). As expected maximal effort eccentric measurements registered higher PT values than their concentric counterparts, both in long and short RoM. The latter, however showed a lower difference between eccentric and concentric values. That is most probably due to the low measurement velocity. Present sample long RoM maximal effort PT values are considerably higher than those found in a previous study using the same protocol[19] in a similar population of male subjects. Whilst, in present sample, mean low velocity (30º/s) PTs registered in concentric and eccentric mode were 38.47Nm and 43.26Nm respectively, previous study counterparts were 27.5Nm and 32.3Nm respectively. High velocity (120º/s) mean PTs registered at concentric and eccentric mode in present sample reached 34.34Nm and 45.74Nm respectively whereas same measurements in previous study registered 21.2Nm and 31.4Nm. The reason of this unexpected finding might be probably due to the fact that in former study[19] gravity correction was not performed (Cybex Norm isokinetic system software did not allow to perform such procedure) whilst in present study was. However other factors such as those related to the subjects, test performers, and isokinetic system hardware and software issues cannot be excluded as sources of present differences.

According to previous studies E/CR analysis shows that submaximal effort values were higher than their maximal effort counterparts. However, significant difference could only be demonstrated in high velocity part of the test for both long and short RoM. In fact, such finding is in the base of DEC raise in submaximal effort and it indicates a lower voluntary control of eccentric contraction at high velocities (see table 1). Comparison of long RoM E/CR values to previous study by Chaler et al.[19] reveals that present low velocity(30º/s) maximal and submaximal effort E/CR (1.13 and 1.24 respectively) were close to the previously found with the same protocol (1.17 and 1.23 respectively). On the other hand, high velocity E/CR found in present sample at maximal and submaximal conditions (1.35 and 1.80 respectively) differed substantially to the previously described (1.48 and 3.52 respectively). The remarkable difference of submaximal effort high velocity(120º/s) E/CR between the two studies is highly conspicuous and, as discussed below, directly affects DEC power in submaximal effort detection in present sample.

DEC analysis (see table 2) showed, as expected, that all submaximal effort values (namely for long and short RoM) were significantly higher than their maximal effort counterparts. Mean DEC values registered in maximal effort, in both long RoM (0.215 ± 0.126) and short RoM(0.014 ± 0.154), were well within the DEC value range reported in previous studies performed in different muscle groups (-0,007-0,68) [8-13,15,16,19].It is particularly interesting to note that, comparing to the previous study[19] were DEC in identification of shoulder external rotator effort sincerity performed in a long RoM (60º) was tested (0.311 ± 0.175), present study maximal effort mean DEC was lower (0.215 ± 0.126). Whilst it is not an unexpected finding, a possible explanation is as stated above that in present study gravity correction was performed and in the previous one not (the software did not allowed the tester to do so). The difference found when comparing present study maximal effort mean DEC to the unaffected side DEC of a sample[20] of patients is even greater, but in this particular case, age and gender composition of the sample was different, thus indicating that age and obviously gender might have a key role in maximal effort DEC value. In any case and in brief, present finding indicates that DEC cutoff levels calculated upon results of a particular isokinetic device brand may not be applicable when another brand is used. Furthermore, young male derived shoulder external rotator effort DEC values might not be useful to test other population (namely, older populations and, obviously, female) maximality of external rotation effort. Short RoM maximal effort mean DEC shows, as in previous studies testing short ROM in upper limb[11,15] a much lower value. Regarding submaximal effort long RoM DEC (0.556 ± 0.597), it was much lower than the one registered in previous study using the same protocol in a different isokinetic device[19] (2.925 ± 1.945). Thus, the difference between maximal and submaximal effort DEC, although significant, is much lower. Such fact might, as discussed below, affect the sensitivity of the test for submaximal effort detection in the present sample.

Sensibility (namely, the ability of the DEC to detect submaximal ER isokinetic effort) and specificity (namely, the ability of DEC to detect maximal ER isokinetic effort) are depicted in Table 3. The higher the confidence level applied the higher the specificity whilst the lower the confidence level the higher the sensitivity reached. It is important to note that DEC specificity reaches 100% in all cases and conditions (short and long RoM) regardless of the confidence level set. However, sensitivity is much lower, both for long RoM measurements and, especially, short RoM ones. The latter are too low to be acceptable. The reason might be the low difference between maximal and subaximal short RoM DEC. It may be hypothesized that the gradient used (1:4) to calculate the DEC is too low. Probably, a higher gradient may yield better sensitivity records in healthy volunteers. In fact, in a previous study that tested DEC use in shoulder flexors maximility of effort detection, a gradient higher than 1:4 was recommended in healthy volunteers[15]. However, such a recommendation should be carefully evaluated, since the higher the isokinetic tests velocity is set the higher the possibility of not reaching the isokinetic velocity and, thus, lower the reliability of the test. This might be especially relevant in real patients, which may have true difficulties to reach very high velocities. Thus, clinical use of present approximation may be valid in real patients. In such situation, repetition of the test as much as needed could help to point out false negative submaximal performers from real negative ones. Most probably the latter would show similar DEC scores in different tests whilst the former would have difficulties to show similar DEC scores in two separate tests. All studies on DEC behaviour, including present one show the low variability of maximal effort DEC whilst submaximal effort one is highly variable.

Summarizing injures involving the shoulder are frequently treated in musculoskeletal rehabilitation and occupational medicine settings. Isokinetic evaluation is a very valuable tool in the rehabilitation progress assessment of these injures. Maximal effort of the subject is required for the validity of the test. Thus, one of the concerning problems is the lack of collaboration of the subject during the evaluation test. Therefore, having tools to handle this problem is crucial for the evaluation of these patients. In fact, previous studies focusing in DEC use in shoulder external rotators effort had revealed that the parameter was efficient and useful both in healthy individuals and patients[19,20],. Present study adds that DEC is a good tool to detect a submaximal long RoM external rotator isokinetic regardless of the device used to perform the test. However the cut-off levels differ from previous ones defined in another system. On the other hand, pertaining short RoM evaluation, present results yield a too limited sensitivity in detecting submaximal efforts. Thus, its use should be conducted with extreme care in the clinical setting.

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Table 1. Strength scores (mean ±SD, In Nm) and Ecc/Con ratios obtained under maximal and feigned shoulder external rotation efforts.

ROM: Range of motion; Con: Concentric; Ecc: Eccentric.

a All maximal effort strength scores were significantly higher than their feigned

ROM (degrees)	Velocity, degrees/sec	Mode	Maximal Effort	Feigned Effort	Ecc/Con Maximal	Ecc/Conc Feigned
Long (60)	30	Con	38.47 ± 7.732a	20.50 ± 7.556	1.13 ± 0.110	1.24 ± 0.557
		Ecc	43.26 ± 7.760a	23.07 ± 5.589		
	120	Con	34.31 ± 7.114a	18.08 ± 5.867	1.35 ± 0.111	1.80 ± 0.491b
		Ecc	45.74 ± 6.694a	30.72 ± 6.587		
Short (20)	10	Con	34.41 ± 7.953a	19.26 ± 6.106	1.07 ± 0.145	1.14 ± 0.270
		Ecc	36.03 ± 6.272a	21.14 ± 5.794		
	40	Con	34.87 ± 7.794a	18.56 ± 5.301	1.08 ± 0.078	1.36 ± 0.412c
		Ecc	37.58 ± 8.151 a	24.00 ± 5.707		

counterparts ($p<0.001$ in all cases).

b Submaximal effort 120°/s Ecc/Conc ratio is significantly higher than its maximal effort counterpart ($p=0.005$)

c Submaximal effort 40°/s Ecc/Conc ratio is significantly higher than its maximal effort counterpart ($p=0.026$)

Table 2. Average difference between the eccentric to concentric strength ratios (DEC) values ant the associated differentiation power.

Long ROM (60º) DEC values ± SD		Short ROM (20º) DEC values ± SD	
Maximal effort	Feigned Effort	Maximal effort	Feigned Effort
0.215 ± 0.126	0.556 ± 0.597a	0.014 ± 0.154	0.216 ± 0.292b

Cutoff	Confidence level	Cutoff
<0.454	80%	<0.306
<0.483	85%	<0.342
<0.552	90%	<0.426
<0.580	95%	<0.461
<0.646	99%	<0.540

ROM: Range of motion

a long ROM feigned effort DEC is significantly higher than its maximal effort counterpart $p = 0.049$

b short ROM feigned effort DEC is significantly higher than its maximal effort counterpart $p = 0.028$

Table 3. Submaximal effort detection sensitivity and specificity of long ROM and short ROM DEC at different confidence level.

	confidence level (%)	Cut-off	Sensitivity (%)	Specificity (%)
Long ROM	80	0.454	56.25	100
	85	0.483	56.25	100
	90	0.552	50	100
	95	0.580	50	100
	99	0.646	43.75	100
Short ROM	80	0.306	25	100
	85	0.342	18.75	100
	90	0.426	18.75	100
	95	0.461	18.75	100
	99	0.540	12.5	100

ROM: Range of motion

Capítol 5.5

Detection of effort maximality in normal subjects performing isokinetic wrist flexion and extension

Detecció de la maximalitat de l'esforç isocinètic de flexors dorsals i palmars de canell en voluntaris sans

Enviat a publicar a: Eur J Phys Rehabil Med

Detection of effort maximality in normal subjects performing isokinetic wrist flexion and extension

Mercè Torra, Joaquim Chaler, Eduard Pujol, Carme Unyó, Salvador Quintana, Roser Garreta, Zeevi Dvir

Enviat a publicar a: Eur J Phys Rehabil Med

Objectiu

L'objectiu del present estudi va ser examinar la utilitat de la diferencia dels ratis excèntric/concèntric a velocitat alta i baixa (DEC) en la identificació de esforços submàxims de flexors dorsals i palmars de canell.

Per aquest propòsit es van examinar vint voluntaris sans entre 20 i 40 anys d'edat (28.5±3). Els participants van ser instruits per fer un esforç màxim i fingit de flexors dorsals i palmars de canell al llarg de 20º de recorregut articular a dues velocitats de contracció: $10º s^{-1}$ i $40º s^{-1}$. Es van calcular els moments de força màxims, els ratis excèntric/concèntric i els DEC.

Resultats principals

Els DEC registrats en situació submàxima van ser significativament superiors als registrats en situació màxima, tant pels flexors dorsals de canell com pels flexors palmars. La sensibilitat del DEC era d'un 71.4% i 62.5% pels flexors dorsals i palmars respectivament. L'especificitat en tots els casos va ser de un 100%.

Conclusió

El DEC pot ser un paràmetre vàlid per detectar un esforç submàxim de flexors dorsals i palmars de canell en subjectes sans.

Detection of effort maximality in normal subjects performing isokinetic wrist flexion and extension

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Detection of effort maximality in normal subjects performing isokinetic wrist flexion and extension

Abstract

Objective: Previous studies have indicated that DEC is a powerful tool for identifying submaximal effort in other muscle groups but its efficiency in terms of the wrist extensors (WE) and flexors (WF) isokinetic effort has hitherto not been studied. The aim of present study is to examine the usefulness of the difference between isokinetic eccentric to concentric strength ratios at high and low velocities (DEC) for identifying suboptimal wrist extensor and flexor isokinetic efforts

Design: Twenty healthy male volunteers aged 20-40 years (28.5±32) without prior history of upper limb injury were instructed to exert maximal and feigned efforts, using a range of motion of 20º in concentric and eccentric WE and WF modes at two velocities: 10 and 40º/s.

Results: Feigned maximal effort DEC values were significantly higher than their maximal effort counterparts, both for WF and WE. The sensitivity of the DEC was 71.43% and 62.5% for WE and WF respectively. The specificity of the DEC and was 100%.

Conclusion: The DEC may be a valuable parameter for detecting feigned maximal WF and WE isokinetic effort in healthy subjects.

Key words: Wrist, Feigning, Effort, Identification

Introduction

Injuries involving the elbow and forearm, especially lateral and medial epicondylitis, are, together with those involving the shoulder, the knees and the back, among the main causes of occupational disease and musculoskeletal disorders [1]. Evaluation of forearm muscle strength may be an essential component to assess the functional status of patient presenting with upper limb disorders. In patients with epicondylitis forearm muscle strength assessment has been used as an evaluation or research tool [23]. Wrist muscles strength measurement performed using isokinetic dynamometry provides accurate and reproducible findings [4,5]. Isokinetic test results can serve as guidelines for planning and monitoring strength training programs, as well as for establishing permanent impairments. However, patient collaboration is crucial in order to generate reliable results. Thus estimation of the level of collaboration during an isokinetic strength test is of great interest, particularly when medicolegal claims are involved.

A number of parameters such as coefficient of variation (CV), eccentric to concentric ratios (ECR) and, specially, DEC have been advocated to differentiate between maximal and submaximal efforts using isokinetic testing [6-17]. Among them, the difference between isokinetic eccentric and the concentric strength ratios at high and low velocity (DEC) is the most widely accepted. Specifically, DEC has been proven to be highly effective at identifying feigned maximal muscular effort in different joints and actions in both healthy subjects [9-15,18] and in patients [16,17].

It has been postulated that the effectiveness of DEC depends on the different central nervous system pathways of activation and control of concentric contractions compared to their eccentric counterparts [19,20]. It has also been hypothesised that eccentric strength was less “controllable” than concentric strength. Therefore, in submaximal efforts, i.e. when individuals try to produce less strength than what they are capable of, eccentric to concentric ratios (ECR) increase, especially at high velocities, which in turn increase the value of the DEC. This increase in DEC in submaximal situations makes it possible to establish, based on studies involving volunteers, cut-off levels to determine whether an isokinetic test hast been submaximal, namely the individual has not developed maximal possible strength.

To the best of our knowledge, the efficiency of the DEC for detecting submaximal WE and WF isokinetic strength has not been studied, hence the present study.

Material and Methods

Subjects

Twenty healthy male volunteers aged 20-40 years (28.5±32) without prior history of elbow, wrist or hand pathology took part in this study. All subjects signed an informed consent form, which contained detailed information about the study. The study was reviewed and approved by the local Ethics Review Board.

Protocol

The test was conducted using a CONTREX (CMV AG, Dűbendorf/Schweiz) isokinetic dynamometer. The main parameter registered was peak torque (PT).

Subjects were sat and stabilised using cross-chest straps. During the test, the elbow was flexed at 90º with the forearm in pronation. The dynamometer axis was aligned with the ulnar styloid. Two special forearm straps were placed, one towards the front and one towards the back, in order to prevent it from moving during the test (Fig. 1).

The approximate duration of the test was 40 min and it was performed exclusively on the dominant side. The test's range of motion (RoM) was 20º (from 10º of wrist flexion to 10º of wrist extension), which was selected due to the excellent tolerance reported by patients in preliminary tests. In keeping with previous studies [21] the low and high velocities were set at 10 and 40º/s respectively, namely a 1:4 gradient.

The test protocol started with a familiarisation and warm-up phase which consisted of one set of 5 submaximal concentric contractions followed by a 2-minute rest and one set of 5 submaximal eccentric contractions. In the concentric phase, the subject was instructed to push and pull the lever arm throughout the RoM. In the eccentric phase, the subject was instructed to actively resist the lever arm that was moving in both directions. After a 3-minute rest, the actual test started.

In order to analyse to what extent the DEC was effective to identify suboptimal efforts, the protocol consisted of two experimental conditions: maximal and submaximal.

In the first part of the experiment (maximal effort) subjects were asked to initially exert maximal effort against the lever arm at 10º/s. This effort consisted of 4 pairs of concentric and eccentric contractions, with a 5-s inter-contraction pause and a 25-s inter-pair pause. After a 30-s pause, the velocity was raised to 40º/s and the same protocol was repeated. Three minutes later the second part (submaximal effort) started. During this one, the subject was instructed to apply reduced force during the test, feigning weakness. The subject was told to imagine that one year ago he had an accident and, although he had now fully recovered, he had to try convincing the doctor that he still had weakness, with the purpose of receiving compensation. After these instructions the full protocol was repeated.

Data and statistical analysis

The effort level (maximal vs. submaximal) / contraction mode (concentric vs. eccentric) and velocity (10º/s vs. 40º/s)-specific peak torque (PT) values were derived from the dedicated software and used to calculate the eccentric/concentric strength ratio (E/CR) e.g. the E/CR_{40° of the WF was PTecc/PTcon at this velocity.

From these values, the following parameter was calculated for each test condition:

DEC= E/CR 40º/s- E/CR 10º/s

The findings were analysed using the statistical software SPSS V13. The statistical tests used were t-student for coupled data and analyses of variance (MANOVA) with repeated measurements with DEC as the dependent variable and effort level as a fixed factor. A $p \leq 0.05$ indicated statistical significance. The DEC and SEC tolerance interval for maximal effort was calculated, and the cutoff level was calculated from normal distribution tolerance intervals [22]. Finally, in order to assess the DEC efficiency, the sensitivity and specificity was determined.

Results

Tables 1 and 2 outline the mean PT values for wrist extensors and flexors respectively in the two experimental conditions. In both muscle groups, the mean PTs at maximal performance were significantly higher than those registered for the feigned maximal counterpart ($p \leq 0.001$).

The differences in PT of the WE between maximal and sub-maximal effort (Table 1) were significantly lower in high velocity eccentric measurements than their concentric counterparts ($p=0.004$). Low velocity differences did not yield significant differences. On the other hand, WF analysis did not indicate significant differences regarding maximal and submaximal peak torque differences at any instance (Table 2).

Table 3 outlines the mean values (SD) of WE and WF muscle E/CR for both high and low velocities and conditions (maximal and submaximal). For all modes and velocities, the E/CR values at submaximal condition were higher than that found for the maximal condition. Significant differences regarding E/CR values were demonstrated between maximal and feigned maximal contractions in all cases except for WE at low velocity.

Feigned effort DEC values (Table 4) were significantly higher than their maximal effort counterparts, both for wrist extensors ($p<0.0001$) and flexors ($p=0.030$).

Cut-off values were then calculated using the DEC scores to allow identification of feigned maximal efforts in case these values were exceeded.

The cut-off level value derives from the calculation of tolerance intervals for normal distribution [22]. Following the present study maximal effort DEC scores, for a 95% confidence level, their respective values for WE should exceed 0.384 and 2.665, respectively, to label an effort as submaximal. Obviously, the higher the level of confidence selected is, the higher the cut-off level. Therefore, for a confidence level of 99% the cut-off value for DEC should be 0.576, whereas for 90% the cut-off value would drop to 0.303 (see Table 5).

Regarding wrist flexors, the DEC cutoff value for a confidence level of 95% was 0.317. Exceeding this would result in labelling the performance sub-maximal. For a higher level of confidence, of 99%, the value duly increased to 0.486 while for a 90%, level of confidence, the value decreased to 0.245(see Table 6). For each of these cut-off values, Table 7 outlines the corresponding figures for sensitivity and specificity. There was not even one case where the DEC score in maximal effort condition, exceeded the cut-off for the 99% confidence level, resulting in a specificity of 100%. Lower cutoff levels (namely, calculated for a 90% and 95% confidence level) have not resulted in lower DEC specificity for both WF and WE, Notably the DEC sensitivity increased as lower confidence levels were selected. It showed higher sensitivity in the case of submaximal WE compared to submaximal WF effort.

Discussion

The main result of this study is that in healthy male volunteers feigned maximal efforts of WF and WE can be quite efficiently detected using the DEC. Given its associated intricacies this result deserves further elaboration.

Injures involving the forearm are very frequent in musculoskeletal rehabilitation and occupational medicine settings. If these injuries involve a muscular component, which eventually leads to weakness, isokinetic dynamometry is the tool of choice for its evaluation. The latter derives from the fact that in addition to its high accuracy and reproducibility, the incorporation of different contraction modes and velocities enable a decision regarding patient's collaboration, a critical condition for the clinical validity of the findings. As shown before [9-18,23] the DEC provides an efficient tool for this objective but its values are muscle group-specific. Moreover, for vindication of its application in select patient cohorts, its validity in healthy subjects regarding the same muscle group, is an essential preliminary step, leading to the current study of hitherto unexplored WF and WE muscle groups.

In the present study, the concentric and eccentric maximal effort PT values in WE: 12.96Nm and 12.56Nm (10°/s), 12.84 and 12.58Nm (40°/s), respectively, were in the range of the reported strength in healthy men for concentric effort:11.3Nm (30°/s) but lower than the eccentric component: 17.1Nm at the same velocity. [4] It is important to note at this point that both eccentric PTs (at 10°/s and 40°/s) were slightly lower than their concentric counterparts. This finding is in variance with the general observation namely that in normal participants the strength of eccentric is higher than their concentric counterparts, within the same velocity resulting in an E/CR > 1.0. [21]. However present both EC/Rs are very close to unity with 1,09 and 0.98 at 10°/s and 40°/s, respectively. Therefore, this slight deviation may be attributed to the relatively low-test velocity.[21]

Regarding WF, the maximal effort concentric and eccentric PT mean values (10°/s: 18.04Nm; 40°/s: 18.84Nm and 10°/s 20.21Nm; 40°/s: 21.11Nm respectively) were lower than the mean PT values reported in the same previous study (concentric values: 30º/s: 26.1; 90º/s: 26.7Nm; and eccentric mean values 60º/s: 33.4 Nm).[4] The gaps noted are due both to the velocity of testing and the use of a different dynamometer. Interestingly, present sample WF tests reveal clearly higher eccentric measurements than concentric ones.

The PT values during the performance of maximal effort were as expected significantly higher than those derived from the sub-maximal condition in all instances and in WE and WF alike. However, this difference was not uniform contractionwise; in WE the mean maximal and sub-maximal PTs at high velocity in eccentric mode were much closer than in concentric mode, an outcome reflecting the more limited central controllability of sub-maximal eccentric contraction control [19,20]. This finding was not as apparent with respect to WF probably due to a higher voluntary control of these muscles.

Most sub-maximal effort E/CR values in present sample were higher than their maximal effort counterparts. The exception was low velocity (10º/s) wrist extensor E/CR. Thus, for WE at 40º/s the high velocity ECR was significantly greater in the sub-maximal effort while remaining substantially the same at the 10º/s test. As highlighted below, these findings provide for a higher power of the DEC in the detection of sub-maximal WE effort, whereas its utility in doing so vis-à-vis WF is slightly lower due to a smaller inter-E/CR difference (see Table 3).

The analysis of the WE and WF DEC (Table 4) showed, as expected, that submaximal effort value were significantly higher than their maximal effort counterparts. The mean DEC value for maximal WE effort (0.01) was well within the DEC value range reported in previous studies performed in other muscle groups (-0.007-1.06), whereas WF one (-0.013) was slightly lower than the lowest score that was previously registered (-0.007). The average DEC values in sub-maximal effort, for WE (0.44) and WF (0.20), were even lower than the ones found in previous studies.(0.68- 6.06) [9-15,18]. One possible explanation is a more refined voluntary control of eccentric contractions in forearm muscles.

From the submaximal DEC values we have calculated the cutoff scores for indicating admission/rejection zones for both the WE and WF (Table 5 and 6). These cutoff values may be of decisive use in relevant medico-legal cases as well as in general clinical practice where isokinetic tests are utilized. However, high sensitivity and specificity are required in order that they are validly applied. At the same time one must bear in mind the interaction between the latter and pre-set level of confidence (loc) namely the higher the loc the higher the specificity while the lower the loc the higher the sensitivity reached. Table 7 outlines the different sensitivities and specificities obtained using 90%, 95% and 99% loc. Notably the DEC retained its perfect specificity (100%) even at a loc of 90% for both muscle groups. In addition, given the substantial stability of the specificity of the DEC and given the wide use of 95% as the standard loc we recommend the use of this loc in testing effort maximality in WE and WF testing.

In present study, DEC has been proven efficient in sincerity of effort detection using an isokinetic test performed at a very short wrist ROM (namely 20º). Dvir [24] has largely advocated short RoM isokinetic tests. They may be highly useful for routine clinical practice, especially when a longer ROM cannot be used due to pain or joint instability, among other reasons.

However attractive the use of the DEC in the medicolegal arena may be, it is essential to keep in mind that the collaboration of a patient during a diagnostic test can be affected by a wide variety of causes such as pain, fear of suffering pain, fear of being injured, anxiety, depression, misunderstanding of the instructions or of the importance of the test and, obviously, interest in obtaining financial benefit[25]. Therefore, it is very important to have a detailed anamnesis, a complete physical exploration (so as to detect the existence of inconsistencies with the clinic) and other complementary tests (that might show the presence of injuries, which could explain any deficiencies) before assessing the patient's collaboration. It is also of essence to note that the current values provide a baseline only to which future studies of muscular strength in patients with wrist function disorders should refer. As recently indicated in as yet unpublished paper [23] the DEC values of the uninvolved side of patients impaired with rotatory dysfunction of the shoulder furnished a more valid reference than DEC values derived from normal subjects.

In conclusion, the DEC may be a valuable parameter for detecting feigned maximal effort in wrist flexor-extension isokinetic tests in healthy subjects. Further research should focus on patients with injuries involving the wrist, both in medico-legal situations and in routine clinical practice.

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Figure Legends

Figure 1 Positioning of the subject.

Table 1. Mean Peak torque (Nm) of wrist extensors by level of effort and speed.

Contraction type	Speed	Maximal effort PT± SD	Submaximal effort PT± SD	Diference Absolute
Concentric	10º/s	12.96± 2.74	6.40± 4.1*	6.52± 2.09
	40º/s	12.84± 3.10	5.22± 3.67*	7.61± 3.12^
Eccentric	10º/s	12.58± 2.72	6.16± 2.94*	6.39± 2.14
	40º/s	12.57± 3.09	6.64± 3.15*	5.94± 2.30^

PT: mean peak torque (Nm)

SD: standard deviation

* $p \leq 0{,}001$ significant difference between maximal and sub-maximal effort.

^ $p = 0{,}004$ significant difference between eccentric and concentric contraction at 40º/s

Table 2. Mean Peak torque (Nm) of wrist flexors by level of effort and speed

		Maximal effort	Submaximal effort	Difference
Contraction type	Speed	PT± SD	PT± SD	Absolute
Concentric	10º/s	18.04±5.31	5.59 ± 3.77*	12.44± 4.09
	40º/s	18.84±5.03	5.12±3.44*	13.71± 4.02
Eccentric	10º/s	20.21±5.50	6.62±4.01*	13.58± 4.51
	40º/s	21.11±6.16	7.15±4.74*	13.96± 5.20

PT: mean peak torque (Nm)

SD: standard deviation

* p≤0,001 significant difference between maximal and sub-maximal effort.

Table 3 Mean eccentric/concentric ratios

		maximal		submaximal	
		E/CR	SD	E/CR	SD
wrist extensors	10º	1.09	0.56	1.11	0.33
	40º	0.98	0.14	1.55*	0.55
wrist flexors	10º	1.12	0.15	1.25^	0.29
	40º	1.11	0.12	1.45^	0.58

E/CR: eccentric/concentric ratio

SD: Standard deviation

* p≤0,001 significant difference between maximal and sub-maximal effort.

^ p≤0,05 significant difference between maximal and sub-maximal effort.

Table 4 Mean DEC and standard deviation (SD) in both experimental conditions: maximal and submaximal effort.

	maximal		**submaximal**	
	mean	SD	mean	SD
wrist extensors	0.01	0.136	0.44*	0.41
wrist flexors	-0.013	0.120	0.20^	0.32

DEC: difference eccentric-concentric

* p≤0,001 significant difference between maximal and sub-maximal effort.

^p≤0,05 significant difference between maximal and sub-maximal effort.

Table 5. Mean DEC and standard deviation (SD) in both experimental conditions: maximal and submaximal effort of wrist extensors. Calculated tolerance or cut-off levels are depicted relative to the different options of confidence level

Wrist extensors		
DEC max		DEC submax
0.01 ± 0.136		0.44 ± 0.41
confidencelevel (%)	Cut-off DEC	
90	>0.303	
95	>0.384	
99	>0.576	

DEC: difference eccentric-concentric

Table 6. Mean DEC and SEC, and standard deviation (SD) in both experimental conditions: maximal and submaximal effort of wrist flexors. Calculated tolerance or cut-off levels are depicted relative to the different options of confidence level

wrist flexors	
DEC max	DEC submax
0.01 ± 0.136	0.44 ± 0.41

Confidence level (%)	Cut-off DEC
90	>0.303
95	>0.384
99	>0.576

DEC: difference eccentric-concentric

Table 7. Sensitivity and specificity of the DEC at different confidence levels.

	wrist extensors			wrist flexors		
Confidence level (%)	Cut-off	Sensitivity (%)	Specificity (%)	Cut-off	Sensitivity (%)	Specificity (%)
90	0.303	74.07	100	0.245	64.5	100
95	0.384	71.43	100	0.317	62.5	100
99	0.576	58.82	100	0.486	57.1	100

DEC: difference eccentric-concentric

Capítol 5.6

Avaluació de l'activitat muscular i fatiga en musculatura flexora dorsal del canell durant contraccions isomètriques

Evaluation of muscle activity and fatigue in extensor forearm muscles during isometric contractions

Conf Proc IEEE Eng Med Biol Soc. 2005;6:5824-5827

Evaluation of muscle activity and fatigue in extensor forearm muscles during isometric contractions

M.A. Mañanas, M. Rojas, F. Mandrile, J. Chaler

Conf Proc IEEE Eng Med Biol Soc. 2005;6:5824-5827

Objectiu

Les patologies musculo-esquelètiques de les extremitats superiors relacionades amb l'activitat laboral poden ser relacionades amb fatigabilitat muscular dels musculs flexors dorsals de canell. L'objectiu d'aquest treball va ser avaluar els nivells d'activitat, fatiga i interaccions entre els principals musculs flexors dorsals del canell.

Per aquest objectiu es van registrar senyals electromiogràfics del primer radial (PR), el extensor comú dels dits (ECD) i el cubital posterior (CP) mentre es realitzaven contraccions isomètriques. Es varen registrar la velocitat de conducció (VC), el valor mitja rectificat de l'EMG (VMR) i freqüència. Les activitats realitzades van ser selectives i no selectives, contraccions voluntàries màximes (CVM), a diversos percentatges de la màxima i finalment un test de fatiga al 50% de la contracció màxima voluntària.

Resultats principals

Els resultats van mostrar que era possible augmentar significativament la VMR del ECD i el CP al realitzar contraccions selectives. En les tasques no selectives, el CP mostrava una disminució significativa de la VMR al revés que els altres músculs quan augmentava la intensitat de contracció. L'activitat del PR era predominant en relació als altres músculs a 80% de la CVM. Els paràmetres espectrals i de VC van mostrar que tots els músculs presentaven fatiga durant una contracció sostinguda al 50% de la CVM.

Conclusió

La conclusió principal de l'estudi seria que s'indiquen comportaments diversos en relació a l'activació pel que fa al CP i el PR, de manera que, mentre el primer disminueix activitat, el segon augmenta la intensitat de la contracció. Aquesta troballa podria tenir implicacions pel que fa a la patogènesi de patologies musculo-esquelètiques d'avantbraç.

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Evaluation of muscle activity and fatigue in extensor forearm muscles during isometric contractions

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Abstract—**Work-related upper extremity disorders as epycondylitis and tendonitis are closely related to localized muscle fatigue of extensor forearm muscles. The aim of this work is to evaluate levels of activity, fatigue and interactions between the main extensor muscles of the wrist. Surface EMG signals were acquired from extensor carpi radialis (ECR), extensor digitorum comunis (EDC) and extensor carpi ulnaris (ECU) muscles during isometric contractions using linear electrode array technique. Parameters such as muscle fiber conduction velocity (CV), EMG average rectified value (ARV) and frequency parameters were estimated to study muscle activity during selective contractions, during a non specific task at different percentage of the maximum voluntary contraction (MVC) level and during a fatiguing exercise at 50% MVC. Results show that it is possible to enhance significantly ECR and ECU muscle ARV during their selective activation. Moreover, in the non selective task, ECU muscle ARV significantly decreases with respect to the other muscles with the increase of the MVC level. The activity of ECR muscle in a non specific task is predominant with respect to the other muscles at 80%MVC. EMG spectral parameters and CV show fatigue in all muscles during a sustained contraction at 50% MVC.**

Keywords—**Electromyography, forearm extensor muscles, musculoskeletal disorders, fatigue plots.**

I. Introduction

Work-related Upper Extremity Disorders (WRUEDs) are conceived of a multi factorial syndrome caused by the effects of excessive repetitive motions, sustained static postures, and muscular stiffness [1].

Workplace stress generates musculoskeletal disorders and localized muscle fatigue [2][3]. Forearm pronation and supination, and increased muscular activity in the wrist extensors have been related to WRUEDs [5].

The aim of this study is the evaluation of level of activation and fatigability of three extensor muscles mainly involved in these diseases. They are the extensor carpi radialis (ECR), the extensor carpi ulnaris (ECU) and the extensor digitorum comunis (EDC).

This study is the first part of a research project among three European research centres. Preliminary results were obtained from forearm muscles of healthy volunteers. A comparison between this control group and a population with WRUEDs will be performed in the near future.

II. Methodology

A. Subjects and Instrumentation

Fourteen healthy male volunteer subjects (age, mean ± standard deviation: 30.2 ± 3.3 years; height: 176.4 ± 6.0 cm; weight: 75.7±7.8 kg) participated in the experiment. No subjects had known symptoms of neuromuscular disorder.

Surface EMG signals were detected from each of the selected forearm extensor muscles by means of a linear adhesive array (LISiN – Spes Medica, Italy, Pat. No. GE2001A000086) of eight Ag-AgCl electrodes with 5 mm inter electrode distance (IED). A non adhesive 16 electrode array (silver bar electrode 1 mm thick, 5 mm long, IED=5 mm, OT Bioelettronica, Italy) was used to determine the proper electrode array position for signal detection as detailed below.

Twenty-four surface EMG signals were recorded with two 16-channel amplifiers (ASE16, LISiN-SEMA Elettronica, Torino, Italy), bandpass filtered (-3 dB bandwidth 10–450 Hz), sampled at a rate of 2048 Hz and stored on a PC after 12-bit analog-to-digital conversion (National Instrument NI-DAQ 6024E and NI-DAQ AI-16E4 A/D cards). Acquisitions were performed in single differential (SD) mode with a reference strip electrode placed around the wrist.

The subject's forearm was placed in an isometric brace (OT Bioelettronica, Italy) in prone position, with the elbow joint at an angle of 90°. This position was selected according to [5] to maximize wrist extensor muscles activity. The torque exerted during wrist extension was measured by means of two torquemeters and recorded on a second PC. Both the acquisition systems were synchronized using an external trigger.

B. Array Placement

The direction of the fibres in the three wrist extensor muscles was marked on the forearm according to anatomical landmarks [5]. The non adhesive array was used to locate the best position for signal detection. The array was moved along the reference line in different positions on each muscle and the subject was asked to perform short contractions in order to locate the innervation zone (IZ) and to find a

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portion of the muscle between IZ and the tendon region in which was possible to detect propagating potentials with similar shape on different EMG channels. Selective contractions for each of the three extensor muscles were performed to maximize the activity of each muscle and to identify the best position for the array [6]. Position and orientation of the electrode array were selected where it was possible to record the most similar and largest single differential potentials along muscle fiber direction [7] and the most similar double differential (DD) signals (highest correlation coefficient, ρ) with conduction velocity estimates within physiological values (considered in the range 2-8 m/s). The best position was marked on the skin and an eight electrode adhesive array was placed after skin shaving and abrasion. Conductive gel (20µl) was inserted under each electrode of the array to provide proper electrode-skin contact, using a gel dispenser (Multipette Plus, Eppendorf, Germany).

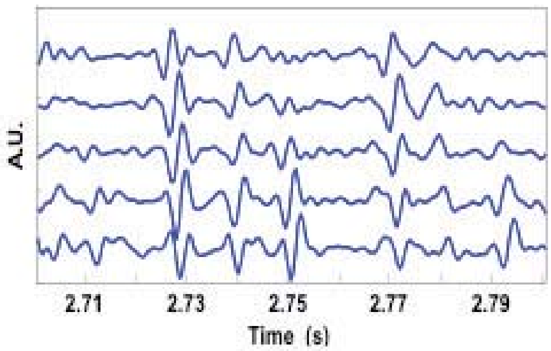

Fig.1. Example of five SD EMG signals recorded from ECU muscle during lateral wrist rotation.

C. *Experimental protocol*

Subject was asked to perform selective contractions for each extensor muscle, with the forearm fixed in the isometric brace. In detail, ECR muscle was activated with extension and medial rotation of the wrist; EDC muscle was activated with extension of the wrist and of the first phalanges of the fingers; ECU muscle was activated with lateral rotation of the wrist [6]. In all cases EMG signals were detected from the three extensor muscles during each selective contraction.

Then, a series of non selective contractions, such as the extension of the wrist with the fingers relaxed, were performed. Maximum voluntary contraction (MVC) level was selected among a series of three maximal contractions. Each subject performed three voluntary isometric wrist extensions at 20%, 50% and 80% MVC in a randomized order. The duration of each contraction was 15 s with 3 minutes of resting period in between to avoid cumulative fatigue.

Finally, a fatiguing contraction was performed, at 50% MVC, up to subject exhaustion to assess the endurance time.

D. *Data processing*

Information from amplitude of EMG signal was obtained by means of the average rectified value (ARV).

Median and mean frequencies (MDF and MNF, respectively) of the power spectrum of the surface EMG signal were selected as spectral descriptors.

Muscle fibre conduction velocity (CV) was estimated using the McGill algorithm [9].

All parameters were computed on signal epochs of 0.5 s and from the best triplet of consecutive SD signal (selected on the basis of the highest ρ related to physiological estimates of CV) in each muscle and exercise. Statistics were carried out by one sample and paired samples t-tests. Significance level was set to the 5% value ($p<0.05$).

III. Results

A. *Isometric non fatiguing contractions*

Mean and standard deviation (σ) of the parameter of interest in the population were obtained. For each of the six exercises (three selective contractions and three contractions at different levels of MVC) and for each subject, ARV was normalized with respect to the maximum of the values obtained from the three muscles on the given exercise (Fig.2). During selective contractions of ECR and ECU muscle, respectively, ARV of the selectively activated muscle was significantly greater with respect to all the others ($p<0.01$). Conversely, EDC activity (ARV) during its selective contraction showed no difference with respect to ECR ARV. ECU muscle activity with respect to ECR and ECU activity (normalised ARV) significantly decreased with the increase of the percentage of MVC ($p<0.003$ between 20 and 80% MVC). Finally, ECR muscle showed greater values of ARV at high levels of contraction ($p<0.04$ at 80% MVC).

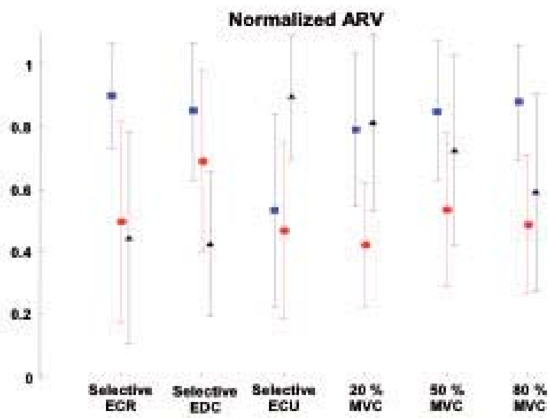

Fig. 2. ARV normalized with respect to the highest value obtained from the three muscles in each contraction. Symbols (,O, Δ) correspond to ECR, EDC and ECU respectively. N=14 subjects, mean±σ.

B. *Fatiguing contraction*

The evolution of the EMG parameters, normalized with respect to their initial value, is called "fatigue plot". Results were calculated as mean ± σ for all the subjects (Fig. 3) from the fatiguing task performed at 50% MVC level up to exhaustion. Endurance time was defined as the time instant from which the subject can no longer maintain the constant MVC level selected with a tolerance of the 10% of that level.

A linear regression was carried out from the evolution of every parameter in each subject. The slope indicated its linear trend during this exercise.

A decrement of CV, MDF and MNF was observed ($p<0.005$ in the slopes of all parameters in the three muscles). Otherwise, a significant increment of EMG amplitude was observed ($p<0.01$ in the ECR and $p<0.03$ in the EDC and ECU for ARV slope).

IV. Discussion and Conclusion

The activity of ECR and ECU muscles (ARV) can be enhanced with respect to the other extensors during their selective contractions.

During the non selective task, a significant decrease of ECU muscle ARV with the increase of the MVC level, with the increase of ECR muscle ARV at higher MVC levels, should be interpreted as a particular paradigm of muscle activity sharing, related to the extension task.

A decrement of CV and of MDF and MNF was observed during the fatiguing exercise, indicating myoelectric fatigue. Spectral changes are generally attributed to a progressive decrease in CV, which also contributes to an increase in the amplitude of the surface EMG signal. A further reason of such an increase could be related to the recruitment of new motor unit [12]. Experimental studies, however, consistently report that relative decreases observed in both the MNF and MDF are substantially greater than simultaneous decreases measured for CV. Factors other than CV thus affect the EMG power spectrum, such as motor unit firing and recruitment patterns [11]. ARV showed a significant increment of the EMG signal amplitude with fatigue.

Finally, this work shows that EMG signals acquired with linear electrode arrays properly placed, can be used to study the level of activity, the activity sharing and the fatigability of the forearm extensor muscles.

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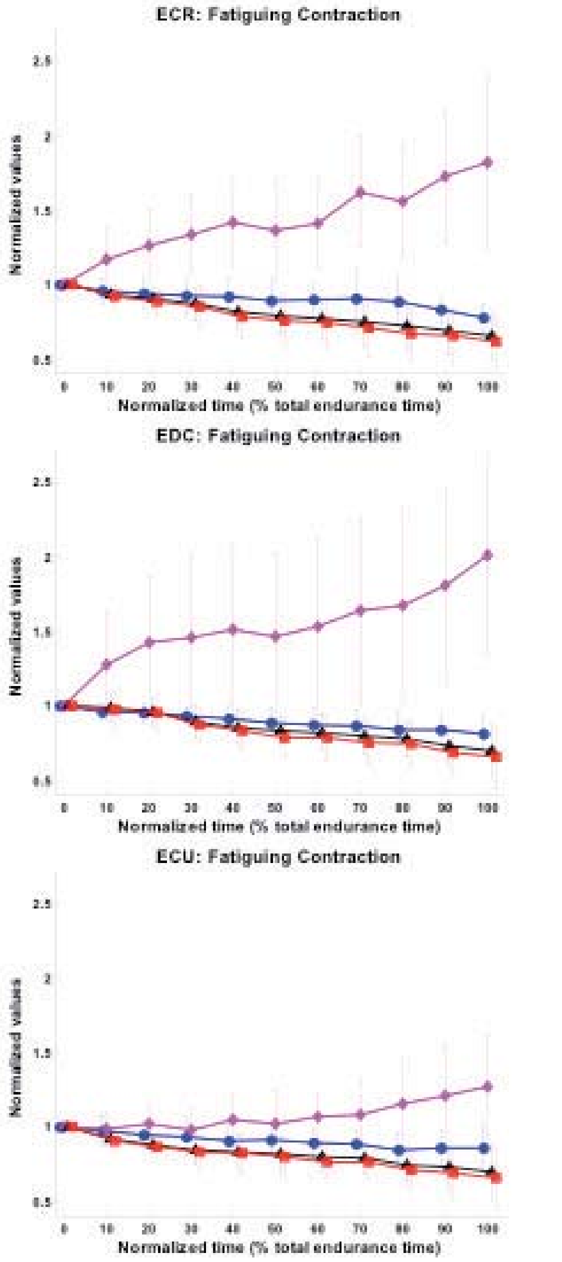

Fig. 3. Evolution of EMG parameters normalized with respect to the initial value from the three muscles at 50% MVC fatiguing contraction. Symbols (◊, ,O, Δ) and magenta, blue, red and black traces correspond to ARV, CV, MDF and MNF , respectively. Time is normalized with respect to the total endurance time for each subject. N=14 subjects, mean±σ.

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Capítol 5.7

Activació dels músculs flexors dorsals de l'avantbraç en pacients afectes d'epicondilitis lateral

Activation of forearm muscles for wrist extension in patients affected by lateral epicondylitis

Conf Proc IEEE Eng Med Biol Soc. 2007:4858-4861

Activation of forearm muscles for wrist extension in patients affected by lateral epicondylitis

M. Rojas, M.A. Mañanas, B. Müller, J. Chaler

Conf Proc IEEE Eng Med Biol Soc. 2007:4858-4861

Objectiu

Les lesions laborals d'extremitat superior son més per microtraumes repetitius que per traumatismes aguts. Per tant la situació muscular dels subjectes en relació a la resposta als microtraumes es important i podria estar relacionada amb la patologia. L'objectiu del present treball va ser comparar la activació muscular de musculatura de l'avantbraç de subjectes sans i pacients amb història prèvia d'epicondilitis (no activa en el moment del test). Per això, es van recollir senyals electromiogràfics del primer radial (PR), el extensor comú dels dits (ECD) i el cubital posterior (CP) mentre es realitzaven contraccions isomètriques. Es varen registrar la velocitat de conducció (VC), el valor mitja rectificat de l'EMG (VMR) i frequència. Les activitats realitzades van ser selectives i no selectives, contraccions voluntàries màximes (CVM), a diversos percentatges de la màxima i finalment un test de fatiga al 50% de la contracció màxima voluntària.

Resultats principals

Es va demostrar una major activació del CP en detriment del PR en pacients amb historia d'epicondilitis en comparació amb subjectes sans. Igualment els paràmetres de fatigabilitat dels pacients eren superiors

Conclusió

Els resultats indiquen un desequilibri muscular en detriment del PR en pacients amb historia d'epicondilitis al mateix temps que una més gran fatigabilitat. Aquestes troballes poden dirigir programes de rehabilitació i ajudar a detectar subjectes en risc alhora que monitoritzar els programes.

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Cité Internationale, Lyon, France
August 23-26, 2007.

Activation of Forearm Muscles for Wrist Extension in Patients Affected by Lateral Epicondylitis

Mónica Rojas, Miquel A. Mañanas, *Member, IEEE*, Bertram Müller, and Joaquim Chaler

***Abstract*—Work related upper extremity disorders are associated with cumulative trauma resulting from the continuous use of forearm muscles rather than from a specific incident. The aim of this work is to compare wrist extensor muscles activation between patients with lateral epicondylitis and healthy subjects. Differences can be used in the design of rehabilitation or injury prevention programs according to biomechanical deficits. Surface EMG signals from three forearm extensor muscles (Carpi Radialis-ECR, Digitorum Communis-EDC and Carpi Ulnaris-ECU) were recorded by linear electrode arrays in wrist extension as well as during selective contractions. Average Rectified Values (ARV) were calculated in order to identify the contribution of each muscle to different tasks. On the other hand, Muscle Fiber Conduction Velocity, Mean and Median Frequencies and also ARV were studied to obtain fatigue indexes related to metabolic changes in the muscles during a high force sustained contraction. Results showed muscular imbalance with lower ECR activity compensated by higher ECU activation, and higher fatigue indexes in patients with lateral epicondylitis.**

I. Introduction

Work related Upper Extremity Disorders (WRUEDs) are very common in occupational rehabilitation medicine and affect populations from various economic sectors, especially those related with manufacturing, construction and mining. This term refers to various musculoskeletal disorders of joints, bones, ligaments, tendon and muscles which result from the repeated use of the upper extremity over time [1]. One of the most common is Lateral Epicondylitis affecting the muscle- tendon units around lateral epicondyle. Different extensor muscles originate in this area: the Extensor Carpi Radialis Longus and Brevis (ECR), the Extensor Carpi Ulnaris (ECU) and the Extensor Digitorum Communis (EDC). The primary function of ECR and ECU is the extension and deviation of the wrist. The EDC muscle also acts synergistically during these tasks although its main function is the extension of the fingers.

The neuron-physiological condition of muscles can be evaluated through multichannel Surface Electromyography (sEMG), a noninvasive tool with benefits that have not yet been thoroughly established in clinical practice [2]. The acquisition of simultaneous signals at different points in space allows the estimation of the temporal delay introduced by the Muscle Fiber Conduction Velocity (CV). Changes in CV are associated with myolectric fatigue and with pathological conditions. Other parameters, such as those related to signal amplitude and power spectral density can be estimated as well from these signals given that the amplitude and the spectral density depend on the number of active motor units (MU) in the contraction [3].

This study focused on the analysis of muscular activation of patients suffering lateral epicondylitis by comparison with results from healthy subjects.

II. Methodology

A. Subjects

Ten healthy male subjects (age, mean ± standard deviation: 31.5 ± 5 years; height: 176.4 ± 6.15cm; weight: 76.3 ±5.48kg) and ten non symptomatic subjects who had suffered lateral epicondylitis (age: 33.3 ± 4.6 years; height: 174.6 ± 5.8cm; weight: 76.92 ± 12.8kg) participated in the experiment. Healthy subjects group did not reported history of musculoskeletal and/or neuromuscular disorders. Patients inclusion criteria were: history of lateral epicondylitis treated with conservative therapy (surgery excluded) and absence of relevant symptoms for at least 3 months prior to the test. In all cases, lesion had been induced by the repetitive use of forearm muscles related to physical effort required by working activities.

B. Experimental Protocol and Instrumentation

Subjects were seated with the back straight and the forearm from the dominant limb placed into an isometric brace (OT Bioelettronica, Italy) in a proned position, and with the elbow joint at an angle of 90º. In this position, the subjects were asked to extend the wrist in vertical direction parallel to the forearm line. In order to reduce any rotation of the wrist, torque was measured at both sides of the hand (Fig. 1) and the subjects were asked to maintain the same level in both. Wrist extension requires the co-activation of the forearm extensor muscles rather than the contraction of an isolated one.

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Linear arrays of 8 electrodes (Ag- AgCl) with inter-electrode distance of 0.5 cm were used (Fig. 1) (LISiN- Spes Medica, Italy, Pat. No. GE2001A000086).

Arrays were placed according to a previous study on the muscles ECR, EDC and ECU [4]. The best location was selected by inspection during the following selective contractions [5]: radial deviation for enhancing the activity of ECR muscle and finger extension and ulnar deviation for enhancing the actions of EDC and ECU respectively. Propagation of Motor Unit Action Potentials (MUAP) and small wave shape differences between subsequent signals were used as criteria for the correct alignment of a linear electrode array parallel to muscle fibres. Before placement of the array, skin was shaved and cleaned with abrasive paste. No statistical differences in the final location of the electrodes between the two groups were found.

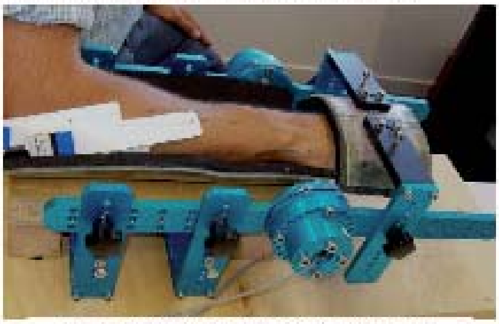

Fig. 1. Isometric Brace used in the experiment.

Surface EMG signals were recorded with two 16-channel amplifiers (ASE16, LISiN-SEMA Elettronica, Torino, Italy), in single differential mode (SD), bandpass filtered (3-dB bandwidth 10–450 Hz), sampled at a rate of 2048 Hz and stored on a PC after 12-bit analog-to-digital conversion (National Instrument NI-DAQ 6024E and NI-DAQ AI-16E4 A/D cards). Seven SD channels referred to an electrode strip placed around the wrist were recorded in each of the muscles.

The selective contractions described above were performed at the beginning of the experiment. Afterwards, each subject was asked to achieve his Maximum Voluntary Contraction (MVC) in three trials during wrist extension. The next part of the test consisted in submaximal contractions at 20%, 50% and 80% MVC that were carried out in a randomized order. Subjects were asked to maintain the level of contraction for 15 seconds or up to exhaustion. Every contraction was followed by a resting period of 3 minutes in order to avoid cumulative fatigue.

C. *Data Analysis*

EMG variables were evaluated on double differential signals (DD) that were obtained offline, in order to enhance the selectivity of the detection system and to reduce crosstalk [6]. DD signals are the result of the spatial filtering on the skin plane parallel to muscle fibers by subtracting two adjacent SD channels.

Amplitude of the EMG signal was estimated through average rectified value (ARV). Median and mean frequencies (MDF and MNF, respectively) were calculated from the power spectrum of the signals. Muscle fiber conduction velocity (CV) was estimated using the spectral matching algorithm proposed by Mc.Gill et al [7].

All variables were computed on 50% overlapping segments of 0.5s (epochs) chosen from the most similar DD pair (selected on the basis of the highest cross- correlation coefficient) where the CV estimate ranged on physiological values. Variables were estimated in the first three seconds of the signal to avoid effects of myoelectric fatigue.

Besides, fatigue plots were obtained by calculating the variables for all the sustained contraction at 80% MVC. DD signals were inspected visually in order to detect the presence of artefacts. Epochs containing artefacts were removed for the final estimation of variables [8].

Intragroup statistics were performed trough the Wilcoxon Signed Rank test and statistics between groups were performed through the Mann-Whitney U test. The significance level was set to 0.05 ($p<0.05$).

III. Results

A. *Muscle Co-activation*

Voluntary effort combines the individual muscle contributions in order to produce and maintain a given task. Consequently, although the net force output may be unchanged it is possible to find different muscle twitch behaviors that vary according to effort level or exercise [3].

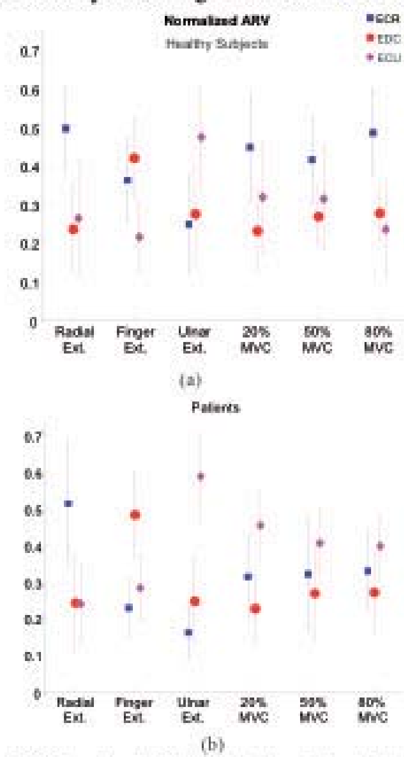

Fig. 2. ARV Normalized with respect to the total contribution of the muscles in each exercise: radial, finger and ulnar extension, submaximal contractions at 20, 50 and 80% MVC.

The objective of this analysis is to observe which muscle mainly supports the co-activation of the extensor muscles under study. ARV was obtained and presented in terms of mean and standard deviation (std) in each group.

Six exercises were analyzed: radial, finger and ulnar extension, and three wrist extensions at submaximal level. For every exercise, ARV of a given muscle was normalized with respect to the sum of the ARV in the three muscles, that is, the sum of the contributions of the individual muscle to the task. Results for healthy subjects (Fig. 2a) were previously reported in [9].

In the case of patients and for selective contractions, normalized ARV (nARV) of the muscle whose activity was enhanced was significantly greater than nARV in the other ones ($p<0.03$ for ECR and $p<0.004$ for EDC and ECU) (Fig. 2b). In the case of healthy subjects it happened only in radial and ulnar extension but not in finger extension where the ECR was also active.

The main contribution to the joint activation is carried out by different muscles in different groups. Regarding the patient group, the normalized ARV in the ECU was greater than that of the EDC at 20, 50 and 80% MVC ($p<0.02$) and was also greater than that of the ECR at 20%MVC ($p<0.05$). In healthy subjects normalized ARV of ECR was greater than in EDC in all levels and greater than in ECU at 80% MVC. Additionally by comparison between groups, the average contribution of ECR was greater for healthy subjects than for patients ($p<0.02$). On the contrary the average contribution of the ECU was greater in the case of patients than in healthy subjects ($p<0.02$).

B. *Myoelectric Fatigue*

During a sustained isometric contraction, changes of EMG variables along time reflect physiological changes in the muscle and in the CNS such as recruitment of MU, type of active MU (slow of fast twitch), firing rate, etc [10].

Plots of EMG variables normalized with respect to their initial values as a function of time, called fatigue plots, are presented as mean and std for all subjects in both groups during the exercise of wrist extension at 80% MVC (Fig. 3).

Endurance time was defined as the time instant from which the subject could no longer maintain the 80% MVC level. The fatigue index for each variable was calculated as the absolute value of the slope from the linear regression of its trend in every subject.

A decrease of CV was observed during the fatiguing exercise in all muscles and both groups ($p<0.02$ for healthy subjects and $p<0.01$ for patients). However, a decrease of the MNF and the MDF variables and an increase of the ARV were found in the group of patients but not in the group of healthy subjects ($p<0.04$ in all variables).

When comparing fatigue indexes between groups, ARV in ECR, ECU and EDC presented higher fatigue indexes for patients than for healthy subjects ($p<0.02$, $p<0.01$, $p<0.03$ respectively).

Decrease of CV during a sustained contraction is a clear manifestation of myoelectric fatigue. The slopes obtained in CV without normalization were more negative in patients than in healthy subjects for EDC ($p<0.04$) and especially for ECR ($p<0.01$).

IV. Discussion and Conclusion

Two biomechanical models have been proposed for lateral epicondylitis: one emphasizing the role of eccentric exertions and the other emphasizing the contact pressure of the radial head [11]. The present study shows new findings

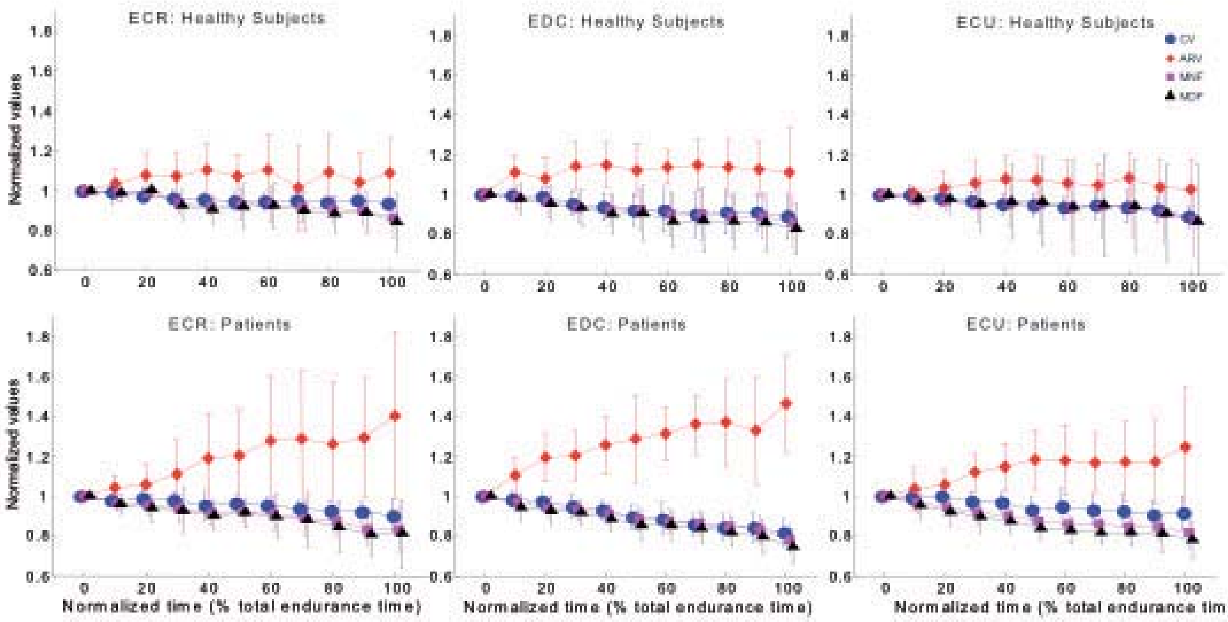

Fig. 3. Fatigue plots for ECR, EDC and ECU for healthy subjects (up) and patients with lateral epicondylitis (down)

which could complete those models since several differences between controls and patients in muscle activation pattern have been identified.

Differences in wrist extensor muscle co-activation pattern during selective actions and wrist extension (namely, less ECR and higher ECU co-activation in patient group when compared with control group) may indicate a muscle imbalance underlying the lateral epicondyle overuse condition. Muscle imbalances, shortenings and weaknesses have been identified as major biomechanical factors underlying cumulative trauma injuries [12]. Continuous training of forearm muscles due to repetitive tasks could possibly lead to a higher level of specialization in patients since they can selectively activate each of the muscles under study but not in the case of healthy subjects.

Biomechanical deficits may both arise after an injury (in which case should be treated in the latter phases of rehabilitation) or precede the actual injury. In any case, the identification of biomechanical deficits is crucial in order to design rehabilitation/injury prevention programs. By pointing the target muscles to be specifically trained, the findings explained above might provide the clue to design programs for lateral epicondylitis rehabilitation and/or prevention. Thus, a recommendation to specifically train the ECR muscle, at least in isometric contractions, would be a reasonable approach following the results of this study.

In regard to fatigue parameters, not surprisingly we found significantly higher ARV fatigue indexes for all the muscles in patients. That is, decreased muscle endurance might be tightly related to the development of an injury in the lateral epicondyle region. It is, to our best knowledge, the first time that such a relationship has been found.

Differences in fatigue indexes might be related to a higher recruitment of MU in the group of patients. Besides, higher decreases in CV for EDC and especially ECR were found in patients than in healthy subjects.

In conclusion, the results of the present study indicate differentiated activation patterns during isometric contractions of wrist extensor muscles between normal subjects and those with history of lateral epicondylitis. Moreover, a significantly increased fatigability has been found in patients. Those findings might be helpful in designing therapeutic approaches. On the other hand, subjects at risk might be detected by the systematic evaluation of workers exposed to repetitive tasks.

Further research will be done in order to check muscle performance in dynamic (both concentric and eccentric) contractions.

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Capítol 5.8

Estudi transversal comparant perfil de força muscular de musculatura flexora dorsal i palmar de canell en pacients amb epicondilitis i voluntaris sans

A cross-sectional study comparing strength profile of dorsal and palmar flexor muscles of the wrist in epicondylitis and healthy men

Eur J Phys Rehabil Med. 2012 Nov 9. [Epub ahead of print]

A cross-sectional study comparing strength profile of dorsal and palmar flexor muscles of the wrist in epicondylitis and healthy men

C. Unyó, J. Chaler, M. Rojas, E. Pujol, B. Müller, R. Garreta, M.A. Mañanas

Eur J Phys Rehabil Med. 2012 Nov 9. [Epub ahead of print]

Objectiu

L'objectiu del present estudi va ser analitzar la relació entre l'epicondilitis i la força muscular dinàmica dels musculs de l'avantbraç així com la seva fatigabilitat dinàmica.

Amb aquest objectiu es va fer un estudi comparant vuit antics pacients afectes d'epicondilitis amb 8 voluntaris sans realitzant uns tests isocinetics de flexors dorsals i palmars de canell a diferents velocitats i modalitats de contracció (concèntrica i excèntrica). Igualment es va realitzar un test de fatiga. Es van analitzar el moment de força mitja de flexors dorsals i palmars, els ratis agonista i antagonista de les contraccions màximes i, finalment, les durades de les mesetes inicials i finals, així com la caiguda de força durant la prova de fatiga.

Resultats principals

En ambdós grups el moment de força mitja produit pels flexors palmars era superior al produit pels flexors dorsals. Els pacients mostraven uns registres de força de musculatura flexora superior als voluntaris sans mentre que els registres de flexors dorsals eren similars. Els ratis flexor palmar/flexor dorsal eren significativament superiors pels pacients. Pel que fa a la fatiga els resultats van mostrar que la força muscular decreixia abans en pacients.

Conclusió

Les troballes del present estudi van indicar un desequilibri muscular en aquests pacients. A més els pacients es fatigaven abans. Per tant, podria ser que els desequilibris musculars i la fatigabilitat estiguessin en la base de l’epicondilitis. Aquesta informació pot ser útil en el disseny de programes per la prevenció o tractament de l’epicondilitis.

Cal més recerca per discernir si les presents troballes son una causa o una conseqüència de l’epicondilitis.

A cross-sectional study comparing strength profile of dorsal and palmar flexor muscles of the wrist in epicondylitis and healthy men

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Background. **Strength training has been proposed by several authors to treat Lateral Epicondylitis. However, there is still a lack of information concerning muscle weakness and its relationship to imbalances and fatigability of forearm muscles during dynamic conditions in subjects after epicondylitis recovery.**

Aim. **To analyze the relationship between lateral humeral epicondylitis, and forearm muscle strength and fatigue.**

Setting. **Rehabilitation specialized center**

Population. **Cross-sectional study in eight former epicondylitis men free of symptoms and actively working at the moment of the evaluation and eight healthy men volunteers.**

Methods. **Isokinetic tests were performed at different velocities in order to assess strength in concentric and eccentric contractions. Additionally, a long-term concentric test was carried out in order to analyze strength during endurance. The following variables were analyzed: Average torque of dorsal and palmar flexors of the wrist and ratio of agonist/antagonist for non-endurance contractions; length of initial and final plateaus and the slope of average torque decay during the endurance test.**

Results. **In both groups, average torque produced by palmar flexor muscles was higher than that produced by dorsal flexor muscles. Patients showed higher strength in palmar flexor muscles, whereas dorsal flexor strength was similar for both populations. Palmar flexor vs. dorsal flexor ratio was significantly higher in patients for eccentric contractions. Regarding fatigue, results showed that torque decreased earlier in patients.**

Conclusions and clinical rehabilitation impact. **Both palmar flexor force and palmar/dorsal ratio in eccentric exercise were significantly higher in patients. This finding indicates a muscular imbalance in patients underlying the epicondylitis condition. Additionally, former patients fatigued earlier. Findings indicate that muscle imbalances and fatigability might be related to lateral epicondylitis. This information may be useful in the design and monitoring of programs intended for lateral epicondylitis rehabilitation. More studies are necessary to conclude if these differences are cause or consequence of the epicondylitis.**

Key words: Tennis elbow - Muscle strength - Endurance - Muscle fatigue.

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Lateral humeral epicondylitis (LHE) is a common condition related to microtraumas of wrist extensor muscles caused by sports or occupational activities involving quick repetitive movements of the wrist and forearm.[1, 2] Such movements may tear the proximal attachments of the muscles in the tendon area.

Lateral epicondylitis affects men and women equally and it has been estimated that its annual incidence is around 1-3%.[3]

Pathological findings in LHE often show a thicker and denser extensor carpi radialis brevis tendon with hypervascularization, granulated tissue, edema, and occasional tear.[4-6] Conspicuously, histological samples do not show inflammation.[7] Acute cases usually improve with rest, anti-inflammatory drugs or local corticosteroid injections while in chronic cases it is important to follow an active treatment.[8, 9]

According to a biomechanical model proposed by Moore,[10] LHE is originated by overload of wrist extensor muscles, especially during eccentric contractions. Muscle fatigability might also play a role in this condition.[11] Consequently, several authors have promoted the use of strengthening exercises, eccentric in particular, for treating LHE.[12-15] In fact, there is evidence that eccentric exercise induces changes in the mechanical properties of the muscles, resulting in an increase in tensile strength and muscle power.[16, 17] Strengthening exercise has been also recommended to increase joint stability.[18] Some *in vivo* studies have indicated that eccentric exercise changes the length-tension relationship of the exercised muscles, by increasing the number of sarcomers.[19] In clinical practice, strengthening exercises are prescribed at the end of epicondylitis' rehabilitation therapy and its usefulness has been rated as B.[15, 20, 21]

Surprisingly, even when strengthening of wrist extensor muscles is a common approach in LHE treatment, there is still a lack of information concerning weakness, muscular imbalance and fatigability of wrist extensor muscles during dynamic contractions. To our best knowledge the relationship between muscular balance and epicondylitis has not been assessed.

Thus, the purpose of this study was to evaluate muscle strength and fatigability during concentric and eccentric dynamic contractions in former epicondylitis patients. Results were compared with a group of healthy volunteers.

Materials and methods

Subjects

Sixteen men were recruited for a cross-sectional study with 8 patients clinically diagnosed and treated for LHE in the past, free of symptoms and pain and actively working for at least 6 months by the time of the experimental session (group I) and 8 healthy volunteer subjects as a control group (group II).

Subjects in Group I suffered LHE related to their occupational activity for a period longer than 2 months. Occupational fields were diverse including carpentry, construction, car industry and gardening, all of them demanding heavy work of the upper-limb. In all cases, the dominant limb was involved. These subjects were selected among those who had been successfully treated at our rehabilitation facilities following a comprehensive treatment which included rest, ice, nonsteroidal anti-inflammatory drugs, local steroid injections (in 3 subjects) and/or physical therapy (in 4 subjects). None played upper-limb related sports.

Subjects in the control group did not reported history of neuromuscular disorders or pain of the upper-limb. All of them were members of the university staff and students exposed to long periods of computer work and did not practice upper-limb related sports.

All subjects in both groups were men, right-handed and with similar age and body mass index in order to have a matched design. In addition, maximal grip strength was measured in order to analyze differences between groups regarding upper-limb functionality. This measure is commonly used as an index of the functional integrity of the upper extremity.[22] No statistical differences were found between groups I and II in none of the indexes described as analyzed from a Kruskal-Wallis test with a significance level set to $P<0.05$ (Table I).

All subjects provided written informed consent previous to the experimental protocol which was approved by the local ethics committee.

Experimental protocol

Dorsal flexors muscles (DFM) and palmar flexor muscles (PFM) strength was assessed by means of an isokinetic device (Biodex System III; Biodex Medical Systems, Shirley, NY, USA).

The procedure described by Forthomme *et al.*[23] was applied: Subjects were seated in the testing chair with the forearm supported and in full pronation and the elbow flexed at about 60°. The joint axis of the wrist was aligned with the rotational axis of the dynamometer. The range of motion was 70° (30° in dorsal flexion and 40° in palmar flexion from the neutral position of the wrist) (Figure 1). Weight of the hand was measured and subtracted at the start of the experimental session for gravity correction of measurements.

Concentric and eccentric isokinetic contractions

TABLE I.—*Characteristics of the population. Results are presented as mean and (standard deviation) for 8 subjects in each group. Statistical level (P) and effect size (η^2) for Kruskal-Wallis test is also presented.*

	Group I	Group II	P	η^2
Right-handed	8	8	–	–
Right arm involved	8	0	–	–
Age (years)	33.75 (3.31)	30.75 (4.18)	0.2	0.11
Body Mass Index	26.06 (3.72)	24.55 (2.70)	0.34	0.06
Grip strength	45.75 (3.58)	42.38 (6.72)	0.3	0.07

Figure 1.—Positioning of the subject during the experiment in the isokinetic device.

for dorsal flexion followed by palmar flexion were measured. Concentric tests were evaluated at 30°/s and 90°/s and eccentric test was evaluated at 60°/s. Five repetitions were performed for each test after muscle warm-up which consisted of three preliminary repetitions at the target velocity. Tests were performed in random order for avoiding biasing effects. Finally, an endurance test for concentric contractions was conducted at 60°/s in dorsal flexion until exhaustion. Fatigue of PFM was avoided by setting a much higher velocity (180°/s) during wrist flexion. In all cases, measurements were performed in the dominant side (which also coincided with the affected side as explained before).

Torque, velocity and position were measured over the entire range of motion and their correspondent output signals were simultaneously sampled and digitalized for offline analysis by means of an external device designed for the study.

Data analysis

For data analysis, only torque signal segments corresponding to values of velocity higher than 90% of the target velocity were considered. The following variables were calculated for DFM and PFM:

— average torque (AT in N.m): AT was calculated by obtaining the mean value of the torque signal for every repetition;

— ratio of palmar to dorsal flexor muscle strength (PDR=DFM AT/PFM AT): it was calculated by dividing average torque produced by PFM over that produced by DFM for each test velocity and contraction modality (concentric and eccentric);

— muscle fatigue was assessed by analyzing average torque as function of repetitions. Three phases could be identified in both groups (Figure 2): an initial plateau followed by a negative slope (*i.e.*, decay of AT) and a final plateau where AT remained almost constant. The curve of AT vs. repetitions was obtained for each participant and parameterized as follows:

a. total number of repetitions (TNoR) performed in the test, up to exhaustion;

b. number of repetitions before reaching the final plateau (total duration, TD). Note that this variable does not necessarily correspond to the total number of performed repetitions which also includes the final plateau;

c. number of repetitions at the initial plateau

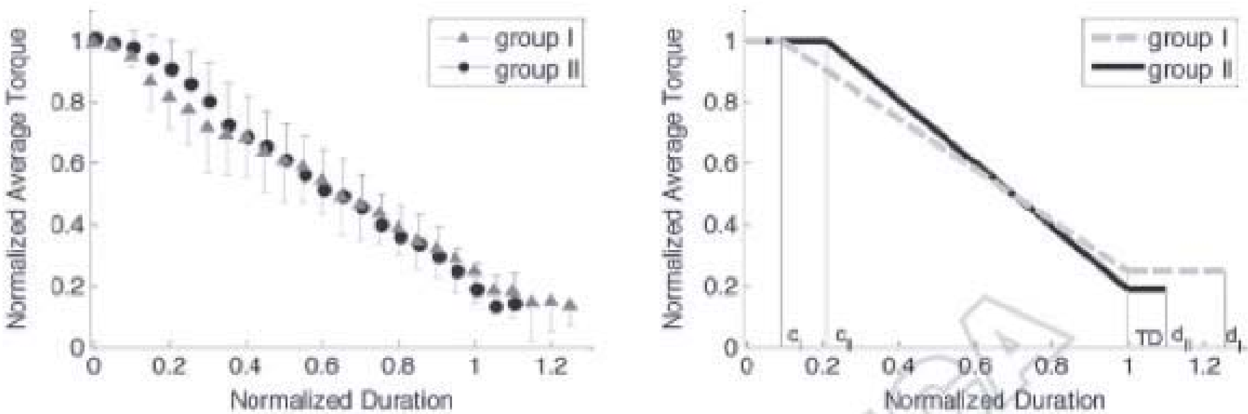

Figure 2.—Normalized AT as function of percentage of total duration (TD) of endurance test. Mean and standard deviation every 5% of TD is shown for both groups (Left). Schematics of changes of DFM AT during endurance test, showing relative number of repetitions at initial and final plateau (segments *c* and *d* respectively) and the decay segment for Group I and II (in shades of gray).

where AT was higher than 90% of the initial torque value and the percentage of such repetitions relative to TD;

d. number of repetitions at the final plateau and its relative value with respect to TD, where AT remained around 10% of its final value;

e. mean value of AT during initial plateau (AT_0) and mean value of AT during final plateau (AT_f);

f. normalized decay of AT. The AT curve was normalized with respect to AT_0 and with respect to TD (y and x axes respectively). The decay was calculated as the slope of the linear regression between the end and the beginning of the initial and final plateaus respectively (Figure 2);

Differences between groups were analyzed through the non-parametric Kruskal-Wallis test and the level of significance was set to 0.05.

In addition, the effect size statistics was calculated in the test from the χ^2 value as in Marascuilo LA:[24]

$$\eta^2 = \frac{\chi^2}{N-1}$$

where N is the total number of cases.

This effect η^2 was calculated to add more information to the inferential p-value statistics which was also obtained.[25] The value η^2 provided a measure of the magnitude of the effect taking into account the sample size used in the present study. A small effect size was considered for $\eta^2>0.04$, and moderate and strong effects were considered for $\eta^2>0.25$ and $\eta^2>0.65$, respectively.[25]

In order to satisfy the assumption of Kruskal-Wallis tests, homoscedasticity of the data was verified by applying a non- parametric Levene's test using the method of ranks. This test was selected because it has shown higher statistical power when compared to other methods commonly used to assess homogeneity of variance in the data.[26] Finally, equality of variance was met in all cases.

Results

As expected, AT developed by PFM was much higher than that by DFM for all concentric and eccentric tests at different velocities in both groups. Results are presented in Table II.

PFM AT was significantly higher in the epicondylitis group (group I) than in the control group (group II) ($P<0.003$ in all cases). As for DFM, there were no significant differences between groups in AT.

PDR was significantly higher in group I than in group II for the eccentric test. Although significant differences between groups for PDR could be also inferred from the Kruskal-Wallis test in the concentric exercise at low velocity (30°/s), the level of significance was not strong enough when a Bonferroni adjustment for multiple tests was applied. No significance was obtained for this variable in the concentric exercise at high velocity (90°/s). Thus, a tendency of lower p-values can be inferred associated with increases in the demand of force according to

TABLE II.—*Results obtained for isokinetic tests under non-endurance condition. Average Torque (AT) for Dorsal Flexor Muscles (DFM) and Palmar Flexor Muscles (PFM) and PFM/ DFM AT ratio (PDR) during concentric (Con) and eccentric (Ecc) contractions at different velocities. Results are presented as mean and (standard deviation) for 8 subjects (N.=8) in each group. Kruskal-Wallis test statistical level (P) effect size (η^2) for the comparison between the two groups is also presented. As variables were measured in three exercises, a Bonferroni correction was applied to the significance level. Differences between groups are marked * when they were significant statistically after these adjustments for multiple testing.*

		Group I (N.=8)	Group II (N.=8)	P	η^2
DFM AT (N.m)	Con 90°/s	6.53 (2.33)	4.75 (1.41)	0.16	0.17
	Con 30°/s	6.14 (1.98)	6.06 (2.15)	0.92	0.007
	Ecc 60°/s	9.47 (3.7)	10.46 (2.69)	0.29	0.07
PFM AT (N.m)	Con 90°/s	18.16 (2.09)	12.88 (3.33)	0.003*	0.58†
	Con 30°/s	18.86 (1.91)	13.07 (1.68)	0.001*	0.75+
	Ecc 60°/s	27.00 (2.72)	17.92 (3.98)	0.002*	0.66+
PDR (Arbitrary units)	Con 90°/s	3.31 (1.86)	2.98 (1.32)	0.83	0.003
	Con 30°/s	3.36 (1.09)	2.32 (0.63)	0.05	0.26
	Ecc 60°/s	3.19 (1.09)	1.85 (0.76)	0.014*	0.40†

* Denotes statistical significance after Bonferroni correction, † Denotes moderate effect size and + denotes strong effect size.

the exercise from concentric at high and then low velocities until eccentric. Figure 3, shows a differentiated pattern for subjects in Groups I and II in the most demanding exercises: concentric test at 30°/s and, especially, eccentric test at 60°/s. Finally, no differences were found for the concentric test at high velocity (90°/s) (Table II).

Regarding the endurance test, Figure 2 shows changes of normalized AT curve for both groups. Results are presented in Table III and discussed as follows:

1. no significant differences between groups were found in the total number of repetitions performed in the endurance test (TNoR);
2. TD was similar for all participants, *i.e.*, there were no significant differences in the number of repetitions before reaching the final plateau;
3. the duration of initial plateau (in absolute and relative values) was lower for Group I (epicondylitis patients) than for healthy subjects (Group II);
4. final plateau was shorter for healthy subjects than for patients, who were able to continue the test maintaining an almost constant torque up the end. These differences were statistically significant for both, the absolute and the relative duration of this plateau;
5. no statistical differences between groups were found on the absolute AT_0 or AT_f, *i.e.* the mean torque produced by DFM at the initial and final plateaus;
6. the slope was significantly different between groups showing differences in the fatigue pattern.

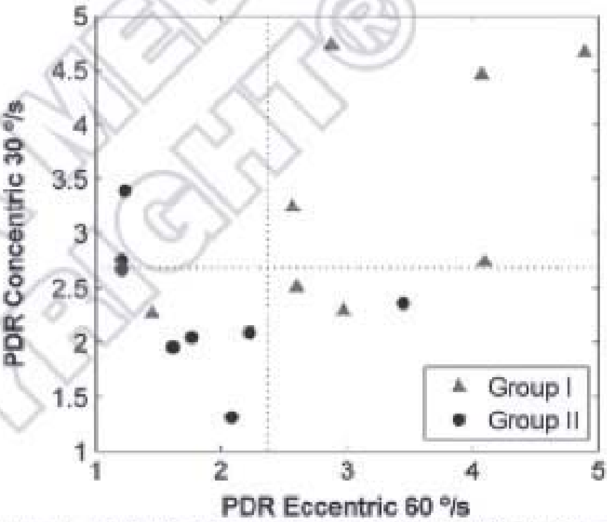

Figure 3.—PDR AT at Eccentric Exercise (60°/s) vs. PDR AT at Concentric Exercise (30°/s). Note that both variables show higher values for group I than for group II

Discussion

The results of this study indicate that forearm muscle strength and fatigability profile are altered in former epicondylitis patients when compared to age, gender and weight matched healthy volunteers. In the present sample, forearm muscle imbalance (*i.e.*, a significantly higher PDR) and significantly different fatigability pattern (*i.e.*, shorter initial pla-

TABLE III.—*Changes in average torque during endurance test. Results are presented as mean and (standard deviation) for 8 subjects in each group. Number of repetitions in each segment of the Average Torque curve for Dorsal Flexor Muscles (AT DFM) (fig 2). Values in the curve were normalized with respect to AT_0 observed in the initial plateau. The curve was also parameterized by the slope in the decay interval (i.e. between the end of the initial plateau and the beginning of the final plateau) and the slope observed in the first half of such decay. Statistical level (p) and effect size (η^2) are also presented.*

		Group I	Group II	P	η^2
Number of repetitions					
DFM AT curve	TD	26.4 (6.3)	27.9 (9.0)	0.46	0.04
	TNoR	33.4 (9.4)	30.1 (10.4)	0.71	0.009
Initial plateau	Absolute duration	2.41 (1.3)	5.3 (2.8)	0.03*	0.32†
	Relative duration (%)	9.1 (4.2)	21.0 (11.4)	0.02*	0.34†
Final plateau	Absolute duration	7 (5.29)	2.25 (2.19)	0.04*	0.27†
	Relative duration (%)	26.08 (20.82)	7.7 (6.02)	0.03*	0.3†
DFM At (N.m)	AT in the initial plateau (AT_0)	6.94 (1.94)	5.71 (1.33)	0.3	0.09
	AT in the final plateau (AT_f)	1.80 (1.14)	1.09 (0.50)	0.2	0.1
Slope in the decay interval (normalized units)	Entire interval	-0.76 (0.06)	-0.91 (0.21)	0.03*	0.32†

* Denotes statistical significance; † Denotes moderate effect size and + denotes strong effect size.

teau, slower decrease and longer final plateau) was found in former epicondylitis patients.

Regarding forearm muscle strength, we found that AT decreased with increasing isokinetic velocity for both groups, as has been previously described.[23] In our study, the strongest isokinetic exercise was performed in eccentric modality at 60°/s.

PFM AT values were significantly higher than those of DFM in all tests performed at different speed for both groups. This fact is coherent with results described by Forthomme *et al.*,[23, 27] who had obtained PDR between 2.02 and 2.55 for healthy men.

Patients did not show significantly lower strength for wrist DFM. In the present study, AT developed by DFM was similar in patients and control groups during concentric and eccentric exercises. On the other hand, a significant higher strength for wrist PFM was found in former patients. These results differ from those obtained by Alizadehkhaiyat *et al.*[28, 29] who compared wrist strength and muscle balance in epicondylitis patients and healthy subjects, although in that case AT was measured only during isometric contractions. Alizadehkhaiyat *et al.* showed that PFM AT was 25% stronger than DFMAT in both groups as in our case but both DFM and PFM strength in patients was 30% weaker when compared to the control group.

According to our results, as derived from absolute values of PFM AT and especially from PDR ratio, which is relative to DFM AT and does not depend on individual differences on actual measurements of AT in N.m, PFM AT was higher in former patients than in healthy subjects. Significant differences were found for PDR when evaluating the exercise with the most demanding condition: eccentric test at 60°/s. This finding indicates a possible muscle imbalance between wrist DFM and PFM. However, no significant differences were found for PDR in concentric tests. Following these findings, we might conclude that intensive tasks usually carried out during work may be contributing to muscular imbalances in former patients and that this imbalances can be observed even after rehabilitation therapy and incorporation to work (that is, even when symptoms disappear). In fact, epicondylitis is a pathological condition that affects DFM and may cause weakness in this muscle group or relative lower strength with respect to the strength developed by PFM. Additionally, the possibility of muscle imbalances prior to the onset of symptoms cannot be discarded in such patients. In any case, DFM relative weakness could play a key role in the pathophysiology of epicondylitis. In this sense, muscle imbalances have been identified as biomechanical predisposing deficits in a number of conditions such as hamstring,[30, 31] rotator cuff [32] and low back injuries.[33] Regarding epicondylitis, forearm muscle imbalance has been previously analyzed in normal subjects compared to epicondylitis patients, as earlier mentioned.[29] No muscular imbalances were identified in that study. However, results obtained by Alizadehkhaiyat *et al.* cannot be compared straight forward with ours because in their case, measurements were performed during isometric contractions and in non- recovered patients unlike the present study where isokinetic exercises were analyzed. A recent study by the same author [34] compared three female groups: former epicondylitis, active epicondylitis and healthy volunteers. It confirmed isometric DFM and PFM weakness in present and former patients observed in the previous study.[28] Another study by Friedman [35] found that women clinically diagnosed of lateral epicondylitis had significant lower peak torques in wrist muscles when compared with control subjects. They also obtained differences between both arms in women with epicondylitis. The greatest significant difference was found in wrist DFM torque. In fact, mean wrist DFM strength in the involved arm was 30% lower than that of the uninvolved arm.

To our best knowledge, results indicating muscle imbalance instead of just muscle weakness in former epicondylitis patients had not been previously reported. Thus, findings of our study would depict more biomechanical deficits than weakness related to pain. In our opinion, they provide important information for rehabilitation or prevention of LHE.

Regarding fatigue tests, initial AT showed no significant differences between groups. However, at the initial phase of the endurance test, and possibly associated with the previous conclusion about relative weakness of DFM, patients maintained significantly less repetitions in the initial plateau than healthy subjects. This was the main difference we found and may indicate a quick fatigue response of these muscles with respect to control group. Final AT did not show significant differences among groups either. Additionally, AT started decaying later with a steeper slope for healthy subjects than for former patients. Finally, patients presented a conspicuous longer final plateau showing an almost constant low torque. Fatigue findings may indicate both, lower initial muscle resistance in patients (*i.e.*, smaller initial plateau due to an early decay of force production), and higher muscle resistance to long-term force production (*i.e.*, longer final plateau). Occupational activity and its training effects in patients may explain the last finding. On the other hand, prior to the analysis of isokinetic exercises, the isometric grip strength and the anthropometric measures were compared and no significant differences were found between groups. In any case, fatigability findings may depict a differentiated and functionally relevant response of forearm muscles' dynamic fatigue (*i.e.*, lower initial muscle resistance) in former lateral epicondylitis patients. To our knowledge, such findings have not been previously described. Therefore, we think that our results regarding the different behavior of DFM during endurance test would be useful in clinical applications, especially in planning endurance training for epicondylitis patients.

Several authors have supported eccentric training for chronic tendinitis patients in order to increase tensile strength of the tendons by remodeling its architecture.[36] They thought that the tendon had to be prepared with a specific strength training program to avoid breakdown in its integrity. If the tasks requested in most of the activities in daily living involve lengthening of the muscle-tendon units, they must be trained in an eccentric manner.[37-39] In this sense, several studies had shown better results with an eccentric program in chronic LHE than with other types of treatment.[13, 40] Findings of the present study indicating relative weakness of DFM with respect to PFM of the wrist could explain the good results obtained by eccentric programs focused on selective strengthening of the DFM in the past. Isokinetic exercises have been commonly used in the past for the evaluation and rehabilitation of lateral epicondylitis.[23, 27, 41] Pienimäki *et al.*[41] found that the exerted torque correlated well with the disability of the forearm in patients with LHE. Additionally, Forthomme *et al.*[27] found a strong reliability of torque measurements during isokinetic exercises and a satisfactory effect associated to the use of such exercises for the treatment of chronic LHE.[8, 13, 38] For these reasons this kind of exercises was evaluated in different modalities in our study, showing a different profile for subjects after recovery of LHE.

Besides, results may also define an assessment framework to monitor and evaluate patients during and after rehabilitation programs in order to reach balance between muscle strength of agonists and antagonists. This conclusion is supported by results reported by Sahin *et al.*[42] in the assessment of ankylosing spondylitis where it was concluded that muscle weakness and fatigue should be monitored with isokinetic exercises similar to those used in our study. Variables related to muscular imbalance between DFM and PFM are more appropriate than absolute DFM strength in order to assess the recovery of patients with LHE during isokinetic exercises. In endurance tests, more important than their duration or number of repetitions is the time to maintain the initial AT before decaying. It is possible to conclude that healthy men have a different isokinetic strength profile than men who have suffered an epicondylitis process; however, further studies would be desirable to confirm these results in rehabilitated patients and the usefulness of the evaluation protocol in rehabilitation prescription. More studies will be also needed to evaluate if the differences reported in this work are a cause or a consequence of LHE.

It is important to note that most of the variables obtained in this study were either normalized or relative to other variables in order to avoid possible bias induced by interindividual differences. Significant differences were found between the two groups when analyzing PDR (PFM/DFM ratio), which can be regarded as relative torque between PFM and DFM. This variable is not subject to interindividual differences since it was calculated for each subject independently and does not depend on the absolute magnitude of the exerted torque. Additionally, variables related to endurance test were also normalized and were not dependent on the actual magnitude of exerted torque or on the duration of the test in the number of repetitions. Finally, although differences due to PFM AT were calculated from absolute magnitude values of these variables (in N.m), the obtained significance level was very high ($P<0.003$ in all cases), allowing the generalization of the results. Moreover, PDR confirmed such findings.

A possible limitation of the present study is related to the sample size. For this reason, it is necessary to extent the results with more subjects in further studies in order to confirm that the selected groups are representative enough for the populations under study and also to confirm the present findings. However, differences obtained between groups were statistically significant, the effect size statistics which depends on the sample size was taken into account, and groups' sizes were even larger than those employed in other studies also related to upper-extremity rehabilitation.[43] For these reasons, we can conclude that these results can be considered relevant and of interest.

Conclusions

In conclusion, findings of the present study indicating DFM/PFM imbalance and a higher fatigability of DFM in former epicondylitis patients may be of great usefulness in the design and monitoring of programs intended for LHE rehabilitation.

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Capítol 5.9

Avaluació de la fiabilitat test-retest d'un protocol de fatiga isocinètic de genoll. Estudi multicèntric

Knee isokinetic test-retest: A multicentre knee isokinetic test-retest study of a fatigue protocol

Eur J Phys Rehabil Med. 2010;46(1):81-88.

Knee isokinetic test-retest: A multicentre knee isokinetic test-retest study of a fatigue protocol

Saenz A, Avellanet M, Hijos E, Chaler J, Garreta R, Pujol E, Sandoval B, Buen C, Farreny A

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Objectiu

L'objectiu del present estudi va ser establir la fiabilitat test-retest d'un protocol d'avaluació de la fatiga de flexo-extensors de genoll durant un esforç isocinètic realitzat amb dinamòmetre *biodex System 3*. Amb aquest objectiu es va endegar un estudi multicèntric amb el reclutament de 90 dones voluntàries sanes entre 20 i 40 anys d'edat. Totes varen dur a terme un test isocinètic consistent en 40 repeticions de flexo-extensió de genoll a 120ºs^{-1}. Per tal d'avaluar la fiabilitat es varen dur a terme 2 tests amb una diferència de 7 dies. Les variables que es van analitzar varen ser: treball total fins repetició màxima (J), el nombre de repeticions fins esforç màxim (nº), el rati treball/pes (J·Kg^{-1}), el treball total (J), el treball durant el primer i darrer terç del protocol (J), el rati de fatiga (W 1r terç/W 3r Terç) i la fatiga del treball (% de treball realitzat per assolir el 50% del treball). Es varen calcular les mitjanes, medianes i els "box-plots". També el coeficients de

correlació intraclasse (CIC) (interval de confiança 95%), t-test i anàlisi de la variància d'una via (ANOVA). La diferencia de mitjanes (di), l'error estàndard de la mesura (EEM) i el 95% de l'interval de confiança (ICdi) també es va calcular.

Resultats principals

Les dades de fiabilitat foren excel·lents (CIC>0,75) pel treball total (0,85), treball durant el primer terç (0,80) i el darrer terç (0,80) en extensió i pel treball total en flexió. Per la resta de variables les dades de fiabilitat varen ser entre correctes i bones (ICC 0,4-0,75). La mediana va variar menys d'un 20% en tots els casos durant el test-retest.

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Knee isokinetic test-retest: a multicentre knee isokinetic test-retest study of a fatigue protocol

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Aim. The aim of this study was to establish the test-retest reliability of a knee extensor and flexor muscle fatigue protocol using a biodex system 3 isokinetic dynamometer.

Methods. Three-outpatient Rehabilitation Departments undertook the study. Fatigue was evaluated in the dominant knee of 90 healthy female volunteers, non-sportswomen, aged between 20 and 40. They performed 40 consecutive concentric knee flexions and extensions, at 120°/s, on a Biodex 3 isokinetic dynamometer. Two evaluations were done over a period of seven days. Analysed variables were: maximal repetition of total work, maximal work repetition number, work to body weight ratio, total work, work during first and last third of the protocol, fatigue ratio, work fatigue. Statistical analysis determined mean values, medians and box-plots. Intraclass Correlation Coefficients (ICC) (confidence interval 95 %), t-test and one-way analysis of variance (ANOVA) evaluated reliability. Difference of means (d_i), standard error of measurement (SEM) and 95% of interval confidence (IC d_i) were also calculated ($P<0.05$).

Results. All participants completed the study. Reliability data were excellent (ICC>0.75) for total work (0.85), work during first third (0.80) and last third (0.80) in extension, and for total work in flexion. Reliability data were fair to good (ICC 0.4-0.75) for the rest of the variables. Median varied less than 20% in all cases during test-retest.

Conclusion. This knee fatigue protocol is reliable for flexion and extension, above all when using the total work as a variable. The desirability of multicentre studies in rehabilitation and standardisation of protocols is emphasised.

KEY WORDS: Exercise test - Fatigue - Muscle strength - Knee.

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The evolution of the isokinetic dynamometer has produced a considerable amount of important information useful both to clinics and investigators. The literature covers the rehabilitation of different injuries as well as the functional capacity of different muscle groups.[1]

Isokinetic fatigue and endurance are different and complex concepts which are often confused. This is because of the different criteria applied to standardise them, and also to define them. In isokinetic dynamometry, fatigue is considered as the relative decrease of work during a series of repeated contractions of a muscle group. After this phase, when the repetitions continue but the work is stable, we talk of endurance.[2] Therefore, when examining an isokinetic graph, fatigue sets in at the moment that output decreases and endurance is the maintained activity, measured by total work achieved during the last phase of the repetitions. One has to bear in mind that all the repetitions are performed at the same speed.[2]

Different protocols for fatigue and endurance have been described with different dynamometers and different muscle groups. Despite this, no clear standard protocol has been established allowing the extrapolation of data.[1, 2] No protocols relating to the knee joint have been defined for the dynamometer Biodex 3, and in consequence there is no standard data since there are no standard data against which to compare data from patients with varied pathologies affecting similar muscle groups. In addition, there are no multicentric studies supporting published protocols against which to compare results from dynamometer Biodex 3.

This study proposes, therefore, to establish the reliability and test-retest of a protocol for knee fatigue in a multicentric study, with the secondary objective of standardising protocol and normative data.

Materials and methods

Centres

Three rehabilitation departments collaborated. Each service possesses a Biodex 3 isokinetic dynamometer (all with the same software, Spanish version 3.34). Two observers operated in each centre.

Participants

Ninety healthy women (N.=90) aged between 20 and 40 years (29.59±4.97) with a body-mass index (BMI) of 21.74±2.97 were included. The criteria for inclusion were no history of previous musculoskeletal injuries to the knees, healthy volunteers but no professional sports-people. All the volunteers signed a consent form before doing the test.

Isokinetic test

Every week the calibration was validated following manufacturer's recommendations.[3] Before doing the test, a 10 minute warm-up with a cygloergometer was performed, plus stretches of both calf and thigh muscles. The positioning was as follows. The chair back was tilted back at 85°; straps were crossed over the trunk, pelvis, and the dominant thigh; the dynamometer axis of rotation was aligned to the external femoral condyle of the knee; the longitudinal adjustment of the pad was 2 centimetres above the upper edge of the peroneal malleolus; the global range of movement was set at 90°, with from 10° to 100° of flexion. Gravity was corrected in each test. In order to familiarise the subject, before starting the test, two series of five repetitions were done at the same speed as during the protocol. The cushioning of the equipment towards the end of the movement was set at one, that is to say, low or hard.

Protocol

Thirty subjects completed the protocol in each centre (N.=30, N.=90), consisting in 40 consecutive repetitions of concentric/concentric flexion and extension of the knee at 120°/s. Oral feedback was given in order to maintain a consistent level. Two sessions were performed with a gap of seven days, with the same observer, at the same time, on the same day of the week.

Variables

The variables taken into account were those defined by the isokinetic software, and in addition a fatigue index was calculated.[1, 2] They included:

— maximal repetition of total work (Joules): calculates the work required to reach maximum repetitions;

— maximal work repetition number (number): quantifies the number of repetitions required to reach maximum effort;

— work to body weight ratio (%): the amount of work generated during the entire test divided by body weight;

— total work (Joules): quantifies the work done throughout the repetitions;

— work during the first third of the protocol (Joules): quantifies the work at the beginning of the test (40 repetitions/3: first 13 repetitions);

— work during the last third of the protocol (Joules): this is the work at the end of the protocol (the last 13 repetitions);

— fatigue ratio: this is the relationship between the work in the first third of the test and the work in the last third. In other publications, the fatigue index is also called the resistance ratio;

— work fatigue (%): the amount of work done to reach 50% of maximum work.

TABLE I.—*Statistics for extension.*

	Mean	Median	Standard deviation
WrepMax 1	99.30	99.00	18.34
WrepMax 2	104.44	104.10	24.90
RepMax 1	3.79	3.00	2.59
RepMax 2	3.07	2.50	2.08
W weight 1	167.88	166.90	34.16
W weight 2	182.52	175.80	49.50
Total W 1	2562.50	2545.25	515.37
Total W 2	2702.74	2754.50	569.74
W first 1	1170.49	1140.40	233.06
W first 2	1254.93	1247.55	274.95
W last 1	548.42	547.00	141.82
W last 2	567.71	575.80	135.91
FRatio 1	2.21	2.10	0.44
FRatio2	2.25	2.20	0.38
W Fatigue 1	52.80	53.30	9.76
W Fatigue 2	54.26	54.65	7.86

WrepMax1: maximal repetition of total work day 1 in Joules; WrepMax2: maximal repetition of total work day 2 in Joules; RepMax1: maximal work repetition number day 1 (number); RepMax2: maximal work repetition number day 2 (number); Wweight1: work to body weight ratio day 1 (%); Wweight2: work to body weight ratio day 2 (%); TotalW1: total work day 1 in Joules; TotalW2. total work day 2 in Joules; Wfirst1: work during first third day 1 in Joules; Wfirst2: work during first third day 2 in Joules; Wlast1: work during last third day 1 in Joules; Wlast2: work during last third day 2 in Joules; FRatio1: fatigue ratio day 1; FRatio2: fatigue ratio day 2; WFatigue1: work fatigue day 1 (%); WFatigue2: work fatigue day 2 (%).

TABLE II.—*Statistics for flexion.*

	Mean	Median	Standard deviation
WrepMax 1	50.78	49.45	12.90
WrepMax 2	55.43	53.55	14.68
RepMax 1	5.41	4.00	5.27
RepMax 2	3.57	3.00	2.74
W weight 1	86.35	84.70	24.93
W weight 2	95.83	93.05	28.27
Total W 1	1342.57	1307.90	377.92
Total W 2	1425.58	1423.10	402.39
W first 1	590.88	578.30	180.97
W first 2	664.06	637.55	186.99
W last 1	308.39	295.20	112.03
W last 2	301.96	295.20	98.25
FRatio 1	2.09	2.00	0.76
FRatio2	2.33	2.15	0.79
WFatigue 1	39.68	49.95	71.87
WFatigue 2	54.08	53.70	10.49

WrepMax1: maximal repetition of total work day 1 in Joules; WrepMax2: maximal repetition of total work day 2 in Joules; RepMax1: maximal work repetition number day 1 (number); RepMax2: maximal work repetition number day 2 (number); Wweight1: work to body weight ratio day 1 (%); Wweight2: work to body weight ratio day 2 (%); TotalW1: total work day 1 in Joules; TotalW2. total work day 2 in Joules; Wfirst1: work during first third day 1 in Joules; Wfirst2: work during first third day 2 in Joules; Wlast1: work during last third day 1 in Joules; Wlast2: work during last third day 2 in Joules; FRatio1: fatigue ratio day 1; FRatio2: fatigue ratio day 2; WFatigue1: work fatigue day 1 (%); WFatigue2: work fatigue day 2 (%).

Statistical analysis

The corresponding mean values, median and standard deviations were determined. The box plot for the test and retest were defined. The different intra-class correlation coefficients were obtained (ICC), as were the confidence intervals (CI) of 95% of every ICC. Finally the mean difference between the average measurements (d_i) the standard deviations (SD_{di}) and the standard error (SE_{di}) and 95% of its CI were also calculated. The level of significance is established at P<0.05 and is considered a highly reliable coefficient, equal or superior to 0.80. The one-way analysis of variance (ANOVA) was used, with repeated measures, to determine the differences between the test and the retest. The statistical analysis was carried out with the computer pack SPSS for Windows (version 11.5 SPSS Inc., Chicago, IL, USA).

Results

The statistical values obtained (mean value, median and standard deviations) are defined in Table I for all the variables during extension. Table II contains the same data, but for flexion. You will notice that for the variables defined by a digit (number of repetitions required to reach maximum work and fatigue index) the variation between test and retest can be more that 20%.[4] Concerning the mean value, both for extension and flexion, no important variations greater than 20% have been observed either in the test or retest. The graphic representation of these facts can be seen in Figures 1, 2, with box plot for all the variables in extension and flexion. Therefore, the protocol could be reliable and reproducible, taking into account the mean value as a statistical factor for central tendency.

Tables III, IV show the ICC for all the variables, in flexion and extension, with their level of significance. In addition, the average differences between average samples, their standard deviation and their standard error are also shown together with 95% of the CI. The last columns show the F statistic of the ANOVA and its level of significance (when F >0.5, that implies a high variability within the variance test).

Highly reliable values have been obtained (ICC>0.75) for total work in extension (0.80) and flex-

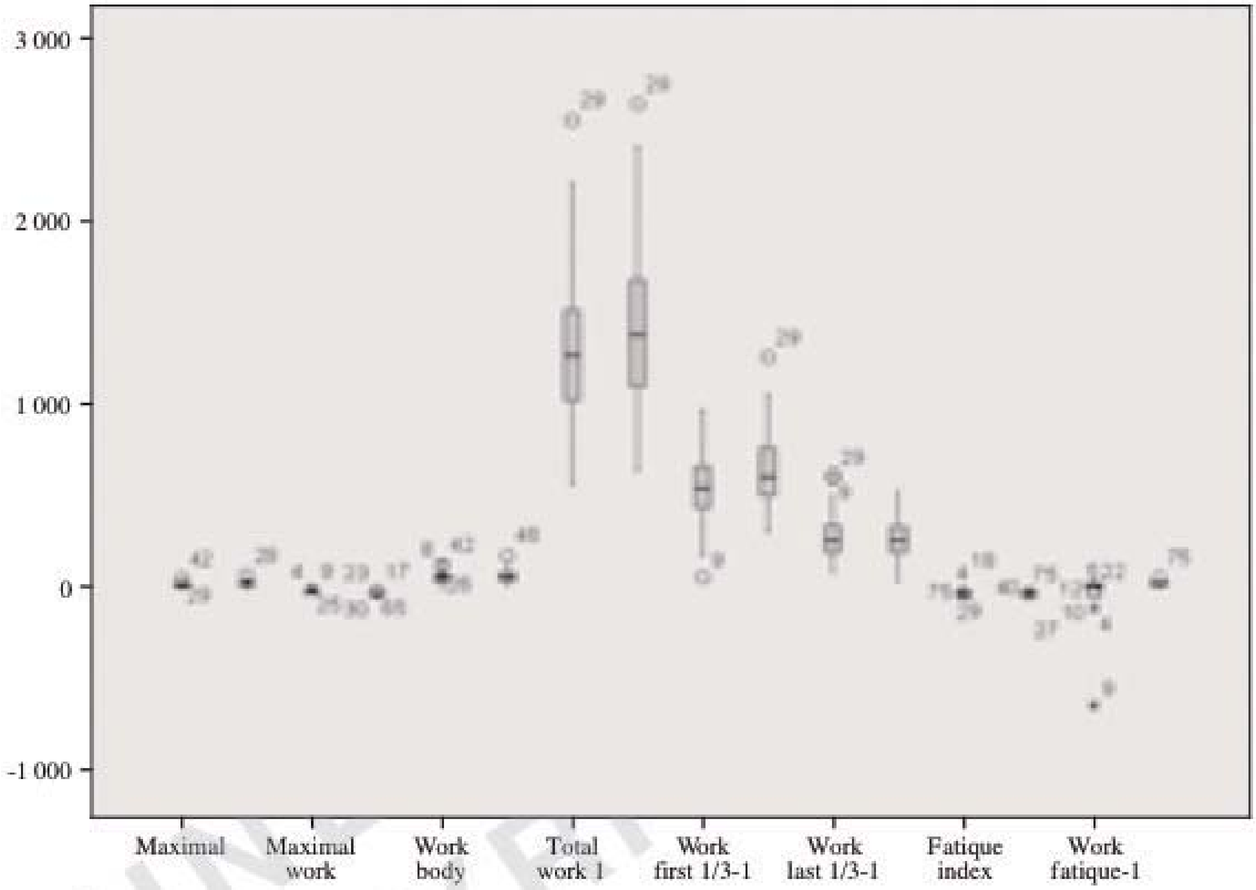

Figure 1.—Flexion variables box-plots.

ion (0.79) as well as for work during the first and final thirds of extension (0.79 and 0.80) and maximal repetition of total work in flexion. Reliable values, between fair and good (ICC 0.4-0.75), were obtained for everything except: work to bodyweight ratio in extension, maximal work repetition number in flexion and work fatigue in flexion.

Practically all the values are significant for the ICC (except work fatigue in flexion). With respect to the averages of the different samples and their standard error, it should be noted that in most cases, in confidence intervals, no such error was observed between 0 and the interval, which enables us to confirm that the data are not only significant but also conclusive.

With respect to the analysis of the variances, in order to evaluate the differences between data obtained between measurements, the significant statistical difference between the data for test and retest in the first variables was confirmed with scarcely any difference between flexion and extension. This means, that despite previous results using ANOVA, there are contradictory data, which must indicate that there is a learning effect.[2]

Discussion

As previously stated, there is no clear protocol for the study of fatigue, partly because of the confusion created by its definitions, and partly because of the dif-

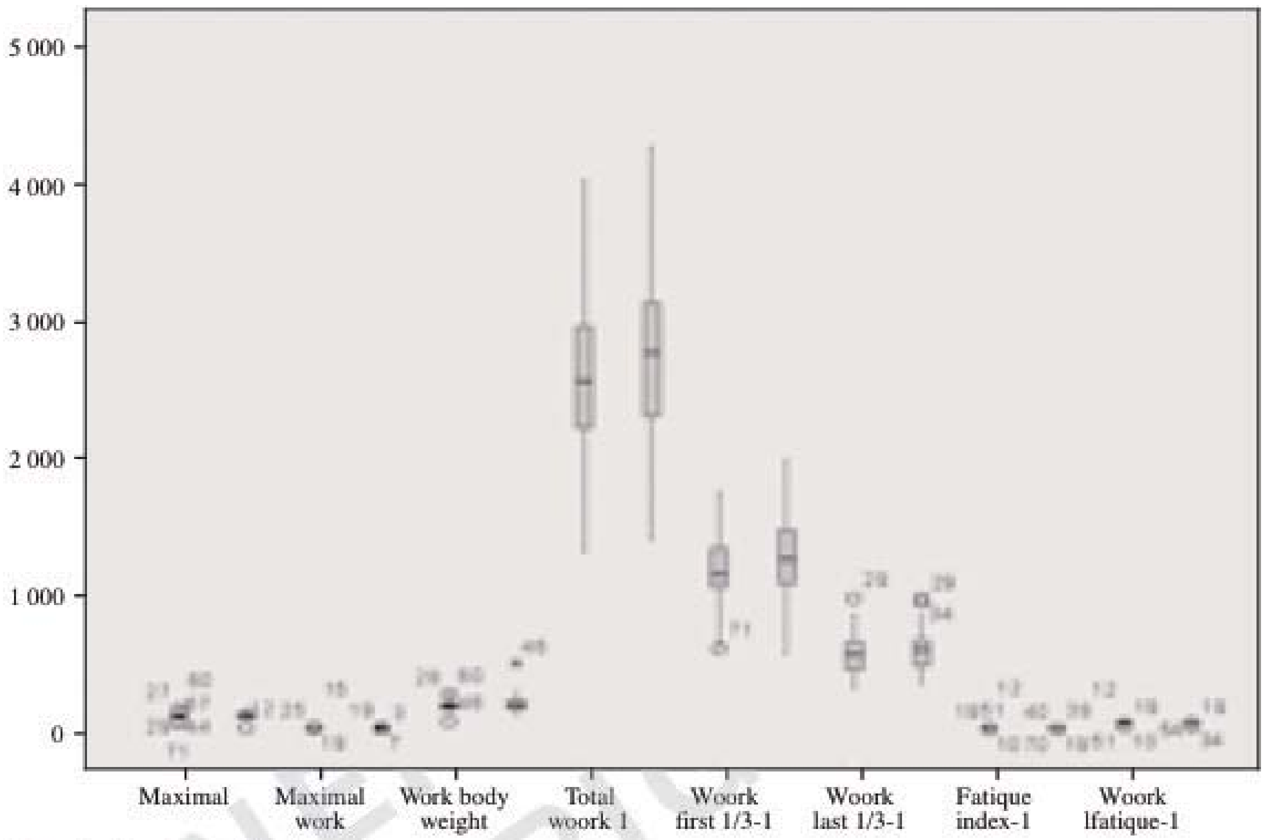

Figure 2.—Extension variables box-plots.

ferent commercial brands on the market, which, in their turn, produce distinct variables in their software.[2] In clinics, as in research, standardisation of the protocols for the isokinetic dynamometer is necessary.[1, 5] This would improve daily use and access to information.[2]

Taking into account the total work and, on occasion, peak torque, fatigue would be the decrease of these variables throughout repetitions, and endurance would be the last plateau. The transition from one to the other is an important indicator, but very subjective and variable.

There are different protocols relating to single-joint knee fatigue. Manou *et al.* published a test in 2002 on which this study is based, using a Cybex Norm dynamometer.[1] They evaluated the dominant lower limb of 12 male volunteers in a test of 40 repetitions. The determining variables were those in the software: total work, total work to body mass, endurance ratio, 50% of fatigue work, 50% of fatigue time and 50% of fatigue repetitions. The ICC obtained were highly reliable, in flexion as well as in extension; unlike to other protocols, it was slightly better in flexion.[1] Of all the protocols studied, it was the one with the most stable data, with an ICC> of 0.819.[2]

There is also a protocol with a Biodex 2, but the sample is very heterogeneous, evaluating both the dominant and non-dominant leg of eight males and eight females. It consisted of 30 concentric repetitions but only evaluated two variables. The range of motion is defined between 10° and 60°. The ICC obtained were excellent (>0.75), contrary to the fatigue index (ICC=0.26).[6]

On the other hand, there is a published test evaluating fatigue in concentric as well eccentric movement. The dynamometer used was a Kin Com, eval-

TABLE III.—*ICC with its level of significance, differences of means, and standard error of measurements (SEM), its 95 % of interval confidence (SE_{di}), F statistic and, its statistical significance, (all of these for extension).*

T test	ICC	Sig ICC	d_i	SD_{di}	SEM_{di}	95 % SE_{di}		F	Sig F
1	0.72	0.000	-5.14	17.37	1.83	-8.77	-1.50	7.86	0.0062
2	0.45	0.000	0.72	2.48	0.26	0.20	1.24	7.65	0.0069
3	0.33	0.001	-14.64	49.98	5.27	-25.10	-4.17	7.72	0.0067
4	0.85	0.000	-140.24	301.68	31.80	-203.42	-77.05	19.45	0.0000
5	0.79	0.000	-84.44	168.90	17.80	-119.81	-49.06	22.49	0.0000
6	0.80	0.000	-19.30	87.28	9.20	-37.58	-1.01	4.40	0.039
7	0.61	0.000	-0.05	0.36	0.04	-0.12	0.25	1.56	0.21
8	0.54	0.000	-1.45	8.56	0.90	0.34	-1.61	2.60	0.11

1: maximal repetition of total work in Joules; 2: maximal work repetition number (number); 3: work to body weight ratio (%); 4: total work in Joules; 5: work during first third in Joules; 6: work during last third in Joules; 7: fatigue ratio; 8: work fatigue (%) ; ICC: intra-class correlation coefficient; Sig ICC: significance ICC; d_i: difference of means; SD_{di}: difference of means standard deviation; SEM_{di}: standard error of measurements; 95 % SEdi : 95 % interval confidence of SEM; F: analyses of variance; Sig F: significance F.

TABLE IV.—*ICC with its level of significance, difference of means (d_i), and standard error of measurements (SEM), its 95 % of interval confidence (SE_{di}), F statistic and its statistical significance, (all of these for flexion).*

T test	ICC	Sig ICC	d_i	SD_{di}	SEM_{di}	95 % SE_{di}		F	Sig F
1	0.78	0.000	-4.65	9.38	0.99	-6.61	-2.68	22.13	0.0000
2	0.19	0.069	1.84	5.45	0.57	0.70	2.99	10.30	0.0019
3	0.59	0.000	-9.49	24.39	2.57	-14.59	-4.38	13.62	0.0004
4	0.79	0.000	-83.01	252.02	26.56	-135.79	-30.22	9.76	0.0024
5	0.68	0.000	-73.18	147.43	15.54	-42.30	-4.71	22.18	0.0000
6	0.74	0.000	6.43	76.94	8.11	22.55	0.80	0.63	0.43
7	0.64	0.000	-0.24	0.66	0.07	-0.10	-3.40	11.61	0.0010
8	-0.003	0.976	-14.40	72.66	7.66	0.82	-1.88	3.53	0.0635

1: maximal repetition of total work in Joules; 2: maximal work repetition number (number); 3: work to body weight ratio (%); 4: total work in Joules; 5: work during first third in Joules; 6: work during last third in Joules; 7: fatigue ratio; 8: work fatigue (%) ; ICC: intra-class correlation coefficient; Sig ICC: significance ICC; d_i: difference of means; SD_{di}: difference of means standard deviation; SEM_{di}: standard error of measurements; 95 % SEdi : 95 % interval confidence of SEM; F: analyses of variance; Sig F: significance F.

uating the dominant lower limbs of 13 males within a range of 10° to 85°, and an index was defined for endurance to fatigue.[7]

In 2007, Maffiulettie *et al.* published a protocol for knee fatigue using a Con-trex isokinetic dynamometer. Fifteen males and 15 females were evaluated, concentric/concentric, with 20 sub-maximal repetitions at a low speed (15° s^{-1}). When the fatigue index was determined, their findings were moderately reliable for the extensors and low for the knee flexors.[8]

There are other fatigue protocols involving other joints, particularly the trunk. In that specific article, four protocols were evaluated using a Cybex Norm. In addition to flexion and extension, an isometric test was done. Sixteen rugby players were evaluated and a fatigue index was also defined.[9]

In our study, visual feedback was not given because it appeared to give a detrimental bias by decreasing the maximal effort and dimishing the total work in the final third.[2]

In this study, it was decided, for various reasons, to follow the lines of the Manou protocol: it follows a series of standard parameters for the software of the dynamometer which facilitates the extrapolation of data. It also facilitates carrying out the test, for example using a speed of 120°/s, which maintains motivation during the test. In addition the total range of motion of 90° (between 10° and 100°) was easier to define.

Even so, there are initial differences. The first, as previously mentioned, was provided by the variables defined by the software. This means that data obtained are only useful for Biodex 3 dynamometers with the same characteristics. Median and box plot have also been added to this statistical study. This is because there is a statistical trend to consider the median as a more stable and reliable measure of the central tendency than mean value.[10-12] Considering the median, one also has to bear in mind Dvir's conclusion concerning data obtained from test and retest, that any difference less than 20% can be considered normal.[4] The data obtained are similar to that in previous studies. The ICC are excellent or good for flexion and for extension, with a slight difference in favour of extension. Of all the variables studied, the best results correspond to total work which would in fact be the most important variable to study. The results for the variables "fatigue ratio" and "work fatigue" are disappointing, but one has to consider that these are data obtained while manipulating specific parameters provided by the machine.

On the other hand, and quite contradictorily, the analysis of the variances shows that there may be a learning effect, contrary to the data obtained by Manou, the only one who had previously investigated it together with Lund.[1, 13] This shows the limitation of this study, totally contradicting the significant conclusions obtained by test/retest, and it is impossible to isolate them from the effect of the familiarisation exercises performed before the test. Consequently another independent study is required. Another possible limitation is the fact that the data cannot be used on other machines with different software.

In fact, a multicentre study was planned to evaluate the results from three different machines with the same potential and power in order to increase the statistical power of the test through increasing the sample. It was also decided to homogenise the sample by choosing female volunteers between the ages of 20 and 40 years old, since these are the most easily available subjects, as in other studies where all the subjects were healthy and/or female. In this way, normal data were obtained through the application of the protocol.[14-16]

Among the doubts raised by the results, the following should be born in mind: in addition to the influence of familiarisation, we need to define whether maximum effort needs to be achieved, as in our case, or sub-maximal effort. It is difficult to determine whether the volunteer can regulate the amount of effort needed to finish the test unless an electromyogram was done simultaneously. Furthermore, sub-maximal effort could cause confusion even though it is the parameter of choice. It is not known whether age or sex could influence the results obtained.[5, 17, 18]

To finish, the following should be considered:

— guidelines need to be established for statistical analysis in the isokinetic fields. It is very difficult to establish protocols for tests if there is no consensus for analysis.

Multicentre studies can help to define those guidelines previously referred to, as has been observed in other evaluation tools and methods in rehabilitation.[19]

This study should be continued in order to define the influence of the training factor which has appeared in the broadening of the sample. This is valid for age, sex and type of effort.

Conclusions

The protocol for knee flexor and extensor muscle fatigue evaluation with the Biodex system 3 isokinetic dynamometer has excellent reliability for total work variable as much in flexion as in extension. Data obtained for this variable, given that it is a multicentre study, allows us to compare data from different pathologies within a similar population.

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Capítol 5.10

Rehabilitació accelerada de la plastia de lligament encreuat anterior en l'entorn d'una mútua d'accidents de treball

Rehabilitación acelerada de la plastia de ligamento cruzado anterior en el entorno de una mutua de accidentes de trabajo

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Rehabilitación acelerada de la plastia de ligamento cruzado anterior en el entorno de una mutua de accidentes de trabajo

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Objectiu

El programa de rehabilitació accelerada després de la reconstrucció del lligament encreuat anterior va ser ben definit per Shelbourne el 1990. La rehabilitació dels accidents laborals té certes peculiaritats per les dificultats d'adherència dels pacients i les derivacions medico-legals que comporta. L'objectiu d'aquest treball era presentar els resultats preliminars del programa de rehabilitació accelerada després de la reconstrucció del lligament encreuat anterior mitjançant la tècnica os-tendó-os en l'àmbit de pacients laborals.

Amb aquest objectiu s'avaluaren 11 pacients que van patir una ruptura aguda del lligament encreuat anterior per accident laboral, nou dels quals exercien professions d'alta activitat física. Nou pacients eren homes i dues dones amb una mitjana d'edat de 25 anys (DE 9,85). Els resultats van ser avaluats en finalitzar el tractament rehabilitador un cop reincorporats al treball. Es va registrar la inestabilitat clínica, el balanç articular, el volum de la cuixa, la puntuació de l'escala de Lysholm, la força muscular concèntrica isocinètica de flexo-extensors de genoll a 180 $^{\circ} \cdot s^{-1}$, els dies de baixa, el nº de sessions de fisioteràpia, el nivell de capacitat laboral a l'alta, la satisfacció i les complicacions.

Resultats principals

Van realitzar una mitjana de 49,8 sessions de tractament (DE 11,8). La mitjana de dies de baixa va ser de 127,3 dies (DE 27,4). No es va registrar cap incapacitat laboral. Deu pacients van tornar al seu mateix lloc de treball, tres van reiniciar les seves activitats esportives i altres tres van desenvolupar una síndrome fèmoropatelar. La puntuació mitjana de l'escala de Lysholm va ser regular (82,6;DE 18,1). El dèficit de força mitjà dels extensors de genoll, avaluat mitjançant dinamòmetre isocinètic, va ser de 23,4% (DE 16,4) i, excloent els tres pacients que van desenvolupar dolor fèmoropatelar, de 15,3% (DE 8,1). No es va apreciar cap inestabilitat clínica, limitació del balanç articular o atròfia muscular rellevant. La majoria dels pacients estaven bastant o molt satisfets.

Conclusió

Es conclogué que un programa de rehabilitació accelerada després de la reconstrucció del lligament encreuat anterior és útil en els pacients laborals i que el desenvolupament d'un síndrome de dolor fèmoropatelar era la principal complicació.

ORIGINAL

Rehabilitación acelerada de la plastia de ligamento cruzado anterior en el entorno de una mutua de accidentes de trabajo

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Resumen.—El programa de rehabilitación acelerada tras la reconstrucción del ligamento cruzado anterior fue bien definido por Shelbourne en 1990. La rehabilitación de los accidentes laborales tiene ciertas peculiaridades por la falta de colaboración de los pacientes y las reclamaciones que comporta. El objetivo de este trabajo es presentar los resultados preliminares del programa de rehabilitación acelerada tras la reconstrucción del ligamento cruzado anterior mediante la técnica hueso-tendón-hueso en el ámbito de nuestra mutua laboral.

Se evalúan 11 pacientes que sufrieron una ruptura aguda del ligamento cruzado anterior por accidente laboral, nueve de los cuales desempeñaban profesiones de alta actividad física. Nueve pacientes eran varones y dos mujeres con una media de edad de 25 años (DE 9,85). Los resultados fueron evaluados al finalizar el tratamiento rehabilitador una vez reincorporados al trabajo.

Realizaron una media de 49,82 sesiones de tratamiento (DE 11,76). El promedio de días de baja fue de 127,26 días (DE 27,38). No se registró ningún baremo ni incapacidad laboral. Diez pacientes volvieron a su mismo lugar de trabajo, tres reiniciaron sus actividades deportivas y otros tres desarrollaron un síndrome femoropatelar. La puntuación media de la escala de Lysholm fue regular (82,55, DE 18,07). El déficit de fuerza medio de los extensores de rodilla evaluado mediante dinamómetro isocinético fue de 23,36% (DE 16,41) y sí excluimos los tres pacientes que desarrollaron dolor femoropatelar de 15,25% (DE 8,10). No se apreció ninguna inestabilidad clínica, limitación del balance articular o atrofia muscular relevante. La mayoría de los pacientes estaban bastante o muy satisfechos.

Concluimos que el programa de rehabilitación acelerada tras la reconstrucción del ligamento cruzado anterior es útil en los pacientes laborales y que el desarrollo de un síndrome de dolor femoropatelar es la principal complicación.

Trabajo recibido el 1-XII-00. Aceptado el 9-VII-01.

Palabras clave: ***Ligamentoplastia. Ligamento cruzado anterior. Tratamiento rehabilitador. Rehabilitación laboral.***

ACCELERATED REHABILITATION OF THE ANTERIOR CRUCIATE LIGAMENT PLASTY IN THE SCOPE OF A WORK ACCIDENT INSURANCE COMPANY

Summary.—The accelerated rehabilitation program after reconstruction of the anterior cruciate ligament was well defined by Shelbourne in 1990. Rehabilitation of work accident subjects has special characteristics due to the lack of collaboration by the patients and the claims involved. This work aims to present the preliminary results of the accelerated rehabilitation program after reconstruction of the anterior cruciate ligament by bone-tendon-bone technique within our work insurance company.

Eleven patients suffering from acute rupture of the anterior cruciate ligament due to a work accident, 9 of whose profession involved a high level of physical activity, were evaluated. Nine patients were male and two female with a mean age of 25 years (SD 9.85). The results were evaluated at the end of the rehabilitation treatment once the patient went back to work.

A mean of 49.82 treatment sessions (SD 11.76) was done. The average days of sick leave were 127.26 days (SD 27.38). No work criteria or incapacity was recorded. Ten patients returned to their same site of work, three reinitiated their athletic activities and three others developed femoropatelar syndrome. The mean score of the Lysholm scale was average (82.55, SD 18.07). The mean strength deficit of the knee extensors evaluated by isokinetic dynamometer was 23.36% (SD 16.41) and if we exclude the three patients who developed femoropatelar pain, 15.25% (SD 8.10). No relevant clinical instability, limitation of articular balance or muscular atrophy was observed. Most of the patients were quite or very satisfied.

We conclude that the accelerated rehabilitation program after reconstruction of anterior cruciate ligament is useful in work accident patients and that the development of a femoropatelar pain syndrome is the principal complication.

Key words: *Ligamentoplasty. Anterior cruciate ligament. Rehabilitation treatment. Work rehabilitation.*

INTRODUCCIÓN

El objetivo fundamental de la rehabilitación de las lesiones ligamentosas de la rodilla es el retorno a la actividad normal. Los objetivos secundarios, aunque no por ello poco importantes, serían la reducción del tiempo de rehabilitación, del tiempo de baja laboral y por tanto, de los costes del proceso.

El programa de rehabilitación tras la plastia del ligamento cruzado anterior (LCA) depende fundamentalmente del tipo de intervención que se lleva a cabo. En nuestro centro la técnica empleada es la plastia hueso-tendón-hueso (H-T-H) utilizando el tendón rotuliano. Posteriormente los pacientes inician un programa de rehabilitación acelerada (PRA) sin ortesis.

Los resultados del PRA a largo plazo, en lo que respecta a la estabilidad articular, son referidos como excelentes según lo publicado por Shelbourne et al en 1995 (1) y 1997 (2), basándose en una muestra de 1.057 individuos. Los mismos autores ha constatado que los resultados en cuanto a reincorporación a la actividad deportiva se mejoran si la intervención se pospone para realizar una pauta de potenciación previa (3). Finalmente, en cuanto al uso de ortesis al inicio del proceso de rehabilitación destacaríamos el trabajo de Howell y Taylor, que demuestra la ausencia de complicaciones sin el uso de ortesis en la fase inicial de la rehabilitación (4).

La mayoría de estos trabajos, y especialmente los de Shelbourne et al, se han realizado con una muestra de deportistas, tanto profesionales y semiprofesionales como recreativos, por lo que presumimos que se trata de pacientes altamente motivados en el seguimiento de un programa de rehabilitación para reincorporarse a su actividad deportiva habitual. Este probablemente no es el caso de los pacientes que han sufrido un accidente laboral. En estos casos se acostumbra a asumir que los resultados deben ser peores por la menor motivación de estos pacientes en el seguimiento de un programa de rehabilitación. La revisión de la literatura es poco ilustrativa. De hecho, hay pocos artículos en revistas indexadas que hagan referencia específicamente a los resultados de la plastia de LCA en pacientes laborales, y menos del PRA. En una revisión de los años 1990 a 2000 encontramos solamente dos artículos que hacen referencia a los resultados de la plastia de LCA en pacientes laborales. Tenemos por un lado el artículo de Noyes y Barber (5), en que compara los resultados de un grupo de pacientes no laborales con uno de laborales después de una plastia de LCA, mostrando una diferencia única y muy marcada en los días de baja laboral (344 de promedio global para los laborales frente a 40 en los no laborales). Por otro lado tenemos el reciente trabajo de Wexler et al (6) en que específicamente se analizan los resultados en una muestra de pacientes laborales americanos tratados en el postoperatorio mediante un PRA. Al analizar los resultados, concluyen que el hecho de ser paciente laboral no compromete los resultados de la técnica.

El objetivo del presente trabajo es analizar los resultados del PRA después de la reconstrucción del LCA en pacientes laborales de nuestro entorno.

PACIENTES Y MÉTODOS

Pacientes

Once pacientes intervenidos de ruptura de LCA secundaria a accidente laboral desde inicios de 1998 a octubre de 1999. El criterio de inclusión fue la aceptación del programa por parte del paciente y la proximidad geográfica al centro de referencia de la mutua laboral. Nueve de los pacientes eran varones y dos mujeres. Ocho eran trabajadores manuales o de la construcción que requerían una actividad física elevada. La media de edad era de 25 años (17-43). Seis de los pacientes presentaban lesiones concomitantes: menisco externo, menisco interno, ligamento lateral interno o síndrome fémoro-rotuliano. Seis no practicaban habitualmente ningún deporte.

Intervención quirúrgica

Plastia de LCA mediante técnica H-T-H de tendón rotuliano, realizada mediante artroscopia. Además, los pacientes afectos de lesiones meniscales fueron intervenidos mediante meniscectomía parcial en el mismo acto quirúrgico.

Programa acelerado de rehabilitación

El programa de rehabilitación desarrollado se basa en el propuesto por Shelbourne et al discretamente modificado para adaptarse a nuestro entorno. Las modificaciones no interfieren los plazos marcados ni la filosofía básica del programa: extensión de rodilla precoz, apoyo precoz y potenciación con ejercicios de cadena cerrada. Un hecho importante es la supresión

TABLA 1. Programa de rehabilitación.

Tiempo	*Programa de rehabilitación*
Días 1-7	Movilización pasiva continua (CPM) iniciando a 0-60° y progresando a 0-110° según tolerancia (10° por día); carga según tolerancia con dos muletas; isométricos de cuádriceps, contracciones de isquiotibiales; flexión y extensión activo-asistida o autoasistida en supino y prono; estimulación eléctrica del cuádriceps, masoterapia de despegamiento de la cicatriz y de la rótula y modalidades según requerimientos (crioterapia, ultrasonido, TENS, interferenciales). El alta hospitalaria es normalmente al 3°-4° día postoperatorio. Los criterios de alta serían: 1) Control del dolor; 2) extensión completa, 3) capacidad de elevar toda la extremidad en extensión de rodilla.
Semana 1-2	La extensión debe ser completa, si no, se prescriben posiciones mantenidas en extensión en decúbito prono con 1 Kg; progresar en el apoyo según tolerancia; libres en flexión; genuflexiones parciales (se puede utilizar el plano deslizante); «steps» de 10-15 cm; series de pies en puntillas.
Semana 3-4	Insistir en patrón de marcha normal; añadir ejercicios de cadena cerrada de flexoextensores de rodilla en prensa de pierna; extensiones terminales de rodilla 20°-0° con electroestimulación a criterio del fisioterapeuta; bicicleta estática. A la 4ª semana se pueden iniciar resistidos de isquiotibiales según tolerancia. Si persiste flexo se pueden iniciar estiramientos. A partir de la 4ª semana se recomienda realizar pauta básica de autoestiramientos globales y cicloergómetro. También se puede iniciar natación.
Semana 5-6	Se pueden iniciar ejercicios de potenciación en carga: Genuflexiones con pesos, etc. El banco de cuádriceps se puede añadir en la semana 6. También se pueden iniciar ejercicios de propiocepción básicos.
Semana 7-12	A partir de esta semana el programa ya depende de la progresión del paciente. Hacia la 8ª semana se realiza una evaluación de la fuerza muscular mediante dinamómetro isocinético a 180°/s limitando la extensión a 20°. Si la fuerza del cuádriceps es del 75% o mejor, se prescribe una ortesis funcional y se empiezan ejercicios de agilidad. La ortesis sólo se usa para actividades que implican cambios de ritmo y dirección. El programa de potenciación se mantiene aumentando la intensidad, añadiendo una pauta submáxima de potenciación isocinética para cuádriceps (cinco series de 15 repeticiones concéntricas tres veces por semana). Generalmente este punto es el de retorno al trabajo. Los ejercicios de agilidad son para entrenar el retorno a actividades que suponen cambios de ritmo y dirección bruscos. Alrededor de la 12ª semana, estando generalmente el paciente reincorporado a su actividad laboral, se inicia el entrenamiento para reanudar la eventual actividad deportiva previa. El criterio es alcanzar una fuerza de cuádriceps medida mediante dinamómetro isocinético del 85% de la sana.
Meses 4-5	Retorno a la actividad deportiva plena. Los criterios serían: 1) balance articular completo; 2) no derrame; 3) rodilla estable, 4) haber completado el programa de agilidad.

de la ortesis inicial. El programa global lo resumimos en la tabla 1. Cabe destacar que los tiempos marcados son los mínimos y que según la respuesta de los pacientes pueden alargarse. Igualmente en las tablas 2 y 3 se resumen los ejercicios constituyentes del programa.

Seguimiento clínico y análisis

Los pacientes incluidos en el programa han sido sometidos a un protocolo de seguimiento semanal realizado conjuntamente por el fisioterapeuta y el médico rehabilitador, que incluye la valoración del dolor con la escala visual analógica, la presencia de derrame articular, la estabilidad articular (a partir de la 6.ª semana), el balance articular, la movilidad de la patela, y la extensión activa de rodilla. El cometido de estas evaluaciones es monitorizar el programa de tratamiento. A éstas, se debe añadir la valoración mediante dinamometría isocinética de la fuerza del cuádriceps a 180°/s limitando la extensión a 20°/s, que se realiza a la 8.ª semana. La información que obtenemos de esta prueba nos sirve como criterio para introducir nuevos ejercicios (tabla 1) y para prescribir un programa de potenciación específico y monitorizarlo.

Para evaluar los resultados finales se ha citado a los pacientes sistemáticamente una vez han sido dado de alta del servicio de rehabilitación para someterlos a una evaluación que comprende los apartados detallados en la tabla 4. Las evaluaciones han sido realizadas en todos los casos por el primer autor del trabajo, tanto las clínicas como las tecnificadas (dinamómetro isocinético). La escala de Lysholm para valorar los resultados funcionales se administró a los pacientes en un cuestionario que fue cumplimentado por ellos mismos.

El seguimiento de estos pacientes se ha diseñado siguiendo a grandes rasgos el realizado por Shelbourne et al en los trabajos a largo plazo (2). La escala funcional escogida (Lysholm y Gillquist) nos parece la más adecuada para pacientes que no son necesariamente deportistas (7).

TABLA 2. Ejercicios de potenciación, propiocepción, resistencia y balance articular.

Ejercicio	*Descripción*
Bicicleta estática	Debe situarse el sillín lo suficientemente elevado para llegar a extensión máxima sin hacer hiperextensión. Cadencia de 80-90 revoluciones por minuto. Utilizar como ejercicio de calentamiento durante 10-20'.
Prensa EEII Genuflexiones (cadena cerrada)	Flexión ideal a 40° y 60° para la genuflexión y la prensa respectivamente, en todo caso no exceder los 90°. Enfatizar el trabajo excéntrico. Los ejercicios se deberían realizar en diferentes posturas los pies. Inicialmente con el pie recto y posteriormente con el pie en rotación externa. La resistencia es progresiva con reevaluación semanal.
Ejercicios de cadera y tobillo	Resistidos progresivos: flexión de cadera en flexión de rodilla, flexión de cadera con extensión de rodilla, flexión de cadera en rotación externa, extensión de cadera, dorsiflexión de tobillo y flexión plantar de tobillo.
Ejercicios isquiotibiales (cadena abierta)	Debe utilizarse un peso que permita al paciente realizar la flexión máxima y estirar lentamente. La resistencia será progresiva y se reevaluará semanalmente.
Ejercicios cuádriceps (cadena abierta)	Realizados en el arco articular no doloroso. Intentar trabajar en rotación externa de cadera, enfatizando los excéntricos, por ejemplo, elevando el peso con ambas extremidades y bajándolo con una sola. La resistencia será progresiva y se reevaluará semanalmente.
Ejercicios propioceptivos	Se realizan apoyando la rodilla manteniendo el equilibrio unipodal. Según tolerancia se progresa a plato basculante hasta equilibrio unipodal en plato basculante.
Tabla deslizante	Es importante mantener la flexión de la rodilla a 45° y utilizar las caderas para evitar el estrés en varo o valgo de rodilla. Se realizan 5 ó 10 min o hasta la fatiga.

RESULTADOS

El tiempo de seguimiento medio es de ocho meses (4-13 m). El número medio de sesiones de tratamiento fue de 49,82 (DE 11,76) para completar el programa. La duración media de la baja laboral total fue de 127,27 días (DE 27,38). Ningún paciente fue valorado como susceptible de indemnización por secuela tipificada. Diez de los 11 pacientes volvieron al puesto de trabajo previo. Solamente tres pacientes reiniciaron actividad deportiva recreativa. La puntuación media de la escala de Lysholm-Gillquist fue de 82,55 (DE 18,07), al límite entre regular y bueno. El déficit de *peak torque* medio fue de un 23,36% (DE 16,41). Tres pacientes registraron un síndrome de dolor femoropatelar de difícil control. Sí excluimos estos últimos del cómputo, las medias de la escala de Lysholm (89,88; DE 13,87) y las del déficit de *peak torque* (15,25%; DE 8,10) mejoran sustancialmente. No se registró déficit de movilidad, flexo, atrofia muscular o inestabilidad clínicamente relevantes. La mayoría de los pacientes (nueve sobre once) manifestaban bastante o mucha satisfacción (tabla 5).

TABLA 3. Ejercicios de agilidad.

Ejercicio	*Descripción*
Carrera lateral	Correr de lado sobre las puntas del pie 50 metros. Empezar corriendo 10 series y progresar a 20 series.
Carrera de espalda	Empezar corriendo a una velocidad mediana, 50 metros, 10 series. Progresar a velocidad máxima, 20 series.
Salto vertical	Saltar a una altura determinada empezando en bipedestación, 10 series, y progresar a inicio de salto corriendo, 20 series.
Saltar a cuerda	Saltar a cuerda iniciando con ambos pies, continuar alternando, y finalmente con un solo pie, durante cinco min. Progresar a 15 min.
Carioca	Correr de lado cruzando el pie primero por delante y después por detrás de la extremidad delantera. Empezar a una velocidad mediana, 10 series de 50 metros, y progresar a velocidad máxima, 20 series.
Subida de escaleras	Subir de una a una, a velocidad mediana, cinco series y progresar a subir de dos en dos, velocidad máxima y 10 series.
Figura de ocho	Correr a velocidad mediana trazando una figura de ocho de 30 m de largo por 15 m de ancho, 10 series. Progresar a velocidad máxima. Reducir progresivamente el tamaño del «8» siguiendo el mismo protocolo.

TABLA 4. Evaluación y registros a final del programa.

Número de sesiones de rehabilitación.
Número de días de baja laboral totales.
Secuelas tipificadas (baremos, incapacidad permanente parcial, etc.).
Retorno al mismo puesto de trabajo.
Reanudación de actividad deportiva regular (2-3 veces por semana).
Complicaciones de la intervención y del programa de rehabilitación.
Determinación del déficit de *peak torque* mediante dinamometría isocinética, el protocolo es a 180°/s concéntrico (cinco repeticiones de calentamiento, 60" de descanso, cinco repeticiones de medición).
Valoración de la estabilidad articular mediante test de Lachman.
Déficit de balance articular mediante goniometría bilateral.
Asimetría de perímetros del muslo medidos a 12 cm por encima del polo superior de rótula.
Flexo mediante goniometría.
Escala funcional de Lysholm y Gillquist.
Satisfacción con la intervención y el proceso: nada, poca, indiferente, bastante o mucha.

DISCUSIÓN

El injerto de tendón rotuliano es uno de los tejidos biológicos más resistente (125-150% más fuerte que el LCA) (8, 9). La utilización de pastillas de hueso fijadas con tornillos interferenciales de diámetro grueso favorecen la fijación biológica, de manera que a las 3-4 semanas de la intervención se ha demostrado consolidación del hueso del túnel y las pastillas comportando una fijación permanente (1). La revascularización del injerto se produce durante los 2-6 meses (10). Este hecho, al menos en teoría, tiene implicaciones en lo que respecta a la resistencia del injerto. En la práctica se ha demostrado que la hipotética pérdida de resistencia que comporta la revascularización no se ha traducido en inestabilidad clínica, tal como demostró Clancy, en los inicios de la implantación de la técnica, en su serie de 50 pacientes tratados mediante una plastia HTH (1). Posteriormente, los trabajos de Shelbourne et al, corroboraron esta afirmación (1, 2, 12).

Las premisas referidas y la observación clínica de que pacientes que «se saltaban» limitaciones de protocolos de rehabilitación restrictivos no presentaban complicaciones relevantes, llevó al desarrollo por parte de Shelbourne et al del PRA en el postoperatorio de una plastia de LCA mediante técnica HTH con tendón rotuliano. El hecho primordial sería el disponer de una fijación de la plastia suficientemente fuerte como para iniciar precozmente el apoyo y la movilización. Los rasgos característicos e innovadores del programa acelerado son la enfatización de la extensión precoz de la rodilla y el uso de ejercicios de cadena cerrada (12, 13). También se ha aplicado con éxito el PRA tras otras técnicas de reconstrucción (injerto combinado de semitendinoso y recto interno) (14).

Dado que la bibliografía es escasa en cuanto a reconstrucción del LCA en pacientes laborales diseñamos este estudio para demostrar la efectividad de la técnica H-T-H y el PRA posterior sin ortesis en nuestros pacientes.

Los resultados en referencia al número total de sesiones de rehabilitación requeridas y de baja laboral nos parecen muy aceptables. De hecho los pacientes han estado poco más de cuatro meses de baja laboral contando el tiempo entre la lesión y la intervención. No tenemos referencias para comparar en nuestro entorno. En la literatura americana —es decir, en un entorno sociolaboral, sanitario y legislativo muy dife-

TABLA 5. Resultados funcionales y de satisfacción.

	N.° sesiones	Días de baja laboral	Secuelas tipificadas	Retorno al mismo puesto de trabajo	Reinicio actividad deportiva regular	Lysholm	Déficit peak torque (%)	Complicaciones	Lachman	Déficit balance articular (°)	Asimetría perímetros (cm)	Flexo (°)	Tiempo de seguimiento (meses)	Satisfacción con intervención y proceso
1	64	153	no	no	sí	78	50	Femoropatelar	no	0	0	0	7,5	Bastante
2	45	123	no	sí	no	57	31	Femoropatelar	no	0	1,5	0	6,5	Poca
3	56	132	no	sí	no	99	17	no	no	8	1	0	8	Mucha
4	55	94	no	sí	no	54	54	Femoropatelar	no	0	1	0	9	Indiferente
5	45	150	no	sí	no	60	25	no	no	0	1	0	8	Bastante
6	47	134	no	sí	no	100	25	no	no	0	1,2	0	5	Mucha
7	38	97	no	sí	sí	89	12	no	no	0	0	0	13	Mucha
8	30	178	no	sí	no	89	13	no	no	0	2	0	7,5	Bastante
9	52	137	no	sí	no	100	0	no	no	3	1	0	10,25	Mucha
10	72	110	no	sí	no	82	12	no	no	0	0	0	11	Mucha
11	44	92	no	sí	sí	100	18	no	no	0	0	0	4,25	Mucha

rente al nuestro— encontramos el artículo de Noyes y Barber (5), que aunque el protocolo de rehabilitación no es igual al que realizamos, habla de tiempos de baja laboral totales de 344 días.

Es francamente destacable que no hubo ningún paciente en nuestra serie que mereciera el inicio de expediente para valorar un baremo o incapacidad. Igualmente todos menos uno volvieron a su trabajo previo, que en definitiva es el objetivo primordial de la rehabilitación llevada a cabo en las mutuas de accidentes laborales.

En cuanto al retorno a la actividad deportiva recreativa previa los resultados son más discretos (3 sobre 6). Ningún paciente realizaba deporte de una manera profesional o semiprofesional. Estos resultados los explicamos por el hecho de que la mayoría de los pacientes, una vez dados de alta laboral, declinan continuar la última fase de rehabilitación. Es decir, la diseñada específicamente para la reanudación de la actividad deportiva. La evaluación clínica del balance articular, estabilidad y atrofia muscular arroja unos resultados excelentes en esta serie.

Merece una mención especial el desarrollo de un síndrome femoropatelar en tres pacientes que ha interferido de una manera importante en el proceso de rehabilitación, remarcando que uno de ellos, el paciente 4, ya lo presentaba previamente a la intervención Consideramos que se debe básicamente a una predisposición individual (acortamientos musculares), sumado al papel de una intervención sobre el aparato extensor de la rodilla. De hecho, en nuestro centro, se está introduciendo recientemente la reconstrucción del LCA con semitendinoso para no incidir en el tendón rotuliano.

El déficit de fuerza medio de extensores de rodilla, determinado mediante dinamometría isocinética es de un 23,36% y está justo por encima del que se considera máximo para iniciar ejercicios de agilidad (25%). Ello indica un nivel de potenciación muscular notable, que comporta una buena protección articular. Si eliminamos los pacientes con síndrome femoropatelar del cómputo, el déficit de fuerza de extensores de rodilla se vuelve irrelevante (15,25%; DE 8,10)

La escala de Lysholm da unos resultados en promedio regulares (82,55, DE 18,07) que, al igual que ocurre con el déficit de *peak torque*, se corrigen sustancialmente al no incluir a los pacientes con el síndrome femoropatelar. De todas maneras, en la serie de Wexler, refieren una puntuación promedio en la escala de Lysholm igual a la obtenida en nuestra serie.

El presente trabajo presenta limitaciones. Básicamente, por un lado se trata de una serie corta. Por otro lado sería deseable una comparación con un grupo control de pacientes no laborales tratados en el mismo entorno. Incluso se podría afirmar que debería considerarse un grupo control de pacientes con lesión de LCA no intervenidos. Hasta incluso se podría intentar comparar con un grupo control de pacientes intervenidos y tratados con un programa «no acelerado». Asumiendo el riesgo de extrapolar, consideramos que los trabajos realizados hasta ahora, principalmente por Shelbourne et al, en una población de pacientes deportivos constituyen una evidencia suficiente de la eficacia y seguridad del PRA tras la plastia de LCA. Igualmente, los pacientes con profesiones de alto requerimiento físico necesitan de una rodilla estable para sus actividades (subir y bajar escaleras, cargar pesos...). Por tanto, se nos haría éticamente inaceptable proponer un grupo de no-intervención y/o de tratamiento rehabilitador «no acelerado» en pacientes laborales. En cuanto a la posibilidad de un grupo control de pacientes no laborales sería una posibilidad interesante pero no factible en nuestro centro.

En definitiva, la única limitación que presenta este estudio a nuestro juicio es la cortedad de la serie. No obstante, y a pesar de ello, los resultados son alentadores y relevantes.

CONCLUSIÓN

Con relación a los objetivos básicos de la rehabilitación laboral, destacamos la corta duración del tiempo de baja laboral, el índice alto de retorno al mismo puesto de trabajo y la ausencia de secuelas y incapacidades tipificadas a medio plazo. Todo ello, en un grupo de pacientes con trabajos de medio-alto requerimiento físico. Igualmente, consideramos alentadores los resultados clínicos y la impresión subjetiva de los pacientes. La incidencia de patología femoropatelar supone el problema de manejo más importante en algunos pacientes. Consideramos que la continuación del estudio y la introducción de nuevas técnicas quirúrgicas nos permitirá perfilar más exactamente la repercusión de este hecho. De todas maneras, y a la luz de los resultados que exponemos, concluimos que el PRA, sin ortesis, tras reconstrucción del LCA mediante técnica H-T-H, es una intervención terapéutica eficaz, eficiente y segura en pacientes laborales en nuestro entorno.

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Capítol 5.11

Aplicacions clíniques de les proves biomecàniques: mites i realitats

Aplicaciones clínicas de las pruebas biomecánicas: mitos y realidades

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Aplicaciones clínicas de las pruebas biomecánicas: mitos y realidades

J. Chaler, R. Garreta

Rehabilitación (Madr). 2010;44:195-8. - vol.44 núm 03

Aquesta editorial es una reflexió sobre el paper clínic i medico-legal de les proves biomecàniques en general i de la dinamometria en particular en la pràctica de la rehabilitació.

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EDITORIAL

Aplicaciones clínicas de las pruebas biomecánicas: mitos y realidades

Clinical applications of biomechanical tests: Myths and realities

En la práctica clínica, habitualmente, se entiende por prueba biomecánica a aquella que evalúa aspectos mecánicos o fisiológicos de la motricidad humana como son la fuerza muscular, el movimiento y/o coordinación, el equilibrio y patrones de activación muscular dinámica. Así, en la actualidad existen en el mercado diferentes tipos de dinamómetros (isocinéticos, isométricos o isoinerciales), sistemas de análisis del movimiento en 3D, posturógrafos, sistemas de baropodometría y electromiógrafos multicanal de superficie para realizar estudios dinámicos. El denominador común de estas pruebas es que permiten evaluar la función, es decir, el rendimiento del sistema neuromuscular y musculoesquelético en contraposición con la mayoría de exploraciones complementarias «clásicas», en las que el paciente o sujeto es eminentemente pasivo. Esta característica las ha convertido en herramientas imprescindibles en la investigación básica de patología musculoesquelética y neurológica así como en la medicina deportiva o rendimiento deportivo. Pero también las hace de un inmenso interés en la práctica clínica de la rehabilitación, tanto musculoesquelética como neurológica, para registrar déficits, monitorizar procesos y, si se da el caso, determinar secuelas. Un ejemplo bien conocido es la validez de los dinamómetros isocinéticos en la monitorización de la fuerza muscular dinámica en diferentes condiciones[1–3]. Asimismo, las pruebas biomecánicas se han utilizado clínicamente en la planificación quirúrgica. Concretamente, y a modo de ejemplo, es de destacar que para diseñar un plan quirúrgico multinivel en pacientes afectos de parálisis cerebral, en estos momentos, la realización de una prueba de análisis de movimiento en 3D es determinante en la toma de decisiones[4–6]. En el campo de la medicina deportiva tienen un papel crucial. Precisamente en este campo, Davies et al[7] definieron un algoritmo muy útil para encuadrar conceptualmente la valoración funcional. En él se describen tres niveles. Un primer nivel engloba pruebas funcionales básicas (p.e. el balance articular, la medida de los acortamientos musculares y el equilibrio); en un segundo nivel pruebas de fuerza y/o potencia (p.e tests isoinerciales e isocinéticos) y finalmente pruebas de campo o de rendimiento (p.e «hop-test», «Yo-yo test» o incluso pruebas de análisis del movimiento). Este algoritmo presupone no sólo la obtención de datos cuantitativos (el ejemplo más claro es la dinamometría isocinética, en que se obtienen datos de fuerza dinámica y potencia de una articulación aislada), sino también cualitativos que dan información objetiva de la función de múltiples estructuras (como por ejemplo un «hop test»[8,9], en que se analiza el rendimiento de un salto mediante un protocolo predefinido y comparando un lado afecto con uno sano)[10]. Esta aproximación en la que se propone una evaluación más cualitativa tiene mucho que ver con un cambio de modelo de rehabilitación, cada vez más basada en algo más que ejercicios ejecutados de una manera pura y aislada[11]. Este cambio de modelo es aplicable a otros ámbitos de la rehabilitación, como puede ser la neurológica, la ortopédica o la ocupacional. Igualmente, el algoritmo definido por Davies et al[7], también nos puede ayudar a agrupar en distintos niveles los sistemas de evaluación biomecánicos descritos más arriba. Así tendríamos, entre otros, los diversos sistemas dinamométricos (isocinéticos, isoinerciales e isométricos), eminentemente cuantitativos integrados en el segundo nivel que se corresponde con las fases intermedias de la rehabilitación. En estas fases nos interesa objetivar de una manera precisa, fiable y válida «qué» vamos ganando con las diferentes terapias dirigidas a ganar fuerza. Finalmente, podríamos agrupar en el último nivel los sistemas, eminentemente cualitativos, de análisis del movimiento en 3D, electromiografía de superficie, posturógrafos o baropodometría que nos pueden dar datos del «cómo» utiliza el paciente lo que tiene y a veces nos dan respuestas al «por qué», evidentemente con alta validez clínica. Un buen ejemplo de la importancia de una evaluación cualitativa es el estudio de la marcha humana. Para este cometido disponemos de

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sistemas de evaluación cuantitativos que miden los parámetros básicos de la marcha (simetría, velocidad, cadencia, longitud del paso, etc.). Estos sistemas aplicados a, por ejemplo, un paciente hemipléjico con un pie equino nos pueden detectar alteraciones en estos parámetros e incluso objetivar evoluciones positivas o estabilizaciones. Por el contrario, un sistema de medición cualitativo, como el análisis de la marcha en 3D con electromiografía dinámica nos puede dar información objetiva y muy valiosa en relación a la naturaleza u origen del pie equino (espasticidad, debilidad, co-contracciones) que ayuda a tomar decisiones terapéuticas dirigidas, es decir, mucho más validas[12]. En definitiva, tanto los sistemas cuantitativos como los cualitativos son de un interés muy alto en los procesos de rehabilitación, los primeros más en fases intermedias y los segundos más al final del proceso. En todo caso, permiten modular y decidir nuevos tratamientos, planificar el retorno a la participación o reincorporación laboral u objetivar secuelas. En este último sentido, en los últimos años está creciendo muchísimo su aplicación evaluadora y médico-legal, sobre todo en pacientes afectos de lesiones ocupacionales.

En este punto, surge la cuestión de cómo seleccionar los dispositivos más adecuados. Evidentemente, el primer escollo es el económico. No hay prácticamente sistemas biomecánicos baratos. Probablemente éste es el aspecto que limita más el desarrollo de la disciplina en la clínica. La utilización de pruebas cuantitativas, como algún tipo de dinamómetro, ya está más o menos establecida, aunque su difusión no es ni mucho menos general, en muchos entornos clínicos. Por el contrario, las cualitativas y especialmente los sistemas de análisis del movimiento, no generan tanto consenso. Aquí se identifica uno de los mitos de la biomecánica: los sistemas de análisis del movimiento son muy complicados y poco factibles en la práctica clínica. Esta aseveración es parcialmente cierta. Es verdad que se trata de una aproximación más compleja y que requiere un esfuerzo de formación y el trabajo en equipo con bioingenieros, pero por otro lado, solamente la incorporación de los clínicos en el equipo puede dar contenido de validez a estas pruebas. Precisamente, este debate está de actualidad en referencia a la utilización clínica del análisis del movimiento en 3D para la planificación quirúrgica en pacientes con parálisis cerebral infantil y otros objetivos. Concretamente, la bibliografía refiere que se requiere una mayor implicación de clínicos e interacción con los bioingenieros en este cometido para enriquecer la validez de estos sistemas[5,13]. En definitiva, no son menores los escollos a superar (económicos, formación, etc.) pero sería imprescindible una mayor implicación de los clínicos para dotar de validez las pruebas y por tanto enriquecer la práctica clínica.

Un punto fundamental en las pruebas biomecánicas es su fiabilidad. Existe la idea de que la precisión (derivada de su calidad intrínseca) de los dispositivos biomecánicos asegura su fiabilidad. Nada más alejado de la realidad. De hecho, la fiabilidad, que está en la base de la validez, es un tema mayor y complejo en las pruebas biomecánicas. Un test biomecánico es una experiencia singular en que uno o varios examinadores evalúan mediante un dispositivo más o menos complejo un sujeto o paciente que realiza una acción. Por tanto, se pueden identificar múltiples factores que pueden afectar la reproducibilidad[14]. En primer lugar los derivados del dispositivo como la calibración o el proceso de los datos. En segundo lugar los relacionados con el procedimiento (instrumentación del paciente, posicionamiento, fijación, aplicación de electrodos, etc.) y protocolo de valoración (número de tests, periodos de descanso, estímulos verbales, etc.). Finalmente los factores más ligados a los observadores (explicación al paciente, interpretación de datos, etc.) y, muy especialmente al paciente o sujeto en sí (motivación, colaboración, comprensión, etc.). Como muy bien resume Dvir[15] en su última monografía sobre isocinéticos, las medidas derivadas de estos, y probablemente de todos los dispositivos biomecánicos, incorporan múltiples fuentes de variación, desde aspectos puramente (y aparentemente sencillos) técnicos hasta aspectos neuro-conductuales tan complejos como la motivación. No obstante, y a pesar de las dificultades, la fiabilidad de las diferentes pruebas biomecánicas ha sido establecida en diversas publicaciones. Como por ejemplo para dinamómetros isocinéticos[1,15], la dinamometría isométrica de mano[16], la baropodometría[17], la posturografía[18], la electromiografía dinámica[19,20], el análisis del movimiento en 3D de la marcha[21], de la columna cervical[22], y el hombro[23] entre otros sistemas. Por tanto, dado que en estos momentos la disciplina en su aplicación clínica está, al menos en nuestro entorno, en sus inicios y la divulgación es fundamental, al diseñar pruebas e informes biomecánicos seria deseable facilitar las citas pertinentes y reproducir con el máximo rigor las metodologías descritas. Igualmente es de gran importancia añadir o reflejar los datos de calibración de los sistemas utilizados pues está en la base de la fiabilidad.

El tema de la «motivación» de los pacientes merece una atención aparte porque el establecimiento de laboratorios de biomecánica, que está experimentado un gran auge en los últimos años en España sobre todo en centros de rehabilitación laboral y en centros independientes dedicados a la valoración de secuelas, tiene mucho que ver con la evaluación de este particular aspecto. Es decir, con el uso médico-legal de los sistemas biomecánicos. Como se ha comentado más arriba, la motivación o colaboración del paciente es fundamental para asegurar la fiabilidad y, al mismo tiempo, la validez de la prueba. Por ello siempre es deseable tener algún dato que nos indique el nivel de colaboración en la realización de la prueba, sobre todo si el resultado se ha de emplear en la determinación de secuelas y/o incapacidades. En la literatura encontramos parámetros diversos para analizar el nivel de colaboración en algunas pruebas biomecánicas. Así, disponemos de la diferencia excéntrico concéntrico (DEC) para evaluar la maximalidad del esfuerzo en las pruebas isocinéticas[24,15]; el coeficiente de variación y el test de intercambio rápido para las pruebas isométricas de fuerza de garra[25]; la relación del coeficiente de variación con el recorrido articular para el análisis de movimiento de la columna cervical[26] y la detección de patrones afisiológicos para la posturografía[27], por ejemplo. El hecho de detectar, mediante alguno de los parámetros descritos, signos de falta de colaboración implica una consecuencia crucial: La prueba no es fiable y por tanto, la valoración del paciente no es válida. Por el contrario, no necesariamente nos diagnostica el paciente de simulador. He ahí una de las grandes fuentes de confusión que ha hecho crear el mito de que los sistemas biomecánicos son detectores de simuladores. En este punto es necesario puntualizar dos aspectos fundamentales. En primer lugar, hay que remarcar que se han identificado múltiples causas de falta de colaboración en la realización de una prueba o exploración. A saber, dolor, miedo al dolor, miedo a la recaída de la lesión, ansiedad, depresión, falta de comprensión y, finalmente, ganancias secundarias o simulación[28]. Por tanto, el diagnóstico diferencial es amplio. En segundo lugar, a pesar de que los resultados de tests biomecánicos pueden constituir pruebas muy valiosas para apoyar el diagnóstico de simulación, este se encuadra dentro del universo de entidades psiquiátricas caracterizadas por la producción más o menos consciente de síntomas y signos falsos, por tanto su diagnóstico compete a los especialistas en psiquiatría o psicología puesto que está bien definido en el Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV)[29]. Así, es altamente recomendable evitar, en los informes de pruebas biomecánicas, términos como «simulador-a», «magnificador-a», «exagerador-a» entre otros, y en su lugar utilizar términos como «se registran datos afisiológicos», «hay signos de falta de colaboración» o «signos de esfuerzo submáximo». Por otro lado, es de gran utilidad, sobre todo en usos medicolegales pero también en la práctica clínica habitual, confrontar los resultados obtenidos en la prueba biomecánica con los de la historia clínica, la exploración física y los de exploraciones complementarias más convencionales. Esto refuerza definitivamente la validez de las pruebas y evidentemente requiere una alta implicación de un clínico en su realización e interpretación. Las pruebas biomecánicas no son ni más ni menos que una fuente de datos más que se añade a los que ya teníamos.

En definitiva, la biomecánica clínica cumple todos los requisitos para convertirse en una nueva subespecialidad dentro de la rehabilitación. Su futuro es altamente dependiente de la implicación de los médicos especialistas en rehabilitación. Pues éstos, actuando con rigor y exigencia, son los más capacitados para llenar de validez clínica la disciplina. Este objetivo requeriría un esfuerzo de formación, incluyendo la materia de biomecánica en los currículos de licenciaturas de medicina y programas de formación de especialistas, e inversión de los sistemas de salud. Todos los esfuerzos se verán recompensados con un gran salto cualitativo de la rehabilitación y evaluación de los pacientes con disfunciones y discapacidades secundarias a infinidad de patologías, así como con la apertura de vastos campos de investigación clínica y básica.

Conflicto de intereses

Los autores declaran que no existe ningún conflicto de intereses.

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Capítol 6

Discussió General

Els resultats dels presents treballs indiquen que la dinamometria isocinètica pot ser una eina válida en l'avaluació de pacients musculoesquelètics laborals.

En la base de la validesa dels tests isocinètics està el que l'esforç sigui màxim. La determinació d'aquest fet mitjançant la utilització del DEC es l'aportació central d'aquesta tesi i els resultats principals amb les dades pràctiques més importants estan resumits a la taula 2.

La present conclusió general es pot desglossar en diferents aspectes addicionals estudiats que es discutiran articulació per articulació.

	Subjectes			Acció avaluada-Aparell-Protocol					Punts de tall DEC (sup.)		Tall inferior
Cita	N	Sexe	Edat (mitja ±DE)	Acció	Aparell	Rang articular	Velocitats		95%	99%	DEC_{max}-2DE
Dvir et al, 1996	16	homes	21-30*	Extensió de genoll	KinCom	80º	30ºs^{-1}-180ºs^{-1}		1.02	1.14	-0.11
Dvir et al, 1997	15	homes	21-55*	Flexió de colze	KinCom	30º (20ºF-50ºF)	20ºs^{-1}-60ºs^{-1}		1.11	1.29	-0.733
						60º (20ºF-80ºF)	20ºs^{-1}-60ºs^{-1}		1.23	1.47	-0.780
Dvir, 1999	17	dones	20-25*	Prensió d'urpa	KinCom	8º(4cm)	4ºs^{-1}-16ºs^{-1}		2.12	3.27	-3.41
Dvir et al, 2001	18	homes	38.5 ± 12.2	Extensió de tronc	KinCom	20º (10ºF-10ºE)	10ºs^{-1}-40ºs^{-1}		0.69	0.95	n.c.
	17	dones	28.3 ± 11.4	Extensió de tronc	KinCom	20º (10ºF-10ºE)	10ºs^{-1}-40ºs^{-1}		0.75	1.02	n.c.
Dvir et al, 2002	17	homes	29.1 ± 2.4	Flexió d'espatlla	KinCom	16º (82ºF-98ºF)	8ºs^{-1}-32ºs^{-1}		0.36	0.41	-0.17
						16º (82ºF-98ºF)	8ºs^{-1}-64ºs^{-1}		0.55	0.61	-0.01
						80º (50ºF-130ºF)	40ºs^{-1}-160ºs^{-1}		0.99	1.09	-0.02
Chaler et al, 2007	***17***	***homes***	***27.7 ± 6.1***	***RE***	***Cybex Norm***	***60º (55RI-5RE)***	***30º·s^{-1} 120º·s^{-1}***		***0.81***	***1.079***	***-0.039***
Olmo et al, 2009	20	homes	30.9 ± 13.2§	FD/FPl de turmell	Biodex SII	60º	30ºs^{-1}-120ºs^{-1}	FPl:	1.9§	2.34§	-0.1§
	18	dones						FD:	2.2§	2.71§	0.14§
Chaler et al, 2013 en premsa	***41***		***47.8 ± 10.8***	***RE d'espatlla***	***Cybex Norm***	***60º (55RI-5RE)***	***30º·s^{-1}-120º·s^{-1}***	***H:***	***1.84***	***1.96***	***-0,6***
	33	***dones***	***48.5 ± 9.6***					***D:***	***2.64***	***2.85***	***-0.83***
Torra et al, enviat	***20***		***28.5 ± 3.2***	***FD/FP de canell***	***Contrex***	***20º (10ºFD-10ºFP)***	***10º·s^{-1}-40º·s^{-1}***	***FD:***	***0.37***	***0.58***	***-0.26***
								FP:	***0.33***	***0.49***	***-0.25***
Pujol et al, enviat	***16***		***33.6 ± 6.1***	***RE d'espatlla***	***Contrex***	***60º (55RI-5RE)***	***30º·s^{-1}-120º·s^{-1}***		***0.58***	***0.65***	***-0.04***
						20º (55RI-35RI)	***10º·s^{-1}-40º·s^{-1}***		***0.46***	***0.54***	***-0.29***

DE: desviació estàndard; *DE no proporcionada a l'article, es reflexa el rang d'edats; **RE:** rotació externa; **FD:** flexió dorsal; **FPl:** flexió plantar; **FP:** flexió palmar; **F:** Flexió; **E:** extensió; **RI:** rotació interna § El promig d'edat i els resultats d'homes i dones es mostren barrejats en aquest estudi; **H:** homes; **D:** dones; **n.c.:** no calculable

Taula 2. Estudis on s'ha demostrat la utilitat del DEC en la detecció d'esforços submàxims: característiques dels subjectes, acció avaluada, dispositiu utilitzat, rang articular, velocitats, punts de tall als nivells de confiança del 95% i del 99% i, finalment límit inferior de valor de DEC acceptable calculat restant dues DE del promig del DEC màxim. S'afegeixen i es ressalten en color blanc, cursiva-negreta els resultats dels treballs recollits en la present tesi.

6.1. Articulació de l'espatlla

L'alta freqüència de les lesions al voltant de l'articulació de l'espatlla ha portat a que en la present tesi s'hagi dedicat una atenció molt especial a aquesta articulació. S'hi dediquen quatre treballs (Chaler et al., 2002; Chaler et al., 2013; Chaler et al., 2007; Pujol et al., 2012) que primordialment estan focalitzats en l'avaluació de la sinceritat de l'esforç, la seva utilitat clínica i, també, en la validesa dels resultats de les proves isocinètiques en la pràctica/decisions clíniques.

El primer article (Chaler et al., 2002) va ser una primera aproximació en que es va utilitzar el RE/C per intentar estimar la sinceritat de l'esforç dels diferents grups musculars de l'espatlla (flexo-extensors, rotadors i abdoadductors). En aquell moment l'aproximació es va estimar vàlida però el temps la va revelar insuficient i poc fiable, básicament per la alta variabilitat que presentava el RE/C en pacients que realitzen un esforç màxim. Val a dir, no obstant, que en aquell recull de pacients les limitacions del RE/C per valorar la sinceritat de l'esforç es varen compensar en part realitzant una avaluació molt exhaustiva de la força muscular de l'espatlla abarcant totes les accions enumerades més a munt. Aquest fet millorava la fiabilitat de la prova i la seva validesa en la presa de decisions. En tot cas, cal destacar que en el nostre entorn va suposar la primera vegada que es va utilitzar un paràmetre basat en la fisiologia de la contracció muscular per avaluar la sinceritat de l'esforç.

L'article següent (Chaler et al., 2007) va ser un pas molt important en l'avaluació de la sinceritat de l'esforç durant la realització d'una prova isocinètica de rotadors externs. Els resultats de l'estudi vàren mostrar que el DEC era un paràmetre molt eficient en la detecció de la sinceritat de l'esforç de rotadors externs durant una prova isocinètica en voluntaris sans. De fet, els resultats pel que fa a la potència del DEC varen ser extraordinaris doncs, en la mostra de subjectes sans, el DEC va mostrar una sensibilitat i una especificitat del 100% utilitzant un punt de tall amb un nivell de confiança del 95% (0.81). La figura 7 mostra l'imatge gràfica d'aquest fet que ilustra la gran potència d'aquest paràmetre en aquella mostra de subjectes sans (Chaler et al., 2007). D'altra banda, la concordància dels resultats del present estudi amb previs realitzats fins aleshores (Dvir & David, 1996; Dvir, 1997; Dvir, 1999; Dvir & Keating, 2001; Dvir, 2002; Dvir, Steinfeld-Cohen, & Peretz, 2002; Dvir & Keating, 2003) en el sentit que el DEC submàxim era superior al màxim, reforçava la validesa del paràmetre DEC.

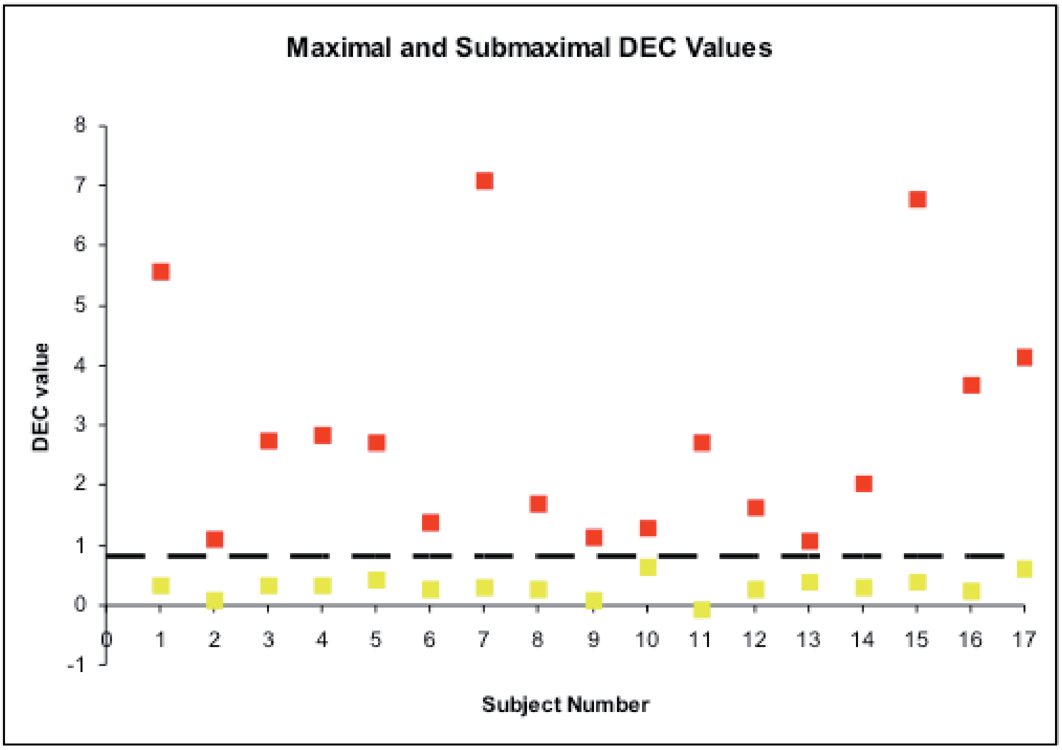

Figura 7. Representació dels valors màxims i submaxims de DEC de rotadors externs en volun-taris sans (Chaler et al., 2007). Destaca que no hi ha cap valor de DEC registrat en esforç màxim (quadrats grocs) que estigui per sobre del nivell de tall (línia discontinua a 0.81), ni cap DEC registrat en esforç submàxim (quadrats vermells) per sota del punt de tall. Per tant, la sensibilitat i especificitat son del 100% en ambdós casos per aquesta mostra.

D'ença que es va poder demostrar que el DEC era un paràmetre eficient en la detecció de la sinceritat de l'esforç, la seva utilització es va implantar en la pràctica quotidiana del servei de rehabilitació d'Egarsat per tal d'assegurar la validesa dels tests isocinètics de rotadors externs. El següent article (Chaler et al., 2013), central en la present tesi, recull l'experiencia de l'us del DEC en la pràctica diaria de les valoracions isocinètiques en l'entorn d'un servei de rehabilitació laboral. Fins aquest moment només hi ha dos estudis on s'analitza la utilitat del DEC en 34 pacients de diferents diagnòstics (Dvir, 2002) i en 44 pacients afectes de dolor lumbar crònic (Dvir & Keating, 2003). En aquests moments, per tant, el present treball constitueix el recull més llarg de pacients avaluats amb dinamometria isocinètica i aplicació del DEC en una articulació específica. Els resultats d'aquest estudi varen ser molt reveladors pel que fa a la utilitat clínica del DEC. No endebades, no hi ha constància de que s'hagi fet cap recull més llarg de pacients amb valoracions isocinètiques on s'hagi aplicat la utilització del DEC. La conclusió general de l'estudi es que el DEC va ser vàlid en pacients. No obstant hi va haver tot un seguit de troballes (resultats molt anòmals en dones, proporció relativament alta de pacients amb un DEC molt baix, fins i tot negatiu) que ens va portar als autors a definir uns nous punts de tall basats en els resultats de l'extremitat sana dels pacients. Aquesta aproximació va suposar una millora molt substancial dels resultats, especialment de les dones. Cal remarcar que també es dona per fet un efecte de l'edat (de fet el DEC de referencia que manegavem previament era calculat en uns subjectes sans que tenien una edat mitja de 27.2 anys mentre que la mostra del present treball tenia una mitjana d'edat de 47.78 i 48.48 anys per homes i dones, respectivament) i molt probablement per fet de ser un pacient (i potencialment medico-legal). Comparant els resultats del present estudi amb els estudis en que es va aplicar el DEC en poblacions de pacients (Dvir, Steinfeld-Cohen, & Peretz, 2002; Dvir & Keating, 2003), crida molt l'atenció que en el present estudi el percentatge de pacients etiquetats de "no col·laboradors" era molt més alt que en els estudis previs. Aquest fet es remarcable i, molt probablement, degut a causes poblacionals o de la peculiaritat del centre on s'ha realitzat l'estudi. Es probable, també, que la mostra del present estudi sigui esbiaixada cap a pacients en situacio medico-legal. Es a dir, que les proves isocinètiques amb l'aplicació del DEC es tendeixen a seleccionar per avaluar pacients amb més probabilitat de mostrar una situació medico-legal que més fàcilment pot comportar manca de col·laboració. En tot cas, els resultats també indiquen la probable limitació de la utilització de valors de referència de DEC extrets de voluntaris sans en poblacions de pacients. Tot plegat, fa extremadament necessari avaluar cas per cas, amb molta cura i prendre conclusions amb la màxima prudència en la pràctica clínica quan es fan exploracions de la força muscular mitjançant la dinamometria isocinètica. No cal dir que calen i, per tant, es faran molts més estudis en poblacions de pacients amb l'objectiu de definir millor el paper del DEC en aquest entorn, molt especialment, quan s'imbrinquen aspectes medico-legals.

En tot cas, en aquest recull de pacients, es molt destacable, des del punt de vista de la validesa clínica, que l'avaluació dels resultats dels dèficits de pacients (homes, doncs no hi havia prou dones per analitzar) que es van etiquetar de col·laboradors màxims vàren mostrar una tendència a la correlació amb la severitat del diagnòstic i, pel que fa als resultats funcionals finals, una correlació excel·lent. Així s'observa que els pacients que varen requerir tractament quirúrgic mostraven uns déficits superiors en totes les medicions que els pacients no quirúrgics. Pel que fa al resultat funcional final, si que es pot demostrar que els que varen acabar amb curació sense seqüela presentaven uns dèficits significativament inferiors als que varen acabar amb seqüela en totes les medicions (veure la taula 3). Es de destacar, malgrat la bona correlació entre la presencia de seqüeles i el dèficit de força de rotadors externs, el resultat de la prova no era la única eina de decisió de seqüela laboral a l'alta. Aquesta troballa és d'una gran importància i indica d'una manera molt nítida la validesa de les proves dinamomètriques en pacients laborals sempre que s'hagi assegurat la màxima col·laboració amb l'ús de paràmetres com el DEC. No hi ha constància de estudis previs en que s'hagi avaluat la validesa de la dinamometria isocinètica en pacients laborals.

	Dèficit isocinètic de rotadors externs (%)			
	30º·s-1 conc	30º·s-1 exc	120º·s-1 conc	120º·s-1 exc
Grups diagnòstics:				
Tendinopatia manegot (n=9)	26.60 ± 38.35	16.43 ± 21.41	30.12 ± 33.58	13.51 ± 24.97
Pacientsquirúrgics (n=7)	47.98 ± 37.34	31.60 ± 23.32	41.16 ± 29.61	27.39 ± 23.52
Capacitat laboral a l'alta:				
Curació complerta (n=15)	19.22 ± 34.77	9.88 ± 18.24	19.62 ± 31.99	8.96 ± 20.89
Algun grau d'incapacitat (n=10)	58.86 ± 17.65*	38.38 ± 21.31*	50.89 ± 15.82*	32.52 ± 19.75*

Conc: contracció concèntrica
Exc: contracció excèntrica

* Els pacients amb una discapacitat final mostraven uns dèficits de rotadors externs significati-vament més alts que els que no van patir discapacitat laboral.

Taula 3. Es representen els dèficits de rotadors externs(en % i en les modalitats de contracció concèntrica i excèntrica i velocitats alta i baixa) del grup d'homes que es varen catalogar de col·laboradors màxims. Es comparen els dos grups diagnòstics principals (patologia de manegot no quirúrgica i patologia de manegot quirúrgica) i els dos resultats funcionals finals principals (curació versus qualsevol tipus de seqüela). Cal destacar que els pacients que varen acabar amb algun tipus de discapacitat/seqüela pel que fa al seu treball (Lesió permanent no incapacitant, incapacitat laboral parcial o incapacitat laboral total) mostraven uns deficits significativament mes alts que aquells que van acabar amb curació. Els pacients quirúrgics també mostraven dèficits superiors als no quirúrgics però en aquest sense significació estadística.

El darrer estudi de la serie de treballs dedicats a l'espatlla (Pujol et al., 2012) també suposa una aproximació inedita al tema del DEC, en tant que es va assajar un mateix protocol de detecció de un esforç submàxim de rotadors externs en un dispositiu diferent. Mentre el primer estudi (Chaler et al., 2007) va ser realitzar en un dispositiu isocinètic Cybex Norm, el segon (Pujol et al., 2012) es va dur a terme en un dispositiu Contrex. Com era d'esperar, això comporta canvis en el nivell de tall del DEC (mentre en el primer estudi el punt de tall era 0.81 amb un 95% de confiança, en el segon 0.58) i, el més important, la sensibilitat en el Contrex es molt més baixa (50% en el present estudi front un 100% en el previ) mentre que la especificitat es manté (100%). Un altre aspecte que es va avaluar en aquest estudi es la eficiencia del DEC en la detecció de la sinceritat de l'esforç de rotadors externs en una prova feta en un rang curt (20º). Aquesta aproximació, proposada en diverses ocasions pel professor Dvir, s'ha mostrat eficaç en l'avaluació de la flexo-extensió de colze, flexo-extensió d'espatlla i tronc (Dvir, 1997; Dvir & Keating, 2001; Dvir, Steinfeld-Cohen, & Peretz, 2002). En el present cas, també s'ha demostrat eficient i amb una molt bona especificitat (100%), no obstant la seva sensibilitat es molt baixa a un nivell de confiança del 95% (18.75%) i això fa que la seva utilització hagi de ser amb una extrema precaució. Es evident que la utilitat del DEC en aquesta acció específica, en rang curt, es molt limitada seguint els presents resultats. En tot cas, cal més investigació en aquest aspecte per acabar de definir el paper del rang curt en l'avaluació de la rotació externa d'espatlla.

6.2. Articulació del Canell

El primer article dedicat al canell (Torra et al., 2012) preten definir la eficiència del DEC en la detecció de la maximalitat de l'esforç de flexors dorsals i palmars. Efectivament el DEC es demostra eficient per aquest objectiu. Així, pels primers, el nivell de tall amb una confiança del 95% es de 0.384 mentre que pels segons es 0.317. En aquest cas, la sensibilitat es més que acceptable amb un nivell de confiança del 95%, superior no obstant en la detecció de esforços submàxims de flexors dorsals (71.4%) que palmars (62.5%). Es la primera vegada que es demostra la efectivitat del DEC en l'avaluació de flexió dorsal i palmar de canell. La seva possible utilitat clínica i medico-legal es enorme i, de fet, ja s'estan recollint pacients, eminentment afectes d'epicondilitis. No endebades es tracta d'una de les patologies laborals més freqüents.

Els següents tres articles (M. A. Mañanas, Rojas, Mandrile, & Chaler, 2005; Rojas, Mañanas, Müller, & Chaler, 2007; Unyó et al., 2012) estan precisament centrats en l'estudi de l'activitat elèctrica i la producció de força isocinètica de la musculatura de l'avantbraç en pacients amb epicondilitis antiga. Els resultats principals mostren, a part d'una activació electromiogràfica diferenciada de la musculatura de l'avantbraç durant la producció d'esforços isomètrics, un desequilibri muscular mesurat per dinamometria isocinètica, de manera que en els pacients que han patit una epicondilitis (no activa en el moment de la mesura) es detecta una predominància dels flexors palmars sobre els dorsals. No tenim coneixement que aquesta troballa s'hagi comunicat mai i la seva confirmació podria afegir una data molt important que podria millorar els plantejaments preventius i terapèutics en pacients afectes o en risc de patir epicondilitis. Els desequilibris musculars han estat identificats en altres nivells i relacionats amb la predisposició a patir diverses patologies: lesions de isquiotibials (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008) i supraespinós (Page, 2011); per tant, la seva identificació pot ser fonamental en el tractament i prevenció de lesions. Es molt destacable aquesta darrera possibilitat. De fet la detecció de desequilibris musculars mitjançant dinamometria isocinètica, que poden ser l'avantsala de lesions li donen a la tècnica una validesa predictiva molt interessant. L'aplicació en pacients laborals amb risc de patologia d'extremitat superior podria ser molt vàlida de cara a prevenir lesions tan prevalents com la epicondilitis mitjançant la preparació física i la monitorització de la mateixa.

6.3. Articulació del genoll

El primer article centrat en l'avaluació isocinètica del genoll (Saenz et al., 2010) explora la fiabilitat de la dinamometria isocinètica en l'avaluació de la fatigabilitat de la musculatura flexo-extensora. Els resultats presentats varen mostrar una alta fiabilitat del parametre treball total ("total work") i, per tant, indiquen que la dinamometria pot ser vàlida en l'avaluació d'aquest aspecte del rendiment neuromuscular.

El darrer artícle (Chaler et al., 2001) es tracta d'un descriptiu de pacients laborals intervinguts de ruptura de lligament encreuat anterior que realitzaren la rehabilitació mitjançant l'aplicació d'un protocol accelerat. Aquest protocol havia estat desenvolupat per tractar esportistes. En el present treball es mostren aspectes sobre la seva efectivitat en pacients laborals. Com en el cas dels esportistes, la dinamometria isocinètica mostra la seva validesa en la presa de decisions en el procés de rehabilitació. Específicament, cal destacar la major debilitat d'extensors mesurada per dinamometria isocinètica en pacients que patien com a complicació un dolor anterior del genoll. Això és un signe que pot indicar la validesa de la mesura en la pràctica de la rehabilitació.

Capítol 7

Conclusions

1. El DEC es un paràmetre eficaç per detectar el esforç submàxim de rotadors externs de l'espatlla en subjectes sans (Chaler et al., 2007).
2. El DEC pot ser útil en l'avaluació de la sinceritat de l'esforç de poblacions de pacients amb patologia musculoesquelètica de l'espatlla. No obstant, els valors de referència obtinguts en voluntaris sans poden no ser vàlids i, per tant, es proposen valors calculats a partir de la extremitat no afecta dels pacients. Aquesta aproximació millora la validesa de la prova (Chaler et al., 2013).
3. Les dades de disfunció muscular de l'espatlla de pacients mesurades mitjançant dinamometria isocinètica poden tenir validesa en la presa de decisions clíniques en l'entorn de la rehabilitació laboral (Chaler et al., 2013).
4. En avaluacions isocinètiques de la força muscular de rotadors externs utilitzant un rang articular curt, el DEC pot ser una eina vàlida per analitzar la sinceritat de l'esforç (Pujol et al., 2012).
5. El DEC es un paràmetre vàlid per avaluar la sinceritat de l'esforç durant la realització de proves isocinètiques de flexors dorsals i palmars del canell (Torra et al., 2012).
6. En pacients antics d'epicondilitis, la EMG de superficie de la musculatura de l'avantbraç permet identificar patrons d'activació específics significativament diferenciats de subjectes sans (M. A. Mañanas, Rojas, Mandrile, & Chaler, 2005; Rojas, Mañanas, Müller, & Chaler, 2007).
7. La realització d'una avaluació de força muscular isocinètica a antics pacients d'epicondilitis mostra un desequilibri de la musculatura de l'avantbraç consistent en una debilitat relativa dels músculs flexors dorsals respecte als palmars. Per tant, un desequibri muscular podria predisposar al desenvolupament d'una epicondilitis (Unyó et al., 2012).
8. L'avaluació de la fatigabilitat de musculatura flexoextensora de genoll mitjançant dinamometria isocinètica es fiable (Saenz et al., 2010).
9. Els protocols accelerats de rehabilitació després d'una plàstia de lli-gament encreuat anterior son factibles i eficaces en pacients laborals. Pel que fa a la força muscular, la dinamometria isocinètica es vàlida en la monitorització i avaluació dels resultats finals (Chaler et al., 2001).

Conclusió general: Per avaluar els resultats de la rehabilitació de pacients laborals amb trastorns musculoesquelètics, la dinamometria isocinètica es una eina fiable i vàlida que permet la presa de decisions clíniques i medico-legals. En aquests entorns, on és molt important disposar de mesures per estimar la sinceritat de l'esforç, el DEC representa una bona opció.

Capítol 8

Epíleg

"(...) tot metge ha d'investigar, i no només per descobrir alguna cosa (...) Perquè la investigació ensenya a pensar, i aquesta disciplina millora la flexibilitat cognitiva: la clau de la bona praxis mèdica."

Peter Wagner
President de la Societat Americana de Fisiologia
Editor en cap Journal of Applied Physiology i Journal of Clinical Investigation
Extracte de l'entrevista feta per Lluís Amiguet
Secció "La Contra" del diari La Vanguardia. Dijous 3 de gener de 2013

La frase del Prof. Wagner, que encapçala aquesta secció, la vaig llegir quan estava ordenant totes les idees que he anat desenvolupant en aquest treball. La veritat es que reflexa d'una manera nítida un pensament que tenia i que mai hagués pogut expressar millor. L'activitat de recerca i la pràctica clínica no són dos aspectes excloents sino complementaris i les fites assolides en recerca milloren la pràctica clínica i a l'inrevés. Ho he viscut personalment durant tots aquests anys, mentre pensava com dissenyar, desenvolupar, analitzar, interpretar i escriure treballs cientifics millors, alhora millorava la manera d'afrontar (concretament en el camp de l'avaluació) els pacients que han passat per les nostres mans per rehabilitar-los. En els annexos 1 i 2 es pot veure com ha evolucionat l'informe de valoracions isocinètiques i sinceritat de l'esforç que fem a Egarsat. Es veu com vam començar amb una aproximació amb paràmetres de consistència i hem acabat refiant-nos plenament en paràmetres fisiològics com el DEC. Tot ha estat fruit d'una dedicació, que ha estat esperonada per l'ansia de conèixer, i també per una gran dosi de curiositat en el què està "realment" passant als pacients. Ha estat (i continua essent) una aventura intelectual de primer ordre que en l'entorn en que treballo crec que ha millorat d'una manera molt substancial la pràctica de la meva especialitat: la rehabilitació. Realment, hores d'ara, no em puc imaginar la pràctica de la rehabilitació musculoesquelètica sense la realització de proves biomecàniques en general i dinamomètriques en particular. Es per això que penso que un model de la rehabilitació on les consecucions d'aquesta es vagin avaluant i/o monitoritzant amb tests biomecànics i dinamomètrics hauria de estar generalitzat. Es més, crec fermament que el futur de la meva disciplina passa per aquí: estandaritzar la utilització clínica de les proves biomecàniques. Es per això que la Dra. Garreta i jo ens vam decidir a enviar a publicar una editorial a la revista *Rehabilitación* (Chaler & Garreta, 2010) en que es reivindica aquest model. Estic segur que la implantació de les avaluacions descrites en el present treball i moltes d'altres de l'ambit de la biomecànica revertirien en un enfortiment i millora extraordinaria de la eficàcia i eficiència de la pràctica de la rehabilitació. En definitiva, suposaria una gran millora de l'atenció dels pacients lesionats i/o discapacitats, la missió central de tots els que estem en aquest mon.

Estaria molt satisfet si aquest treball i d'altres com aquest contribuissin ni que fos una mica a la progressió d'aquesta apassionant especialitat: la rehabilitació.

Barcelona, 20 de febrer de 2013

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Annex 1. Primer informe dinamometria isocinètica amb estimació de la sinceritat de l'esforç realitzat a Egarsat

INFORME ISOCINETICOS. Servei de Rehabilitació. Mútua Egara

Fecha informe:	18/12/98
Nombre y apellidos:	
Edad:	52
Sexo:	Varón
Antecedentes laborales:	Operario matadero municipal
Antecedentes patologicos:	Sin interés
Diagnóstico principal	Hombro doloroso en el contexto de cirugía de manguito
Tratamientos ortopédicos/ quirúrgicos:	Intervención sobre hombro derecho el 13/7/98: Acromioplastia, liberación del ligamento acromioclavicular y adherencias de manguito y reparación de supraespinoso.
Médico responsable:	Dr. Alcazar
Articulación evaluada	Ambos hombros (flexoextensión, abducción, adución y rotaciones)
Metodología de evaluación	Se le explica al paciente el cometido de la evaluación isocinética: Analizar la fuerza muscular y sus posibles déficits de una manera objetiva. A continuación se calibra el dinamómetro isocinético (CybexNorm®) delante del paciente y se realiza una exploración física básica del mismo. La prueba consiste en la evaluación del hombro sano y el afecto en los tres ejes más arriba indicados mediante el dinamómetro. El protocolo de evaluación es el descrito por Mayer y cols. (1994)[1]. En todas las exploraciones se hacen 3 series:

1ª. 6 repeticiones de calentamiento a 60º/seg.

2ª. 5 repeticiones a 60º/seg

3º. 5 repeticiones a 180º/seg

(entre cada una de las repeticiones se deja 1 min de descanso)

(Todas la mediciones se han hecho en el modo concéntrico dado que es el modo en que se registra menos variabilidad en el test re-test)

(Los sets que se evaluan para el análisis son los dos últimos)

La Abducción-adducción ha sido explorada con el paciente en sedestación con un rango articular 180º-20º; la flexo-extensión con el paciente en decúbito supino en el rango articular 180º-20º; las rotaciones en 60º-0-40º (en este caso la rotación externa se ha tenido que limitar a 40º por dolor). El posicionamiento del paciente se realizó siguiendo los estándares marcados por la casa comercial..

De esta manera han estado evaluados los dos hombros para poder determinar el déficit. Con el objeto de evaluar posibles inconsistencias en el esfuerzo realizado se ha realizado la exploración completa de los dos hombros dos veces dejando 30 min de descanso entre ellas.

Resultados:

- **Exploración básica:** Punto doloroso a la palpación de troquíter

  No atrofias evidentes

  Cicatrices quirúrgicas a nivel de cara lateral de hombro

  Balance articular:

  Elevación 140

  Rot externa 65

  Rot interna L1

  Balance muscular: FLEX 4/5; ABD 4-/5; RE 4/5

- **Actitud** El paciente se ha mostrado colaborador a lo largo de la exploración.

- **Media de los parámetros más relevantes**

	S1[2]	S2[3]	A1[4]	A2[5]	S1/2[6]	A1/2[7]	S/A[8]
Peak Torque FLEX 60º/seg	**59**	**48**	**35**	**34**	**-18%**	**-2%**	**-68%**
Angulo	45	38	44	99	-16%	+66%	/
Peak Torque EXT 60º/seg	**54**	**50**	**44**	**43**	**-7%**	**-2%**	**-22%**
Angulo	104	100	71	60	-4%	-18%	/
Peak Torque FLEX 180º/seg	**265**	**46**	**34**	**23**	**-476%**	**-32%**	**-679%**
Angulo	8	94	27	49	+1075%	81%	/
Peak Torque EXT 180º/seg	**188**	**39**	**32**	**25**	**-382%**	**-21%**	**-487%**
Angulo	186	101	187	25	-84%	-648%	/
Peak Torque ABD 60º/seg	**62**	**54**	**48**	**43**	**-14%**	**-10%**	**-29%**
Angulo	34	32	36	35	-6%	-2%	/
Peak Torque ADD 60º/seg	**51**	**62**	**28**	**31**	**+21%**	**+10%**	**-100%**
Angulo	117	146	47	59	+25%	+25%	/
Peak Torque ABD 180º/seg	**39**	**53**	**40**	**36**	**+35%**	**-10%**	**-47%**
Angulo	47	54	35	34	+14%	-3%	/
Peak Torque ADD 180º/seg	**155**	**52**	**0**	**6**	**-198%**	**-**	**-766%**
Angulo	136	115	0	82	-16%	-	/

	S1[9]	S2[10]	A1[11]	A2[12]	S1/2[13]	A1/2[14]	S/A[15]
Peak Torque RE 60°/seg	**20**	**19**	**8**	**8**	**-5%**	**0%**	**-150%**
Angulo	84	87	74	52	+3%	-30%	/
Peak Torque RI 60°/seg	**32**	**34**	**25**	**25**	**+6%**	**0%**	**-28%**
Angulo	19	78	12	13	+310%	+8%	/
Peak Torque RE 180°/seg	**12**	**12**	**3**	**3**	**0**	**0**	**-300%**
Angulo	73	76	8	34	+4%	+325%	/
Peak Torque RI 180°/seg	**20**	**24**	**11**	**10**	**+20%**	**-9%**	**-81%**
Angulo	63	78	31	92	+23%	+196%	/

Comentario:

La valoración de los resultados la realizamos tomando como base los índices de variabilidad para mediciones concéntricas establecidos por Meyer y cols. Los valores de variabilidad por debajo de estos no se pueden considerar como significativos:

Flexión: 19%

Extensión: 18.3%

Abducción: 16.6%

Adducción: 18.2%

Rotación externa: 18.4%

Rotación interna: 20.6%

En lo que respecta al ángulo en que se alcanza el peak torque máximo, la variabilidad es más importante, con lo cual se interpreta que no es una medida tan útil. Sólo se dispone de los valores guía para:

Flexión: 41.1%

Extensión: 30.7%

Abducción: 39.7%

Adducción: 36.1%

Si analizamos los valores de la variabilidad en % del Peak torque entre la primera y segunda pruebas observamos que en 7 ocasiones (en rojo) sobre 23 (hemos descartado la medicion que compara la ADD a 180º por ser imposible calcular un %) aparecen valores superiores a los de referencia. Al analizar estos valores se observa que hay una concentración de disparidad entre las medidas sucesivas del peak torque en FLEX/EXT a 180º/s. El resto de los valores dispares en relación a los valores de referencia se dan exclusivamente en el hombro sano en las medidas de ADD/ABD. la relación test-retest de las mediciones realizadas en el hombro afecto han sido consistentes en todos los casos valorables excepto en la prueba ya mencionada de FLEX/EXT a 180º/s. Es especialmente remarcable la consistencia plena de todos los valores obtenidos en RE/RI.

La variabilidad de los ángulos está, en los casos valorables, mayoritariamente dentro de los rangos de referencia excepto en cinco ocasiones: La FLEX/EXT a 180º/s en todos las mediciones y la FLEX del hombro afecto a 60º/s.

Se aprecia una disminución del Peak torque al comparar la extremidad sana y la afecta en todas las mediciones realizadas. La FLEX y RE están más afectadas que la EXTy RI. Paradógicamente, teniendo en cuenta la patología del paciente, se da una disminución más importante de la fuerza de ADD que la de ABD.

La observación de las gráficas a tiempo real, en que se observan las 5 repeticiones, muestran en la mayoría de los casos trazados en gran medida homogeneos.

En resumen, considerando las mediciones de Peak Torque y ángulos hemos observado variabilidades por encima del los rangos de referencia en el 26% de los casos. Dentro de estos, en el 67% de los casos (8/12) ha acontecido en las mediciones sobre FLEX/EXT a 180º/s. El resto de variaciones relevantes se dan en el hombro sano. Este hecho lo interpretamos como una mala adaptación del paciente a esta particular velocidad angular y plano de movimiento (FLEX/EXT a 180º/s), por tanto la consideramos no valorable. Las variaciones entre el hombro sano y el patológico són constantes (en el sentido de desarrollar un menor peak torque en el afecto) y las consideramos especialmente relevantes en el caso de la RE/RI dado el alto grado de consistencia en las mediciones realizadas en esta posición. No encontramos explicación a los peores resultados de la ADD respecto a la ABD

Tanto por la actitud del paciente como por los resultados, con la salvedad del tema ABD/ADD, no podemos concluir de una manera rotunda que ha habido poca colaboración.

En este contexto y en relación con su actividad laboral consideramos que puede realizar esfuerzos de una manera segura siempre que no supongan la elevación del brazo por encima del nivel del hombro.

Fecha y firma:

R. Garreta J. Chaler

Nota: Adjuntamos los datos de calibración del dinamómetro, los "reports" realizados por el software y las gráficas en tiempo real.

[1] Mayer F, Hortsmann T, Kranenberg U, Röcker K, Dickhuth HH. Reproducibility of Isokinetic Peak Torque and Angle at Peak Torque in the Shoulder Joint. Int J Sports Med. 15 S26-S31. 1994.

[2] Primera prueba en extremidad sana

[3] Segunda prueba en extremidad sana

[4] Primera prueba en extremidad afecta

[5] Segunda prueba en extremidad afecta

[6] Incremento entre la primera y segunda prueba en extremidad sana

[7] Incremento entre la primera y segunda prueba en extremidad afecta

[8] diferencias en % entre la extremidad sana y la afecta

[9] Primera prueba en extremidad sana

[10] Segunda prueba en extremidad sana

[11] Primera prueba en extremidad afecta

[12] Segunda prueba en extremidad afecta

[13] Incremento entre la primera y segunda prueba en extremidad sana

[14] Incremento entre la primera y segunda prueba en extremidad afecta

[15] diferencias en % entre la extremidad sana y la afecta

Annex 2. Informe dinamometria isocinètica amb estimació de la sinceritat de l’esforç actual realitzat a Egarsat

egarsat MATEPSS Nº 276 | suma intermutual

Informe mèdic

Nom	**Nº Expedient**
	CP 2012-8686

INFORME DINAMOMETRIA ISOCINÈTICA FLEXO-EXTENSORS DE ESPATLLA

Pacient de 31 a intervinguda de tenotomia de PLB el 9/5/12. Remesa per valoració dinamomètrica al final de tractament rehabilitador.

Troballes:

Es registren uns DEC de flexors dins els rangs considerats com indicatius de bona col·laboració en la realització de la prova (veure taula 4). En aquests context es poden valorar els dèficits de força registrats en la mesura (veure taula1). Els dèficits registrats son en tots els casos lleus, es a dir, inferiors la 40%.

Conclusions:

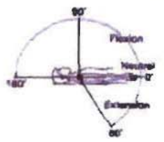
En un context de bona col·laboració es registren deficits de força de flexors i extensors de l'espatlla afecta lleus.

Dra. Roser Garreta Figuera
Col. 16.242
Cap de Servei de Rehabilitació

Dr.: JOAQUIM CHALER VILASECA
Medicina Física i Rehabilitació
Nº Col. 08-27522-8
dilluns, 8 octubre 2012

RHB - Biomecànica aplicada

Test isocinètic de flexió/extensió d'espatlla



Sexe: Dona

Nº de contingència: 12 / 8686

Dia de la prova: 05/10/2012

Prova realitzada per: J. Chaler

Exploració

A l'exploració física destaca un BA simètric. La pacient refereix dolor a la palpació de corredera bicipital esquerre i no hi ha signes d'afectació de supraespinós

Resultats

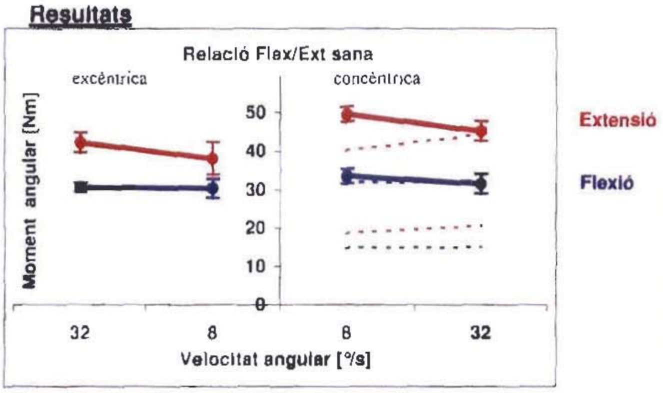


Figura 1

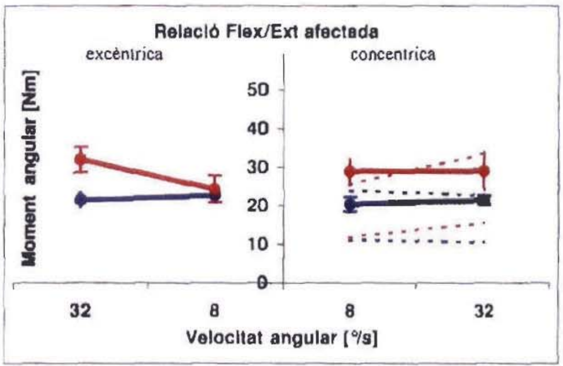


Figura 2

Taula 1: Valor "Peak torque" i Dèficits

	PT sana	PT afectada	Dèficit
FL con 8º/s	33,6	20,4	39%
EX con 8º/s	49,7	29,1	41%
FL exc 8º/s	30,4	22,7	25%
EX exc 8º/s	38,2	24,3	36%
FL con 32º/s	31,6	21,5	32%
EX con 32º/s	45,3	29,2	35%
FL exc 32º/s	30,6	21,6	30%
EX exc 32º/s	42,3	32,0	24%
Mitjana Dèficit FL concèntric:			36%
Mitjana Dèficit FL excèntric:			27%
Mitjana Dèficit EX concèntric:			38%
Mitjana Dèficit EX excèntric:			30%

Taula 2: Rati FL/EX

	sana	afectada	Normal
Con 8º/s	0,68	0,70	
Con 32º/s	0,70	0,73	
Exc 8º/s	0,80	0,93	
Exc 32º/s	0,72	0,67	

Taula 3: Rati excèntric/concèntric

	sana	afectada
FL 8º/s	0,90	1,11
FL 32º/s	0,97	1,00
EX 8º/s	0,77	0,84
EX 32º/s	0,93	1,10
FL exc/EX con 8º/s	0,61	0,78
FL exc/EX con 32º/s	0,68	0,74
EX exc/FL con 8º/s	1,14	1,19
EX exc/FL con32º/s	1,34	1,49

Taula 4: DEC

	sana	afectada
DEC FL:	0,06	-0,11

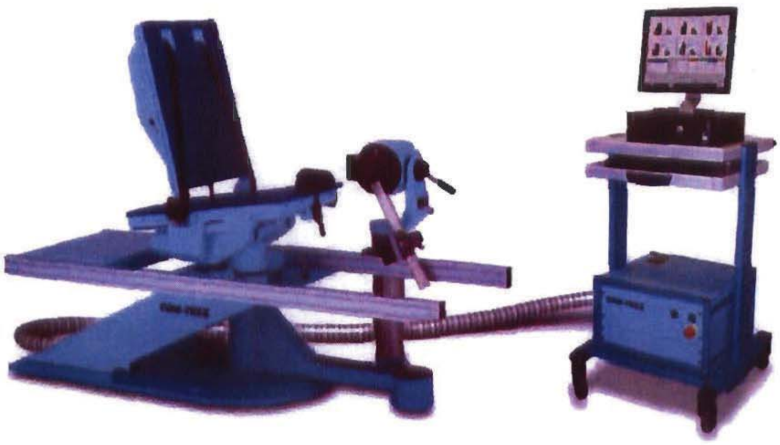
Incidències en la prova:

Cap

METODOLOGIA AMB SISTEMA CON-TREX

Descripció de l'equipament

La exploració es realitza amb dinamòmetre isocinètic CONTREX



Calibratge

El dinamòmetre es precalibrat i s'adjunten dades de la calibració a l'annex 3.

Obtenció de consentiment informat del pacient

S'explica al pacient l'objectiu de la prova i en què consisteix assegurant que ho enten. Igualment se li comenten els possibles efectes secondaris. Al mateix temps s'interroga el pacient i es revisa la història per detectar possibles contraindicacions de la realització de la prova. Finalment se li fa signar un full de consentiment informat que s'adjunta a l'annex 2.

Descripció del protocol (Dvir et al, 2002)

Es realtiza l'avaluació dinamomètrica dels flexo-extensors de l'espatlla en un recorregut reduit a 16° (de 82° a 98° de flexió) a 8°/ s i 32°/s en modalitat concèntrica i excèntrica (4 repeticions de cada modalitat i velocitat de contracció). A partir de les mitjanes de les 4 medicions de les dues extremitats es calculen els ratis excèntric/concèntric i el DEC (diferència entre el rati excèntric/concèntric a velocitat alta i l' obtingut a velocitat baixa) per tal d'estimar la col·laboració en la realització d'esforç de flexió.

Finalment es calculen els dèficits de força de l'afectada respecte a la sana.

Paràmetres avaluats i perquè

El PT (peak torque o moment de força pic) es el paràmetre fonamental d'avaluació de la força muscular isocinética i es el valor a partir del qual es fan tota la resta de càlculs (*Dvir, 2004*). De fet l'objectiu central de al prova es registrar els PT de l'extremitat afecta i establir un dèficit en comparar-los amb la sana (o amb dades normatives en el seu defecte).

En les proves dinàmiques, estimar o establir d'una manera fiable el nivell de col·laboració durant la realització de les mateixes es fonamental per garantir la veracitat de tota la prova. El DEC es un paràmetre proposat per Dvir (*Dvir, 2004*) per tal d'estimar el nivell de col·laboració en les valoracions amb dinamometria isocinètica.. La seva validesa ha estat establerta en l'avaluació de la força muscular de diferents articulacions i accions. Entre elles la valoració de la força muscular dels flexo extensors d'espatlla (*Dvir et al, 2002*). Cal remarcar que la determinació de la validesa del DEC en l'avaluació del nivell de col·laboració en realitzar un test isocinètic de flexo extensors ha estat realitzada en un dinamòmetre Kin Com. Per tant, si s'aplica el protocol en un altre dinamòmetre (com el Con-Trex), la utilització dels nivells de tall proposats te menys fiabilitat.

En alguns casos valorem els ratis agonista/antagonista que ens permeten acabar de definir-los clínicament. No obstant, no tenim referències fiables pel que fa a aquest punt.

Finalment, en casos d'afectació bilateral comparem amb precaució els registres de PT amb dades normatives publicades previament (*Dvir et al, 2002*). En aquest punt, es important tenir en compte que normalment aquestes dades normatives no es poden assumir com perfectament vàlides per la nostra població i mètode d'avalució i que estan realitzades en homes. Per tant la comparació es purament orientativa.

Processament de les dades

A partir de les mitjanes de les 4 medicions de peak torque (els registres s'adjunten a l'annex 1) de les dues extremitats es calculen els ratis excèntric/concèntric i el DEC (diferència entre el rati excèntric/concèntric a velocitat alta i l' obtingut a velocitat baixa) per tal d'estimar la col·laboració.

A continuació, es calculen els dèficits de força de l'afectada respecte a la sana aplicant la següent fòrmula:

$$\text{Déficit} = 1 - \frac{\text{PT afecta}}{\text{PT sana}} \times 100$$

PT= moment de força pic promig

Així els deficits obtinguts s'expressen en %.

Finalment es calculen els ratis agonista (RE) / antagonista (RI) per cada velocitat i modalitat de contracció.

Criteris

Un DEC > 0.36 és indicatiu de manca de col·laboració en la realització de l'esforç de flexió amb un nivell de confiança del 95% (*Dvir, 2002*)

Els dèficits > 20% es consideren rellevants: fins el 40% lleus, >40% moderats i >60% severs (*Dvir, 2004*).

Bibliografia

- Dvir Z, Steinfeld-Cohen Y, Chava P,. Identification of feigned Shoulder flexion weakness in normal subjects. Am J Phys Med Rehabil 2002 81: 187-193
- Dvir. Z. Medicolegal applications. En: Z. Dvir, Isokinetics: Muscle Testing, Interpretation and Clinical Application, Churchill Livingstone, London, 2004.

ANNEX 1

Dades registrades per l'aparell.

Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

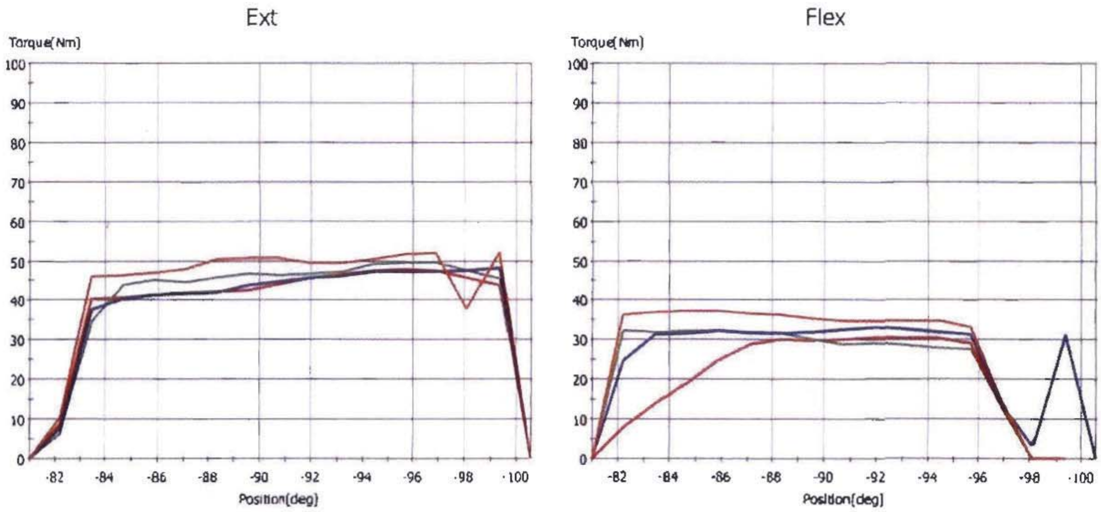
12/8686

1 05/10/2012 12:45:30 Right Shoulder Ext/Flex Isokinetic classic Con/Con 8/8 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

2 05/10/2012 12:44:33 Right Shoulder Ext/Flex Isokinetic classic Con/Con 8/8 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

3 05/10/2012 12:43:32 Right Shoulder Ext/Flex Isokinetic classic Con/Con 8/8 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

4 05/10/2012 12:42:25 Right Shoulder Ext/Flex Isokinetic classic Con/Con 8/8 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter



Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-81.8	-81.8	-81.8	-81.8
Maximum RoM Flex	[deg]	-97.8	-97.8	-97.8	-97.8
Torque max Ext	[Nm]	48.1	49.8	48.4	52.3
Torque max Flex	[Nm]	-30.8	-32.7	-33.3	-37.5
Torque max aver. Flex/ Ext	[%]	64.1	65.6	68.9	71.7
Torque max aver. Ext/ kg	[Nm/kg]	0.78	0.80	0.78	0.84
Torque max aver. Flex/ kg	[Nm/kg]	-0.50	-0.53	-0.54	-0.60
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	57.4	66.3	71.2	72.5
Peak Power Ext	[W]	6.6	6.9	6.7	7.3
Peak Power Flex	[W]	4.8	4.9	5.2	5.6
Work average Flex/ Ext	[%]	57.2	66.5	70.4	72.1
Work average Ext/ kg	[J/kg]	0.19	0.20	0.19	0.22
Work average Flex/ kg	[J/kg]	0.11	0.13	0.14	0.16
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX human kinetics

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Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

12/8686

1 05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8
12:45:48 Measurement 1 repet. pause 60s, Gravity Correction, Low pass filter

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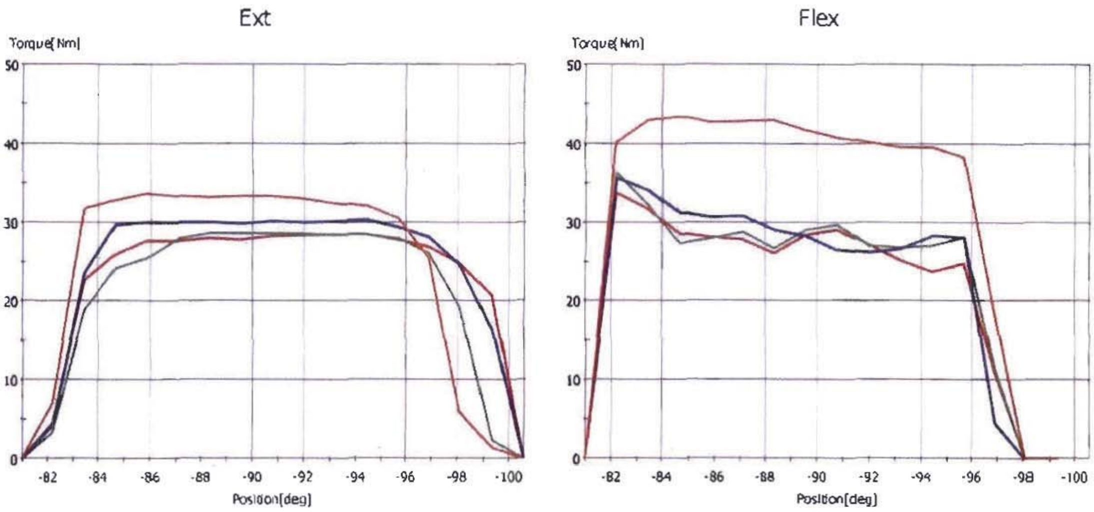
12:44:52 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

3 05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8
12:43:55 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

4 05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8
12:42:47 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter



Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-81.8	-81.8	-81.8	-81.8
Maximum RoM Flex	[deg]	-97.8	-97.8	-97.8	-97.8
Torque max Ext	[Nm]	-28.5	-28.6	-30.6	-33.8
Torque max Flex	[Nm]	34.7	37.3	36.4	44.4
Torque max aver. Flex/ Ext	[%]	121.7	130.3	119.0	131.4
Torque max aver. Ext/ kg	[Nm/kg]	-0.46	-0.46	-0.49	-0.54
Torque max aver. Flex/ kg	[Nm/kg]	0.56	0.60	0.59	0.72
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	110.4	125.5	121.1	153.4
Peak Power Ext	[W]	4.1	4.1	4.4	4.9
Peak Power Flex	[W]	4.2	4.4	4.5	6.2
Work average Flex/ Ext	[%]	108.5	122.6	110.1	149.7
Work average Ext/ kg	[J/kg]	0.11	0.10	0.12	0.12
Work average Flex/ kg	[J/kg]	0.12	0.13	0.13	0.18
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX *human kinetics*

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page 1 / 1

Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

12/8686

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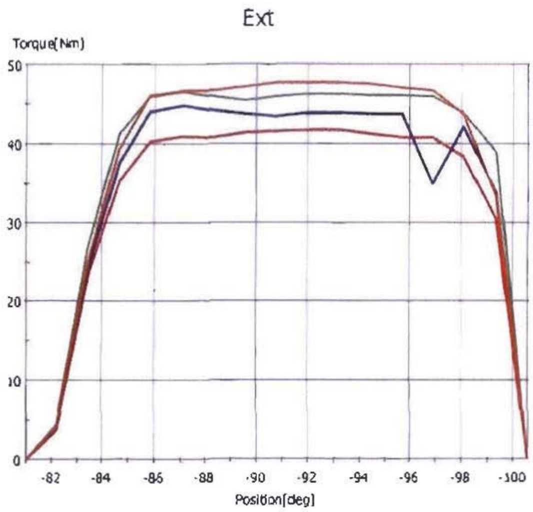
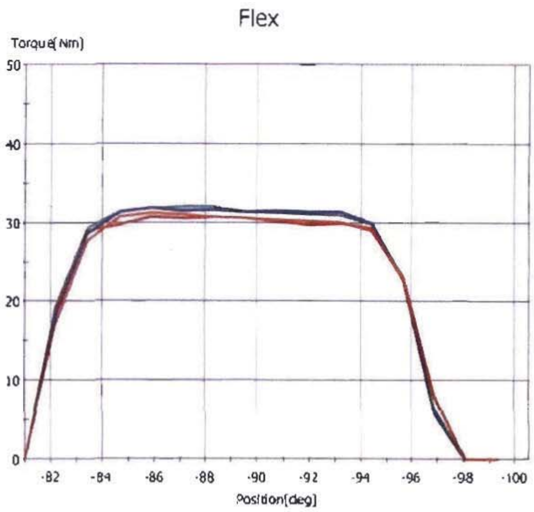
3 — 05/10/2012 12:47:47 Right Shoulder Ext/Flex Isokinetic classic Con/Con 32/32 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

4 — 05/10/2012 12:47:00 Right Shoulder Ext/Flex Isokinetic classic Con/Con 32/32 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter





Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-81.8	-81.8	-81.8	-81.8
Maximum RoM Flex	[deg]	-97.8	-97.8	-97.8	-97.8
Torque max Ext	[Nm]	41.8	46.6	44.9	47.7
Torque max Flex	[Nm]	-30.9	-32.1	-32.1	-31.3
Torque max aver. Flex/ Ext	[%]	74.0	68.7	71.4	65.6
Torque max aver. Ext/ kg	[Nm/kg]	0.67	0.75	0.72	0.77
Torque max aver. Flex/ kg	[Nm/kg]	-0.50	-0.52	-0.52	-0.50
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	72.5	63.4	59.3	66.8
Peak Power Ext	[W]	23.0	25.8	24.8	26.1
Peak Power Flex	[W]	17.2	17.9	18.1	17.4
Work average Flex/ Ext	[%]	75.2	68.2	71.8	66.0
Work average Ext/ kg	[J/kg]	0.16	0.18	0.17	0.18
Work average Flex/ kg	[J/kg]	0.12	0.13	0.12	0.12
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX human kinetics

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Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

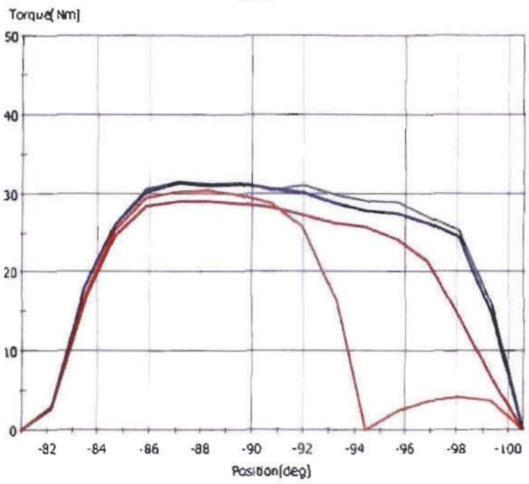
12/8686

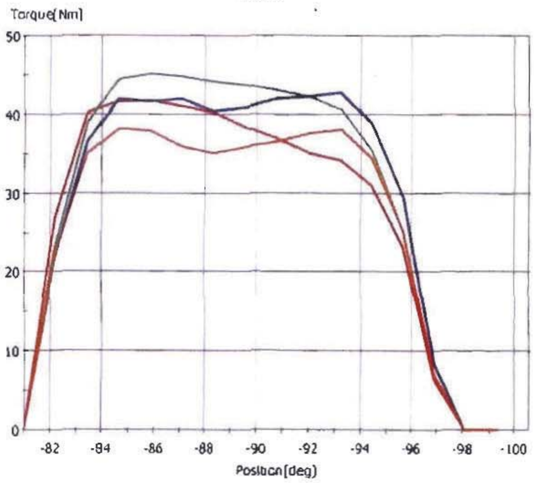
1 05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32
12:49:31 Measurement 1 repet. pause 0s, Gravity Correction, Low pass filter

2 05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32
12:48:46 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32
12:48:01 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

4 05/10/2012 Right Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32
12:47:14 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter





Description	Unit	1	2		4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-81.8	-81.8	-81.8	-81.8
Maximum RoM Flex	[deg]	-97.8	-97.8	-97.8	-97.8
Torque max Ext	[Nm]	-29.1	-31.5	-31.4	-30.4
Torque max Flex	[Nm]	41.9	45.3	42.9	39.0
Torque max aver. Flex/ Ext	[%]	144.1	143.6	136.8	128.4
Torque max aver. Ext/ kg	[Nm/kg]	-0.47	-0.51	-0.51	-0.49
Torque max aver. Flex/ kg	[Nm/kg]	0.68	0.73	0.69	0.63
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	151.4	157.5	150.6	259.7
Peak Power Ext	[W]	16.2	17.5	17.4	15.5
Peak Power Flex	[W]	22.0	24.0	24.0	21.4
Work average Flex/ Ext	[%]	155.8	144.0	145.5	224.0
Work average Ext/ kg	[J/kg]	0.10	0.12	0.11	0.07
Work average Flex/ kg	[J/kg]	0.15	0.17	0.16	0.15
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX *human kinetics*

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Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

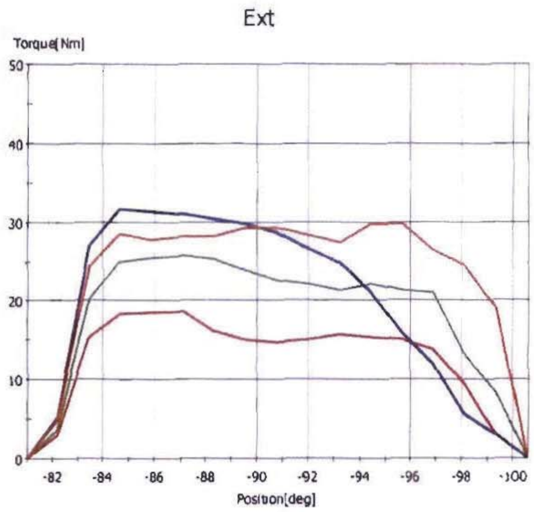
12/8686

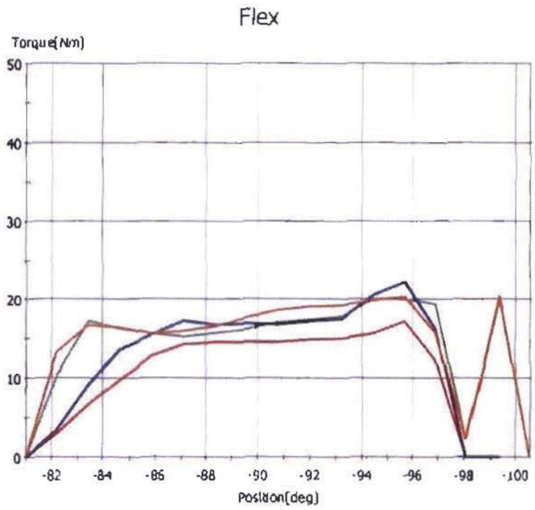
1 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 8/8
12:27:52 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

2 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 8/8
12:26:52 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

3 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 8/8
12:25:54 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

4 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 8/8
12:24:18 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter





Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-82.1	-82.1	-82.1	-82.1
Maximum RoM Flex	[deg]	-98.1	-98.1	-98.1	-98.1
Torque max Ext	[Nm]	18.9	25.7	31.9	29.8
Torque max Flex	[Nm]	-17.9	-20.7	-22.6	-20.5
Torque max aver. Flex/ Ext	[%]	95.1	80.8	71.0	68.9
Torque max aver. Ext/ kg	[Nm/kg]	0.30	0.41	0.51	0.48
Torque max aver. Flex/ kg	[Nm/kg]	-0.29	-0.33	-0.37	-0.33
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	111.5	84.2	67.0	72.4
Peak Power Ext	[W]	3.0	3.9	4.7	4.4
Peak Power Flex	[W]	2.8	3.2	3.5	3.3
Work average Flex/ Ext	[%]	95.5	85.3	75.2	68.2
Work average Ext/ kg	[J/kg]	0.06	0.09	0.09	0.11
Work average Flex/ kg	[J/kg]	0.06	0.07	0.07	0.08
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX human kinetics

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Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

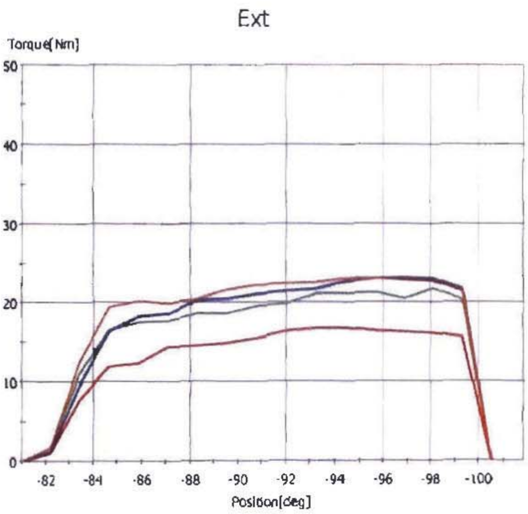
12/8686

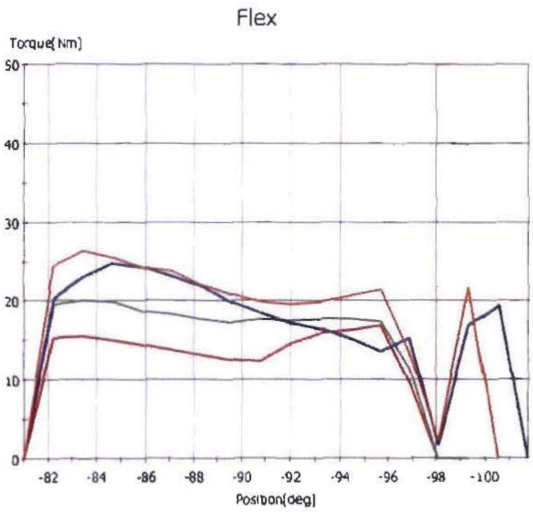
1 — 05/10/2012 12:28:13 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8 Measurement 1 repet. pause 60s, Gravity Correction, Low pass filter

2 — 05/10/2012 12:27:13 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

3 — 05/10/2012 12:26:14 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

4 — 05/10/2012 12:24:39 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 8/8 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter





Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-82.1	-82.1	-82.1	-82.1
Maximum RoM Flex	[deg]	-98.1	-98.1	-98.1	-98.1
Torque max Ext	[Nm]	-16.8	-21.9	-23.2	-23.1
Torque max Flex	[Nm]	17.4	20.4	25.4	27.2
Torque max aver. Flex/ Ext	[%]	103.7	93.0	109.4	117.5
Torque max aver. Ext/ kg	[Nm/kg]	-0.27	-0.35	-0.37	-0.37
Torque max aver. Flex/ kg	[Nm/kg]	0.28	0.33	0.41	0.44
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	98.5	98.1	92.3	109.9
Peak Power Ext	[W]	2.4	3.0	3.3	3.3
Peak Power Flex	[W]	2.5	2.7	3.4	3.5
Work average Flex/ Ext	[%]	98.9	97.8	100.6	106.1
Work average Ext/ kg	[J/kg]	0.06	0.08	0.09	0.09
Work average Flex/ kg	[J/kg]	0.06	0.08	0.09	0.10
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX *human kinetics*

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Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

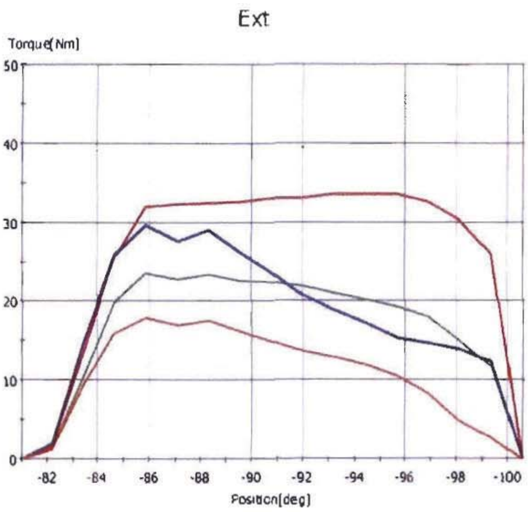
12/8686

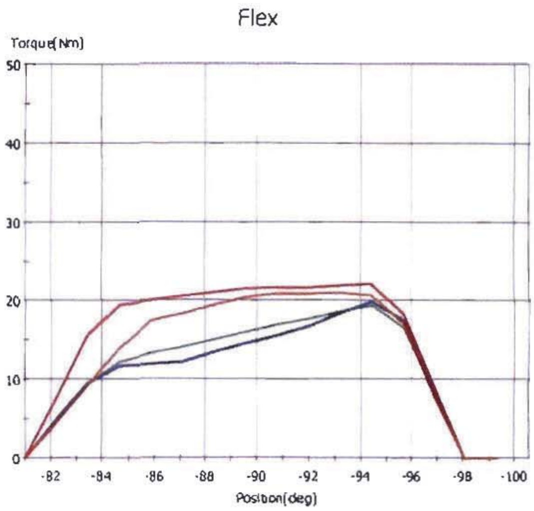
1 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 32/32
12:31:46 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

2 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 32/32
12:31:01 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

3 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 32/32
12:30:15 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter

4 05/10/2012 Left Shoulder Ext/Flex Isokinetic classic Con/Con 32/32
12:29:26 Measurement 1 repet. pause 5s, Gravity Correction, Low pass filter





Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-82.1	-82.1	-82.1	-82.1
Maximum RoM Flex	[deg]	-98.1	-98.1	-98.1	-98.1
Torque max Ext	[Nm]	33.7	24.0	29.9	18.2
Torque max Flex	[Nm]	-22.9	-20.2	-20.9	-21.8
Torque max aver. Flex/ Ext	[%]	68.2	84.4	69.9	119.4
Torque max aver. Ext/ kg	[Nm/kg]	0.54	0.39	0.48	0.29
Torque max aver. Flex/ kg	[Nm/kg]	-0.37	-0.33	-0.34	-0.35
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	63.9	75.8	60.7	160.1
Peak Power Ext	[W]	18.4	13.1	16.5	10.0
Peak Power Flex	[W]	12.6	11.1	11.4	12.2
Work average Flex/ Ext	[%]	64.6	77.3	71.1	144.6
Work average Ext/ kg	[J/kg]	0.13	0.08	0.09	0.05
Work average Flex/ kg	[J/kg]	0.08	0.06	0.06	0.07
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX human kinetics

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Comparison, Speed Controlled

Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

12/8686

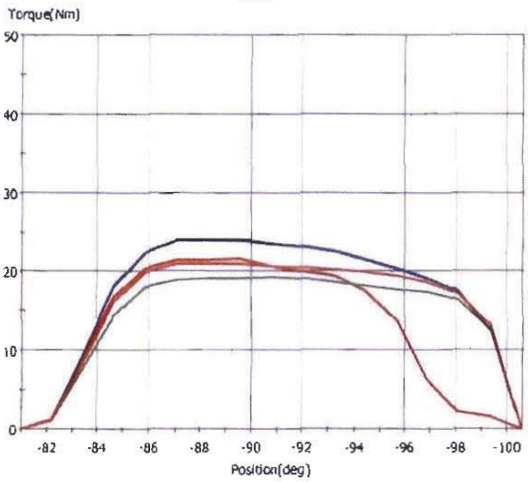
1 05/10/2012 12:32:00 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32 Measurement 1 repet. pause 0s, Gravity Correction, Low pass filter

2 05/10/2012 12:31:14 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

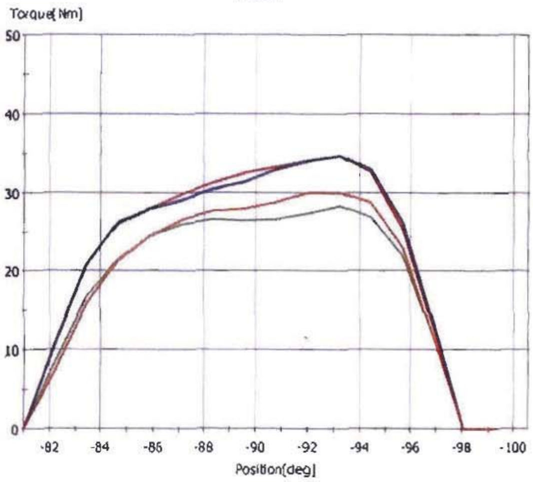
3 05/10/2012 12:30:28 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

4 05/10/2012 12:29:40 Left Shoulder Ext/Flex Isokinetic classic Ecc/Ecc 32/32 Measurement 1 repet. pause 25s, Gravity Correction, Low pass filter

Ext



Flex



Description	Unit	1	2	3	4
Number of repetitions Ext	[n]	1	1	1	1
Maximum RoM Ext	[deg]	-82.1	-82.1	-82.1	-82.1
Maximum RoM Flex	[deg]	-98.1	-98.1	-98.1	-98.1
Torque max Ext	[Nm]	-21.7	-19.3	-24.1	-21.1
Torque max Flex	[Nm]	34.7	28.3	34.9	30.1
Torque max aver. Flex/ Ext	[%]	160.3	146.9	145.1	142.6
Torque max aver. Ext/ kg	[Nm/kg]	-0.35	-0.31	-0.39	-0.34
Torque max aver. Flex/ kg	[Nm/kg]	0.56	0.46	0.56	0.49
Peak Torque Var. Coeff. Ext	[%]	0.00	0.00	0.00	0.00
Peak Torque Var. Coeff. Flex	[%]	0.00	0.00	0.00	0.00
Power average Flex/ Ext	[%]	233.7	124.1	124.5	106.1
Peak Power Ext	[W]	11.7	10.6	13.3	11.7
Peak Power Flex	[W]	19.3	15.7	19.4	16.7
Work average Flex/ Ext	[%]	196.8	141.9	143.8	135.2
Work average Ext/ kg	[J/kg]	0.06	0.07	0.08	0.08
Work average Flex/ kg	[J/kg]	0.12	0.10	0.12	0.10
Work fatigue Ext	[J/s]	0.00	0.00	0.00	0.00
Work fatigue Flex	[J/s]	0.00	0.00	0.00	0.00

CON-TREX *human kinetics*

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ANNEX 2

Consentiment informat signat pel pacient.

HOJA DE CONSENTIMIENTO INFORMADO

Sr./Sra.... ....con DNI 46.7.8.91 56 V

El Dr./Dra. J. Casado......................................del Servicio de Medicina Física y Rehabilitación, me propone el procedimiento de evaluación pericial consistente en:

- ☒ Estudio de la fuerza muscular con dinamometría isocinética, de extremidades y/o columna lumbar (Sistema CON-TREX y/o Biodex).
- ☐ Estudio de la fuerza isométrica de prensión (Sistema DEXTER).
- ☐ Estudio isoinercial de la columna lumbar (Sistema B-200).
- ☐ Análisis cinemático y cinético del movimiento (Sistema CODA).
- ☐ Anàlisis de la presión plantar (Sistema NOVEL).
- ☐ Anàlisis del equilibrio con plataforma dinámica (Sistema SPS).

Me informan de los posibles riesgos de la prueba y he podido preguntar libremente al respecto, así como solicitar ampliación de esta información en cualquier momento. Para que las pruebas sean fiables, debo colaborar al máximo, y que el nivel de colaboración es uno de los parámetros que se valoran durante la prueba.

Considero satisfactoria la información recibida y otorgo mi consentimiento.

Terrassa......5...... de...octubre...............de 2012

Firma del médico

Firma del paciente

ANNEX 3

Registres de dades de calibració i especificacions tècniques aparell.

Standard calibration to 500 [Nm]

Date	28/06/2012	Mech. Module	MJ Mk2	Adapter	Rotational Long
Time	11:49:55	-Serial Number	05402	-Serial Number	5038/1027
Location	Mutua EGARA - Terras:	Power Module	PM-2Mk2i	Weight Set	Cal.Standard 5-5-10-1(
Tester	Manel Marin	-Serial Number	05402		

Weight Stones	50	50	100	100
Serial Numbers	9003	9004	9013	9014

Calibration

Positive Load [V]

	Actual	Nominal
Adapter	0.240	0.242
300 [Nm]	6.242	6.241

Negative Load [V]

	Actual	Nominal
-Adapter	-0.244	-0.248
-300 [Nm]	-6.241	-6.250

Optimization [V]

	Actual	Nominal
Offset	-0.004	0.000
Symmetry	-6.241	-6.243

Previous Calibration

Date	Offset [V]	Adapter [V]	Max [V]
28/06/2012	0.000	0.195	6.209
28/06/2012	-0.040	0.201	6.211

Change from the Last Validation

	28/06/2012	28/06/2012	difference
Slope [mV/Nm]	0.000	20.031	20.031
Offset [V]	0.000	-0.040	-0.040

CON-TREX ***human kinetics***

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CON-TREX
Biomechanical Test- and Training Systems
ACCEPTANCE TEST REPORT

Standard calibration to 500 [Nm]

Date	28/06/2012	Mech. Module	MJ Mk2	Adapter	Rotational Long
Time	12:01:28	-Serial Number	05402	-Serial Number	5038/1027
Location	Mutua EGARA - Terras:	Power Module	PM-2Mk2i	Weight Set	Cal.Standard 5-5-10-1(
Tester	Manel Marin	-Serial Number	05402		

Weight Stones	50	50	100	100
Serial Numbers	9003	9004	9013	9014

Calibration

Date: 28/06/2012, Time: 11:49:55

Positive Load [V]

	Actual	Nominal
Adapter	0.240	0.242
300 [Nm]	6.242	6.241

Negative Load [V]

	Actual	Nominal
-Adapter	-0.244	-0.248
-300 [Nm]	-6.241	-6.250

Optimization [V]

	Actual	Nominal
Offset	-0.004	0.000
Symmetry	-6.241	-6.243

Validation Measured Values

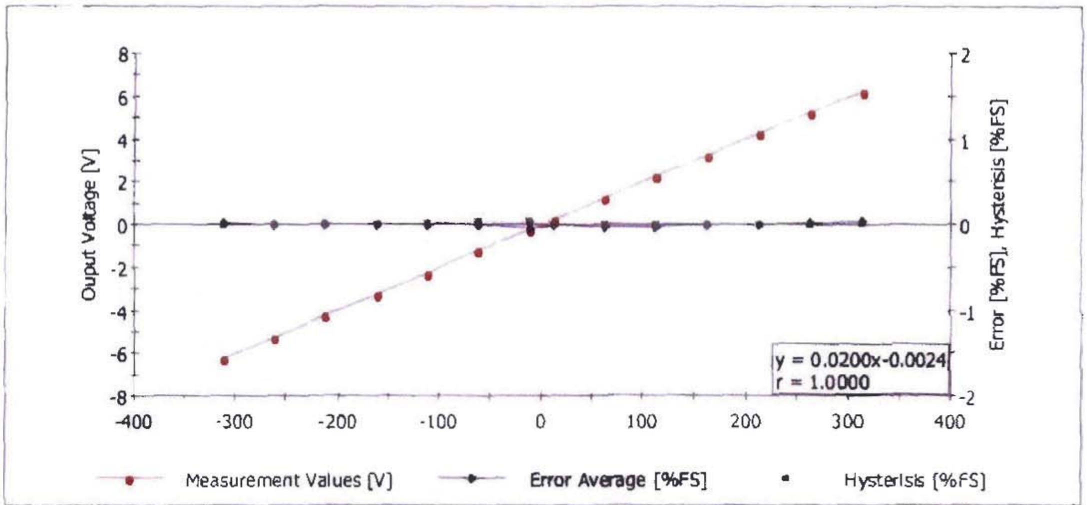
Positive Load [V]

Load	Increase	Decrease	Deviation	Hysteresis
0 [Nm]	0.242	0.242	-0.004	0.000
50 [Nm]	1.241	1.241	-0.005	0.000
100 [Nm]	2.241	2.241	-0.005	0.000
150 [Nm]	3.242	3.242	-0.004	0.001
200 [Nm]	4.243	4.243	-0.003	0.001
250 [Nm]	5.244	5.245	-0.001	0.001
300 [Nm]	6.245	6.247	0.000	0.001

Negative Load [V]

Load	Increase	Decrease	Deviation	Hysteresis
0 [Nm]	-0.249	-0.244	0.000	0.005
-50 [Nm]	-1.246	-1.241	0.003	0.005
-100 [Nm]	-2.244	-2.242	0.003	0.002
-150 [Nm]	-3.243	-3.243	0.003	0.000
-200 [Nm]	-4.242	-4.242	0.004	0.000
-250 [Nm]	-5.242	-5.242	0.004	0.000
-300 [Nm]	-6.241	-6.241	0.005	0.001

Output Voltage / Load



1 [%FS] corresponds to 0.1 [V] and 5 [Nm].
Specified error for MJ Mk2 is 0.5 [%FS], which corresponds to 2.5 Nm.

CON-TREX human kinetics

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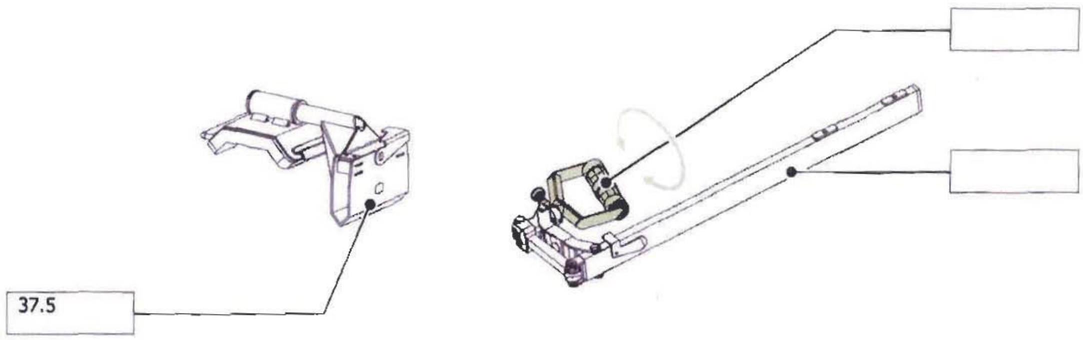
System Scales

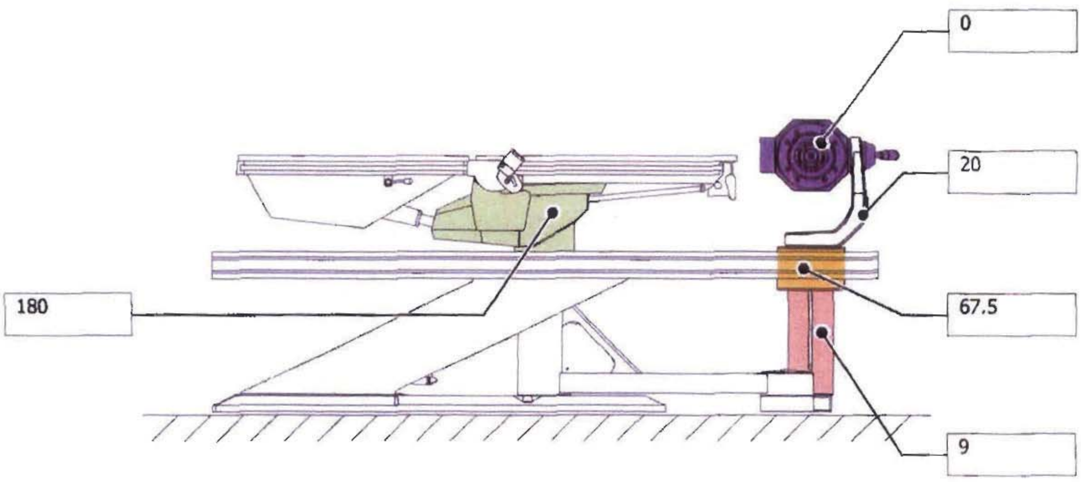
Con-Trex MJ, human kinetics 1.7.3 Filter V 1.7.3

Left Shoulder Ext/Flex Isokinetic classic Con/Con 8/8 — 05/10/2012

ID code	12/8686	Birth date	11/10/1980	Involved Side	left
Last Name		Sex	Female	Injury Date	//
First Names		Weight (kg)	62	Surgery Date	//
Street		Height (cm)	154	Diagnosis	
City		Sports activity	no sports		
Zip		Activity type	aerobic	Doctor	
Tel. Private		Sports		Operator	Pacients
Tel. Business				Insurance	

Memo





CON-TREX *human kinetics*

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