Ayala, F.; Sainz de Baranda, P.; De Ste Croix, M. y Santonja, F. (2013) Fiabilidad absoluta de las medidas isocinéticas para estimar la función muscular / Absolute reliability of isokinetic measurements for estimating muscle function. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 13 (52) pp. 799-830. Http://cdeporte.rediris.es/revista/revista52/artfiabilidad407.htm

REVISIÓN / REVIEW

ABSOLUTE RELIABILITY OF ISOKINETIC MEASUREMENT FOR ESTIMATING MUSCLE FUNCTION

FIABILIDAD ABSOLUTA DE LAS MEDIDAS ISOCINÉTICAS PARA ESTIMAR LA FUNCIÓN MUSCULAR

Ayala, F[1]; Sainz de Baranda, P[2]; De Ste Croix, M.[3] & Santonja, F.[4]

1. Doctor in Sport Sciences and Physical Activity. Sports Research Centre, Miguel Hernandez University of Elche (Spain). ISEN university formation, centre affiliated to the University of Murcia (Spain). fayala@umh.es
2. Doctor in Sport Sciences and Physical Education. Faculty of Sports and Physical Activity Sciences. University of Murcia (Murcia, Spain). psainzdebaranda@gmail.com
3. Doctor in Sport Sciences and Physical Education. Faculty of Sports, Health and Social Care. University of Gloucestershire, Gloucester (United Kingdom). Mdestecroix@glos.ac.uk
4. Doctor in Medicine and Surgery. Faculty of Medicine, University of Murcia. Department of Traumatology, V. de la Arrixaca University Hospital, Murcia (Spain). fernando@santonjatrauma.es

Acknowledgements

“This publication was made possible by the Program of Human Resources Formation for Science and Technology grant number 06862/FPI/2007 from the Seneca Foundation under PCTRM 2007–2010 programme, with INFO and FEDER funding up to 80%.”

Spanish-English translator: Ana Casimiro, e-mail: anacasimiro.trad@gmail.com

Código UNESCO / UNESCO Code: 5899 Educación Física y Deporte / Physical Education and Sports
Clasificación Consejo de Europa / Council of Europe Classification: 11. Medicina del Deporte / Sports Medicine

Recibido 21 de julio de 2011 **Received** July 21, 2011
Aceptado 13 de octubre de 2013 **Accepted** October 13, 2013

ABSTRACT

The main purpose of this systematic literature review was to analyse and compare the absolute reliability of the most common isokinetic indexes used in clinical and sporting contexts for estimating the muscle function of the knee flexion and extension movements (peak torque [PT], angle of peak torque [A-PT], average power [AP] and total work [TW]). A total of 20 research studies were analysed after meeting all the inclusion criteria previously established. The results show that the isokinetic indexes PT, PM and TW appear to present moderate absolute reliability scores, while the results for the A-PT are contradictory. More research studies are necessary that analyse the absolute reliability of the most common isokinetic indexes, specially of the A-PT, throughout testing procedures that use high angular velocities, eccentric movements and different testing positions (seated, lying prone and lying supine).

KEY WORDS: peak torque, inter-session variability, reproducibility, measurement error, isokinetic assessment

RESUMEN

El objetivo principal de esta revisión de la literatura fue analizar y comparar la fiabilidad absoluta de los índices isocinéticos más empleados en el ámbito clínico y deportivo para la estimación de la función muscular de los movimientos de flexión y extensión de rodilla (momento de fuerza máxima [PFM], ángulo de fuerza máxima [A-PFM], potencia media [PM] y trabajo total [TrT]). Un total de 20 estudios científicos fueron analizados tras cumplir con todos los criterios de inclusión previamente establecidos. Los resultados muestran que los índices isocinéticos PFM, PM y TrT parecen presentar una moderada fiabilidad absoluta, mientras que son contradictorios los valores obtenidos para el índice A-PFM. Son necesarios más estudios científicos que analicen la fiabilidad absoluta de los principales índices isocinéticos, especialmente el índice A-PFM, a través de procedimientos exploratorios que empleen velocidades angulares altas, movimientos excéntricos y diferentes posiciones de evaluación (sedentación, decúbito prono y decúbito supino).

PALABRAS CLAVE: peak torque, variabilidad inter-sesión, reproducibilidad, error de la medida, evaluación isocinética.

1. INTRODUCTION

In the field of sports medicine and, in particular, in the field of physical and sports rehabilitation, it is very important and requested to have accurate assessment tests to measure the muscle function in order to evaluate the impact of any therapeutic intervention and/or the effect of a training program (Maffiuletti, Bizzini, Desbrosses, Babault & Munzinge, 2007).

With this aim, by the end of 1960, several studies started recommending and using isokinetic dynamometer devices (Hislop & Perrine, 1967; Moffroid, Whipple, Hofkosh, Lowman & Thistle, 1969; Thistle, Hislop, Moffroid & Lowman, 1967). For over three decades they have been considered instruments for standard research or as a criterion to study an isolated muscle group function and, in particular, the muscles in the leg (Brown, 2000; Maffiuletti et al., 2007).

However, the accuracy of isokinetic devices to evaluate muscle function has been approved by clinicians and scientists under theoretic and empirical knowledge, and, to a lesser extent, under the scientific evidence regarding their degree of validity and reliability. Among the great variety of isokinetic strength parameters described within the scientific literature, the peak torque (PT), the angle peak torque (APT), the average power (AP) and the total work (TW) are the most used to evaluate and monitor changes in the muscle function during processes of rehabilitation and/or physical training (Brown, 2000; Yong-Hao Pua, Bryant, Steele, Newton & Wrigley, 2008).

The validity of a measuring instrument may be defined as the degree of accuracy or correlation by which their scores can predict any criterion variable that was chosen previously (gold standard) (Hopkins, 2000). In this context, the scientific literature suggests that the isokinetic strength parameters previously mentioned (mainly PT and AP), measured by knee flexion and extension movements, have moderate degree of correlation to categorize athletes according to their level of performance in several actions such as the following: (a) vertical jump (Ashley & Weiss, 1994); (b) race (Anderson, Gieck, Perrin, Weltman, Rutt & Denegar, 1991); (c) anaerobic capacity (Brown, Whitehurst & Buchalter, 1994); and (d) muscular endurance (Haymes & Dickinson, 1980). At the same time, isokinetic strength parameters seem to have enough sensitivity to differentiate between people with different levels of performance or between roles in team sports (Brown & Wilkinson, 1983; Wrigley, 2000; Yong-Hao et al., 2008).

On the other hand, the concept of reliability refers to the consistency or repeatability of a measure, that is, if the application of an assessment tool reports consistently the same results under the same conditions. In this sense, the most accurate reliability assessment of an instrument or assement procedure is determined when several tests take place in the short term (internal consistency or relative reliability) and for moderate periods of time (absolute stability or reliability), using the traditional test-retest design (Baumgarter, 1989; Hopkins, 2000).

In a practical way, the absolute reliability analysis (measurement reproducibility) presents more interest due to the fact that it will allow the assessment of “real efficacy” (beyond the measurement error due to technical or biological variation) of intervention programs in muscle function level of patients and athletes (Hopkins, 2000). As such, another important use of absolute reliability is the possibility of comparing between different isokinetic devices and even clinicians and researchers could use this information to determine the size of their study samples.

However, as far as the level of absolute reliability of PT, APT, AP and TW isokinetic strength parameters is concerned, there are few scientific studies about it and their results are usually controverted (Dvir, 2004).

It is important to make a critical and exhaustive analysis of the scientific literature which allows the identification of the level of absolute reliability of PT, APT, AP and TW isokinetic strength parameters. These data will allow the assessment of whether an increment in the results obtained compared to the initial baseline values after the application of intervention programs reflect a real change or, on the contrary, they are related to the measurement error.

Therefore, the main aim of this literature review was to analyse and compare the absolute reliability of the isokinetic strength parameters most used in the medical and sports field in order to estimate muscle function of knee flexion and extension movements.

2. METHOD

2.1. Inclusion criteria

The mandatory inclusion criteria established were the following: (a) original articles, doctoral thesis, short communications and abstracts with a link to the full text (free and under registration); (b) written in English, Portuguese or Spanish; (c) must be controlled clinical trial with pre-test and post-test designs which aims were to analyse and/or compare the reliability of PT, APT, AP and TW isokinetic strength parameters obtained under knee flexion and extension movements; (d) made with asymptomatic men and women of all ages and fitness conditions (sedentary people, physically active people, high level athletes); and (e) present an detailed description of their measurement procedures.

2.2. Search strategy

Articles were taken from the most important online databases in the sports and science field, such as Medline, Cochrane Library, ENFISPO, SportsDiscus, Lilacs Teseo, OVID, together with the meta search Google. The key words used were the following: isokinetic test, peak torque, angle of peak torque, total work, average power, pre-test and post-test, reproducibility, absolute reliability, knee flexion, knee extension, measurement error, variability (table 1).

The term “isokinetic test” was always used as a search criterion, so that in several bibliographic searches it was always used in the searching fields while the others were subordinated preceded by the word “and” plus one of the terms mentioned above. There was no limitation regarding the year of publication of the studies. The search ended on February 2011.

Table 1: Data bases and searching strategies followed.

Data base	Seaching strategies	
PubMed	- Isokinetic test	- Absolute reliability
SportsDiscus	- Peak torque	- Reproducibility
OVID	- Angle of peak torque	- Pre-test y post-test
Cochrane Library	- Total work	- Measurement error
Lilacs Teseo	- Average power	- Knee flexion
Google	- Variability	- Knee extension

The titles and abstracts of the articles found through the searching strategy already described were initially analyzed by the only one expert researcher (Doctor in Physical Education and Sport Sciences with more than 10 years’ experience in the research field) in order to determine whether they fulfilled the established inclusion and exclusion criteria. Therefore, titles and abstracts of the articles found were categorized as: (a) apt; (b) doubtful; and (c) unfit. Those articles whose title and abstract did not provide enough information to decide on their selection were read in full in order to categorize them as apt or unfit. When some doubt existed a second expert's opinion was sought. Once the articles had been selected they were obtained in electronic format.

2.3. Data extraction

A list was developed with methodological variables of interest for coaches, physical trainers, clinicians and other members of the physical activity and sports field (table 2). This list was based on the design previously established by Keating and Matyas (1996), where included are aspects such as (a) design type, (b) sample description, (c) preparation of the exploratory test, (d) some aspects during the assessment procedure, (e) statistics used, (f) results (qualitative and quantitative) and (g) conclusions.

Table 2: List of data extraction in the analyzed scientific studies.

Reference
Design
Type (repeated measures, pretest and posttest)
Number of exploratory sessions
Temporary interval between consecutive exploratory sessions (week, days)
Familiarization session (yes/no)
Population
Number
Sex (man/woman)
Age (average and standard deviation)
Level of fitness (sedentary people, physically active people, athletes [indicate the sport discipline])
Exploratory test preparation
Brand and model of the dynamometer device
Procedure to warm-up (yes/no, type and parameters with training load)
Position adopted by the evaluated subject (sitting position, bipedalism, supine position, prone position)
Stabilization
Lining up the joint axis of rotation with the dynamometer axis of rotation
Length of the telescopic boom
Previous training load for activation
Gravity correction method if applied
During the exploratory test
Evaluated leg (both, dominant or non-dominant, right or left) and order (ramdom or not [indicate strategy followed])
Mode (isokinetic [passive, isokinetic, reactive], isomeric, isotonic)
Method for evaluation of muscular contraction (concentric, eccentric or both)
Type of knee joint movement (flexion, extension, both) and mode (simple cycle [concentric/concentric, eccentric/eccentric], compound cycle (concentric
Joint range of motion evaluated
Angular velocity and evaluation order
Periods of rest
Statistical analysis
Type of statistics used in order to express absolute reliability
Strategy for the selection of the final value of the isokinetic strength ratio for statistical analysis (attempts average, best attempt)
Statistical test used to evaluate the inter-session differences (parametric, nonparametric, indicate name)
Others
Results and conclusions
Quantitative (percentage Δ between pretest and posttest in newton • meters)
Qualitative
Author/s considerations
Other comments

All methodological variables of the articles were extracted, registered and analyzed by the same expert researcher. Those articles which did not specify any of the variables above were categorized as “do not inform” but they were not removed from the analysis process. This data extraction process was recommended by “Cochrane Collaboration Back Review Group” in order to make systematic reviews (Van Tulder, Furland, Bombardier & Bouter, 2003).

3. RESULTS

The strategy to search for and select the articles used in this review obtained a total of 30 articles whose titles and abstracts seemed to fulfill the inclusion and exclusion criteria previously established by the authors. Five of the thirty titles and abstracts categorized as “apt” (n=30), could not be obtained in electronic format due to restricted access. Therefore, a final total of 25 electronic articles was obtained. However, a further five of these were dropped either because their methodology was poorly described (n=3), or because their statistical analysis used were hardly described (n=2). As a result, 34 articles were analyzed and included in this review. All the studies analyzed absolute reliability of PT, APT, AP and TW isokinetic strength parameters during knee flexion and extension movements.

4. DISCUSSION

A detailed analysis of the obtained results by diverse scientific studies related to the degree of absolute reliability of PT, APT, AP and TW isokinetic strength parameters during knee flexion and extension movements is now exposed:

4.1. Absolute reliability of the “peak torque” isokinetic strength parameter

This isokinetic strength parameter is the one that has received the most attention by far in the study of its reliability (n=17). Absolute reliability of PT has been determined under concentric and/or eccentric contractions through a great range of angular velocities, such as 60º, 120º and 180º/s (table 3).

If the studies that determine absolute reliability of the PT strength parameter are analyzed using “standard error of measurement” (SEM) (Atkinson and Nevill, 2001) and “typical error of measurement” (TE) (Hopkins, 2000) statistics using percentages, it is possible that this PT presents a moderate-high reliability (defined as SEM and TE < 10% [Hopkins, 2000]), with an average value of intersession variability of 8.2% (Dauty & Rochcongar, 2001; Deighan, De Ste Croix & Armstrong, 2003; Dervisevic, Hadzic, Karpljuk & Radjo, 2006; Impellizzeri, Bizzini, Rampinini, Cereda & Maffiulet, 2008; Li, Wu, Maffulli, Chan & Chan, 1996; Lund et al., 2005; Maffiuletti et al., 2007; McCleary & Andersen, 1992; Pincivero, Lephart & Karunakara, 1997; Sole, Hamrén, Milosavljevic, Nicholson & Sullivan, 2007; Symons, Vandervoort, Rice, Overend & Marsh, 2004), together with a probability level of 68%.

On the other hand, if statistics which reflect an intersession value of variability that include 95% of the cases are used (eg. 95% limits of agreement [95% LoA]; Ratio limits of agreement [RLoA), it is observed that the PT strength parameter presents a value of variability that range from 5.9% to 33.0% (Iga, George, Lees & Reilly. 2006; Impellizzeri et al., 2008; McCleary & Andersen, 1992; Ordway, Hand, Brings & P

Table 3: Studies which determine absolute reliability of the peak torque isokinetic strength ratio chronologically presented

Reference Population	Design Position of the evaluated subject	Exploratory procedure Process to warm-up	Evaluation process	Results
Perrin (1986) M (n = 15) Healthy Young adults	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (not indicated the degree of hip flexion)	- 3 submaximal cycles con/con of KF and KE at 60º/s - 3 maximal cycles con/con of KF and KE at 60º/s - 1 min rest between warm-up and evaluation	- Both legs evaluated - 5 maximal cycles con/con of KE and KF at 60º/s - ROM: not specified - 2 min rest between evaluation of one leg and another	Knee flexion: - Con 60º FR left: 0.83 ICC - Con 60º FR right: 0.92 ICC Knee extension - Con 60º FR left: 0.84 ICC - Con 60º FR right: 0.85 ICC
Tredinnick et al. (1988) M (n = 14) Healthy Young adults	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Supine position (not indicated the degree of hip flexion)	- 4 submaximal con and ecc contr of KE at 60º, 120º and 180º/s - 1 maximal con and ecc contr of KE at 60º, 120º and 180º/s - 2 min rest between warm-up and evaluation	- Right leg evaluated - 3 maximal con and ecc contr of KE at 60º, 120º and 180º/s - ROM: not specified - 5s rest between con and ecc contr - 3 min rest between velocities	Knee flexion - Con a 60º/s: 0.89 ICC - Con a 120º/s: 0.97 ICC - Con a 180º/s: 0.75 ICC - Ecc a 60º/s: 0.47 ICC - Ecc a 120º/s: 0.84 ICC - Ecc a 180º/s: 0.79 ICC
McCleary et al. (1992) M (n = 26) Athletes (22 footballers and 4 swimmers)	- No familiarization session - 3 evaluation sessions - 24 hours between consecutive sessions - Sitting position (not indicated the degree of hip flexion)	- 4 submaximal cycles con/con of KE and KF - 3 maximal cycles con/con of KF and KE - 30s rest between warm-up and evaluation	- Right leg evaluated - Maximal cycles con/con of KE and KF at 60º/s - ROM: 0-90º	Knee flexion - Con 60º/s: 3 SEM[3]; 2.9 %SEM; 5.9 LoA[3] Knee extension - Con 60º/s: 7 SEM[3]; 4.47 %SEM; 13.7 LoA[3]
Arnold et al. (1993) W (n = 25) Healthy Young adults	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (not indicated the degree of hip flexion)	- 3 submaximal con contr of KE - 1 maximal con contr of KE	- 3 maximal con contr of KE at 60º/s - ROM: 0-90º	Knee extension - Con 60º/s en 30º of KE: 5.9 SEM[3]; 0.84 ICC - Con 60º/s en 60º of KE: 7.6 SEM[3]; 0.87 ICC - Con 60º/s en 75º of KE: 7.3 SEM[3]; 0.83 ICC
Li et al. (1996) M (n = 18) W (n = 12) Adultos jóvenes sanos Healthy Young adults	- 1 familiarization session - 2 evaluation sessions - 4-10 days between consecutive sessions - Sitting position with 110º of hip flexion	- 3 min of stretching - 2 submaximal cycles con/ecc - 1 maximal cycle con/ecc	- Both legs evaluated - 5 maximal cycles con/ecc of KE and KF at 60º/s - 5 maximal cycles con/ecc of KE and KF at 120º/s - ROM: is not specified	NS between legs: data show the average between both of them. NS between gender: data express the results of women Knee flexion - Con a 60º/s: 6.3 %diff; 0.82 ICC - Con a 120º/s: 4.5 %diff; 0.90 ICC

			- 2 min rest between velocities - 3 min rest between muscles - 5 min rest between dominant and non-dominant leg	- Ecc a 60º/s: 9.8 %diff; 0.83 ICC - Ecc a 120º/s: 14.4 %diff; 0.84 ICC Knee extension - Con a 60º/s: 6.6 %diff; 0.83 ICC - Con a 120º/s: 11.0 %diff; 0.85 ICC - Ecc a 60º/s: 11.9 %diff; 0.82 ICC - Ecc a 120º/s: 8.9 %diff; 0.83 ICC
Pincivero et al. (1997) M (n = 10) W (n = 11) Healthy Young adults	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (not indicated the degree of hip flexion)	- 5 minutes of bicycle ergometer (60 rpm) - Stretching - 5 submaximal cycles con/con of KF and KE - 2-3 maximal cycles con/con of KF and KE	- Both legs evaluated - 5 maximal cycles con/ecc of KE and KF at 60º/s - 5 maximal cycles con/ecc of KE and KF at 180º/s – ROM: 0-90º	NS between legs: data show the dominant leg Knee flexion - Con 60º/s: 4.9 %SEM; 0.97 ICC - Con 180º/s: 6.1 %SEM; 0.96 ICC Knee extension - Con 60º/s: 4.8 %SEM; 0.97 ICC - Con 180º/s: 5.6 %SEM; 0.96 ICC
Kellis et al. (1999) M (n = 13) Talented adolescent footballers	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position with 110º of hip flexion	- 15 minutes of bicycle ergometer - 3 submaximal cycles con/con and ecc/ecc of KE and KF at 60º, 120º and 180º/s - 1 maximal cycle con/con and ecc/ecc of KF and KE at 60º, 120º and 180º/s	- Both legs evaluated - 5 submaximal cycles con/con and ecc/ecc of KE and KF at 60º, 120º and 180º/s (randomly) for both legs (randomly) - ROM: 0-90º - 5 min rest between velocities - 10 min rest between evaluation of one leg and another	NS between legs: data show the dominant leg Knee flexion - Con 60º/s: -6.1 +1.5 95%LoA; 0.90 ICC - Con 120º/s: -6.1 +1.5 95% LoA; 0.88 ICC - Con 180º/s: -6.6 +0.4 95% LoA; 0.89 ICC - Ecc 60/s: -7.2 +2.9 95% LoA; 0.85 ICC - Ecc 120º/s: -2.6 +10.7 95% LoA; 0.71 ICC - Ecc 180º/s: -4.2 +8.7 95% LoA; 0.76 ICC Knee extension - Con 60º/s: -1.7 +7.2 95% LoA; 0.98 ICC - Con 120º/s: -0.6 +4.7 95% LoA; 0.96 ICC - Con 180º/s: -1.5 +2.3 95% LoA; 0.98 ICC - Ecc 60/s: -0.6 +11.1 95% LoA; 0.92 ICC - Ecc 120º/s: -3.4 +13.1 95% LoA; 0.88 ICC - Ecc 180º/s: -2.4 + 15.2 95% LoA; 0.80 ICC
Dauty et al. (2001) M (n = 10) Volleyball players of national category	- No familiarization session - 2 evaluation sessions - 21 days between consecutive sessions - Sitting position with 85º of hip flexion	- 5 minutes of bicycle ergometer (70 rpm and 5 w) - Stretching	- Right leg evaluated - 5 maximal con contr of KF at 180º/s - 5 maximal ecc contr of KF at 30º/s - 5 maximal ecc contr of KF at 60º/s - ROM: 0-100º - 3 min rest between con and ecc contr	Knee flexion - Con 180º/s: 7 SEM[3]; 5.6 %SEM; 0.94 ICC - Ecc 30º/s: 15 SEM[3]; 8.1 %SEM; 0.86 ICC - Ecc 60º/s: 16 SEM[3]; 8.6 %SEM; 0.83 ICC

			- 1 min rest between ecc contr	
Deighan et al. (2003) M (n = 10) sedentary prepubertal students	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position with 85º of hip flexion	- 3 minutes of bicycle ergometer (moderate intensity) - KF and KE strenching - 3 submaximal con and ecc contr - 1 maximal con/con and ecc/ecc contr	- Right leg evaluated - 3 maximal cycles con/con of KF and KE at 30º and 180º/s (randomly) - 4 maximal cycles ecc/ecc of - ROM: 0-90º for KE and KF con/con cycles. 0-75º for KE and KF ecc/ecc cycles - 2 mis rest between velocities - 3 min rest between modes	Knee flexion - Con 30º/s: 6% CV; 10 SEM[2]; -8 +11 95% LoA - Con 180º/s: 9% CV; 12 SEM[2]; -11 +14 95% LoA - Ecc 30º/s: 10% CV; 17 SEM[2]; -16 +17 95% LoA - Ecc 180º/s: 7% CV; 13 SEM[2]; -14 +13 95% LoA; - Extensión de rodilla - Con 30º/s: 7% CV; 13 SEM[2]; -8 +17 95% LoA - Con 180º/s: 4% CV; 6 SEM[2]; -7 +5 95% LoA - Ecc 30º/s: 9% CV; 24 SEM[2]; -23 +24 95% LoA - Ecc 180º/s: 11% CV; 24 SEM[2]; -27 +21 95% LoA
Symons et al. (2004) W (n = 25) Healthy older adults	- No familiarization session - 2 evaluation sessions - 2-10 days between consecutive sessions	- 5 minutes of bicyvle ergometer (50 rpm) - 3 submaximal contr at 50-60% of MVC	- Both legs evaluated - 5 maximal KE con at 90º/s - 5 maximal KE ecc at 90º/s - ROM: 0-90º - 2 mis rest between contr	NS between legs: data show the dominant leg Knee extension - Con 90º/s: 7.4%ETM; 20.5 RLoA and 0.92 ICC - Ecc 90º/s: 8.2%ETM; 23.0 RLoA and 0.88 ICC
Lund et al. (2005) M (n = 4) W (n = 9) Healthy Young adults	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position with 90º of hip flexion	No information about stretching	- Dominant leg evaluated - 3 maximal KF and KE con at 60º/s - ROM: 0-90º	Knee flexion - Con 60º/s: 6.9 SEM[1]; 8.8 %SEM; 0.91 ICC Knee extension - Con 60º/s: 10.6 SEM[1]; 6.9%SEM; 0.89 ICC
Dervisevic et al. (2006) M (n = 16) Young adult recreational athletes	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (not indicated the degree of hip flexion)	- 5 minutes of bicycle ergometer - 30s of KF and KE strenching - 2 submaximal con and ecc contr of KF and KE - 1 maximal con and ecc contr of KF and KE	- Both legs evaluated Set 1, ROM: 0-90º - 1 maximal con contr of KF and KE at 90º/s - 1 maximal ecc contr of KE at 90º/s - 1 maximal con cntr of KF and KE at 180º/s - 1 maximal ecc contr of KE at 180º/s Set 2, ROM 30-60º - 1 maximal con contr of KF and KE at 30º/s	NS between legs: data show the dominant leg Knee flexion ROM 0-90º - Con 90º/s: 12 SEM[3]; 12.2 %SEM; 0.85 ICC - Con 180º/s: 12.4 SEM[3]; 12.8 %SEM; 0.80 ICC Knee extension ROM 0-90º - Con 90º/s: 15.5 SEM[3]; 10.9 %SEM; 0.82 ICC - Con 180º/s: 12.5 SEM[3]; 10.6 %SEM; 0.84 ICC - Ecc 90º/s: 36.99 SEM[3]; 22.7 %SEM; 0.33 ICC - Ecc 180º/s: 26.3 SEM[3]; 15.7 %SEM; 0.43 ICC Knee flexion ROM 30-60º - Con 30º/s: 10.2 SEM[3]; 10.4 %SEM; 0.85 ICC - Con 60º/s: 6.7 SEM[3]; 7.2 %SEM; 0.92 ICC Knee extension ROM 30-60º

			- 1 maximal ecc contr of KE at 30º/s - 1 maximal con contr of KF and KE at 60º/s - 1 maximal ecc contr of KE at 60º/s - 30 min rest between sets 1 and 2	- Con 30º/s: 14.1 SEM[3]; 10.1 %SEM; 0.82 ICC - Con 60º/s: 10.7 SEM[3]; 8.5 %SEM; 0.89 ICC - Ecc 30º/s: 18.1 SEM[3]; 11.1 %SEM; 0.83 ICC - Ecc 60º/s: 13.8 SEM[3]; 8.4 %SEM; 0.89 ICC
Iga et al. (2006) M (n = 23) Adolescent footballers	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position with 90º of hip flexion	- Bicycle ergometer - Stretching - 3 submaximal cycles con/con and ecc/ecc of KE and KF - 3 maximal cycles con/con and ecc/ecc of KE and KF	- Both legs evaluated - 5 maximal con/con cycles of KE and KF at 60º, 120º and 240º/s - 5 maximal ecc/ecc cycles of KE and KF at 120º/s - ROM: 10-90º - 30s rest between cycles - 1 min rest between velocities	NS between legs: data show the dominant leg Knee flexion - Con 60º/s: 1.05 x/ ÷ 1.18 RLoA[3] - Con 120º/s: 1.07 x/ ÷ 1.17 RLoA[3] - Con 240º/s: 1.03 x/ ÷ 1.22 RLoA[3] - Ecc 120º/s: 1.05 x/ ÷ 1.14 RLoA[3] Knee extension - Con 60º/s: 1.03 x/ ÷ 1.22 RLoA[3] - Con 120º/s: 1.03 x/ ÷ 1.14 RLoA[3] - Con 240º/s: 1.05 x/ ÷ 1.15 RLoA[3] - Ecc 120º/s: 1.05 x/ ÷ 1.16 RLoA[3]
Ordway et al (2006) M (n = 16) W (n = 17) Healthy older adults	- 1 familiarization session - 2 evaluation sessions - 7-10 days between consecutive sessions - Sitting position with 85º of hip flexion	- 3 submaximal cycles con/con of KE and KF	- Dominant leg evaluated - 5 maximal con/con cycles of KF and KE qt 60º and 240º/s - ROM: not specified - 1 min rest between velocities	Knee flexion - Con 60º/s: 33% RLoA - Con 240º/s: 13 95% LoA[3] Knee extension - Con 60º/s: 21% RLoA - Con 240º/s: 7 95% LoA[3]
Maffiuletti et al. (2007) M (n = 15) W (n = 15) Young adult recreational athletes	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position with 85º of hip flexion	- 20 submaximal con (15º/s) and ecc (15º/s) contr of KE and KF at 60º/s	- 3 maximal con of KF and KE at 60º, 120º and 180º/s - 3 maximal ecc of KF and KE at 60º/s - ROM: 10-80º - 1 mis rest	Knee flexion - Con 60º/s: 3.1% CV; 0.98 ICC - Con 120º/s: 4.2% CV; 0.98 ICC - Con 180º/s: 4.1% CV; 0.98 ICC - Ecc 60º/s: 6.4% CV; 0.97 ICC Knee extension - Con 60º/s: 3.2% CV; 0.97 ICC - Con 120º/s: 2.8% CV; 0.99 ICC - Con 180º/s: 3.3% CV; 0.99 ICC - Ecc 60º/s: 7.0% CV; 0.96 ICC
Sole et al. (2007) M (n = 11) W (n = 7) Athletes with different	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions	- 10 submaximal con and ecc contr - 2 maximal con and ecc contr	-Dominant leg evaluated -3 maximal con/ecc cycles of KE at 60º/s -3 maximal con/ecc cycles of KF at	Knee flexion - Con 60º/s: 4.7 SEM[3]; 6.4 %SEM[3]; 13.1 95% LoA[2]; 17.7 RLoA[2]; 0.94 ICC - Exc 60º/s: 7.2 SEM[3]; 8.2 %SEM[3]; 19.2 95% LoA[2];

levels of performance	- Sitting position with 100º of hip flexion		60º/s -ROM: 0-85º -15s rest between cycles	22.7 RLoA[2]; 0.90 ICC Knee extension - Con 60º/s: 6.4 SEM[3]; 5.4 %SEM[3]; 17.8 95% LoA[2]; 15.1 RLoA[2]; 0.95 ICC - Exc 60º/s: 11.2 SEM[3]; 6.5 %SEM[3]; 31.0 95% LoA[2]; 18.1 RLoA[2]; 0.94 ICC
Impellizzeri et al. (2008) M & W (n = 18) Young adult recreational athletes	- No familiarization session - 3 evaluation sessions - 96 hours between consecutive sessions - Sitting position (not indicated the degree of hip flexion)	- 5-6 submaximal con and ecc contr of KE and KF at 60º/s	- Both legs evaluated - 2 maximal con contr og KE and KF at 60º, - 3 maximal ecc contr at 60º/s of KF - ROM: 10-90º - 1 min rest between contr	NS between legs: data show the dominant leg Knee flexion: - Con a 60º/s: 5.2 %SEM; 14.5 RLoA[2]; 0.95 ICC - Con a 120º/s: 5.7 %SEM; 15.8 RLoA[2]; 0.95 ICC - Con a 180º/s: 5.2 %SEM; 14.3 RLoA[2]; 0.96 ICC - Ecc a 60º/s: 6.5 %SEM; 17.2 RLoA[2]; 0.95 ICC Knee extension - Con a 60º/s: 4.3 %SEM; 12.0 RLoA[2]; 0.98 ICC - Con a 120º/s: 4.8 %SEM; 13.2 RLoA[2]; 0.97 ICC - Con a 180º/s: 4.0 %SEM; 11.1 RLoA[2]; 0.98 ICC - Ecc a 60º/s: 6.8 %SEM; 19.0 RLoA[2]; 0.96 ICC

Contr: contractions; con: concentric; ecc : eccentric ; KF: knee flexion (hamstring) ; KE: knee extension (quadriceps); CV: coefficient of variation ([standard deviation of two assessments/mean of two assessments] x 100); SEM[1]: standard error of measurement (square root of the quadratic error [square of the average residual value] in the ANOVA test); MVC: maximum voluntary contraction; %TEM: Typical error of measurement expressed in % (([antilog {SD (test 1 - test 2) / √ 2}] x 100) - 100); RLoA: ratio of limits of agreement (%TEM x 2.77); ROM: range of motion (0º=complete extension); min: minutes; 95% LoA[3]: limits of agreement (1.96 x standard deviation of the difference between test and re-test); 95% LoA: limits of agreement (difference between test and re-test ± SEM[2]); SEM[3]: standard error of measurement (SD √(1-ICC)); %SEM: SEM expressed as percentage according to the mean of the group; 95% LoA[2]; limits of agreement (1.96x √2x SEM[3]); RLoA[2]: 95% LoA[2] expressed according to the percentage of the mean of the group; RLoA[3]: 95% LoA[2] calculated through logarithms; %diff: percentage of the difference = {(result test 1 - result test 2) / result test 1)] x 100, ICC: intraclass correlation coefficient.

Table 4 goes into the study of absolute reliability of PT strength parameter, since it focuses on the possible influence that (a) the type of muscle contraction (concentric and eccentric), (b) the angular velocity (low: 0º-90º/s; moderate 91º-150º/s; high: >150º/s) and (c) the joint movement (knee flexion and knee extension) could have on its absolute reliability.

Table 4: Studies which analyze absolute reliability of the Peak Torque strength parameter using the standard error of measurement in percentages (68% of probability)

Mucle action Velocity	Studies (n)	Range of reliability (%)	Average of reliability (%)
Concentric knee flexion at low velocity (0-90º/s)	9	3.1 - 12.2	6.2
Concentric knee flexion at moderate velocity (91-150º/s)	3	4.2 - 5.7	4.8
Concentric knee flexion at high velocity (> 150º/s)	6	4.1 - 12.8	7.1
Concentric knee extension at low velocity (0-90º/s)	10	3.2 - 10.9	6.1
Concentric knee extension at moderate velocity (91-150º/s)	3	2.8 - 11.0	6.2
Concentric knee extension at high velocity (> 150º/s)	5	3.3 - 10.6	5.5
Eccentric knee flexion at low velocity (0-90º/s)	6	6.4 - 10.0	8.2
Eccentric knee flexion at moderate velocity (91-150º/s)	1	-	14.4
Eccentric knee flexion at high velocity (> 150º/s)	1	-	7.0
Eccentric knee extensión at low velocity (0-90º/s)	7	6.8 - 22.7	10.3
Eccentric knee extension at moderate velocity (91-150º/s)	1	-	8.9
Eccentric knee extension at high velocity (> 150º/s)	2	11.0 - 15.7	13.4

º: degrees; s: seconds

In this sense, table 4 shows that it seems to be a tendency which shows that concentric contractions may present a lower intersession variability compared to the eccentric one, no matter the selected angular velocity (5.9& and 10.4% of SEM for concentric and eccentric contractions respectively). There is a great number of studies whose results confirm this statement (Dauty & Rochcongar, 2001; Deighan, De Ste Croix y Armstrong, 2003; Dervisevic et al., 2006; Impellizzeri et al., 2008; Li et al., 1996; Lund et al., 2005; Maffiuletti et al., 2007; Sole et al., 2007; Symons et al., 2004; Tredinnick & Duncan, 1988), showing that the first reason for this is the fact that eccentric muscle activation of knee flexion and extension requires a better motor control and higher ability to execute it, so that it is more difficult to execute it than concentric muscle activation. (Kellis, Kellis, Gerodimos & Manou, 1999; Li et al., 1996; Sole et al., 2007).

Regarding the possible influence that the magnitude of angular velocity (low: 0º-90º/s; moderate 91º-150º/s; high: >150º/s) could have on PT strength parameter, the analysis of the analyzed articles (table 4) does not support the theory that claims that high angular velocities generate higher variability if the results obtained in comparison to low and moderate velocities (low: 7.7% SEM; moderate: 8.6% SEM; and high: 8.2% SEM). However, it is important to take into account that this theory, based on the results showed in Table 4, could be biased, since there are a greater amount of studies which use low angular velocities (n=17) than those which use high isokinetic velocities (n=9).

Finally, the study of the impact the joint movement (knee flexion and extention) has on the error of measurement of the PT strength parameter reveals that a tendency may exist that indicates that the knee extension movement if more reliable than the knee flexion one (Dervisevic et al., 2006; Impellizzeri et al., 2008; Kellis et al., 1999; Maffiuletti et al., 2007; Pincivero, Lephart & Karunakara, 1997; Ordway et al., 2006; Sole et al., 2007).The reason for this fact is not clear, and this circumstance is not present in all studies which evaluate both joint movements (Deighan, De Ste Croix & Armstrong, 2003; Lund et al., 2005; McCleary & Andersen, 1992). Kelli et al. (1999) suggest that during motor patterns in races and actions such as kicking a ball or changing direction and sense the knee extension muscle is maximally contracted. Therefore, the person evaluated could be more skillful to activate the knee extension muscle, while the knee flexion muscle acts in several actions as antagonist (in an eccentric way) and/or synergistic muscle. This could provide a possible explanation, although it is based on empiric theories.

4.2. Absolute reliability of the “angle of peak torque” isokinetic stregth parameter

Absolute reliability of this isokinetic strength parameter has only been determined by two studies (table 5). Dauty & Rochcongar (2001) evauated the absolute reliability of the knee flexion APT under concentric (180º/s) and eccentric (30º and 60º/s) contractions in volleyball players of national category (n=10). The results obtained by Dauty & Rochcongar (2001) showed that the APT strength parameter is not a stable measure for eccentric contraction (46.9% and 62.9% of SEM for velocities of 30º and 60º/s respectively), whereas moderate-low values of variability were obtained in the concentric mode (16.7% SEM).

Table 5: Studies which determine the absolute reliability of the APT isokinetic strength parameter chronologically presented

Referece / **Population**	**Design** / **Position of the evaluated subject**	**Exploratory procedure** / **Process to warm-up**	**Exploratory procedure** / **Evaluation process**	**Results**
Dauty et al. (2001) M (n = 10) Volleyball players of national category	- No familiarization session - 2 evaluation sessions - 21 days between consecutive sessions - Sitting position with 85º of hip flexion	- 5 minutes of bicycle ergometer (70 rpm and 50 w) - Stretching	- Right leg evaluated - 5 maximal con contr of KF at 180º/s - 5 maximal ecc contr of KF at 30º/s - 5 maximal ecc contr of KF at 60º/s - ROM: 0-100º - 3 min rest between con and ecc contr - 1 min rest between ecc contr	Knee flexion - Con 180º/s: 7 SEM[3]; 16.7 %SEM; 0.67 ICC - Ecc 30º/s: 9 SEM[3]; 46.9 %SEM; 0.28 ICC - Ecc 60º/s: 10 SEM[3]; 62.9 %SEM; 0.28 ICC
Maffiuletti et al. (2007) M (n = 15) W (n = 15) Young adult recreational athletes	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position with 85º of hip flexion	- 20 submaximal con (15º/s) and ecc (15º/s) con of KF and KE	- 3 maximal con of KF and KE at 60º, 120º and 180º/s - 3 maximal ecc of KF and KE at 60º/s - ROM: 10-80º - 1 min rest	Knee flexion - Con 60º/s: 11.1% CV y 0.52 ICC - Con 120º/s: 10.2% CV y 0.70 ICC - Con 180º/s: 11.6% CV y 0.83 ICC - Ecc 60º/s: 18.1% CV y 0.73 ICC Knee flexion - Con 60º/s: 4.3% CV y 0.91 ICC - Con 120º/s: 4.3% CV y 0.92 ICC - Con 180º/s: 4.0% CV y 0.91 ICC - Ecc 60º/s: 7.1% CV y 0.48 ICC

Contr: contractions; con: concentric; ecc : eccentric ; KF: knee flexion (hamstring) ; KE: knee extension (quadriceps); º: degrees; s: seconds; CV: coefficient of variation ([standard deviation of two assessments/mean of two assessments] x 100); SEM[3]: standard error of measurement (SD √(1-ICC)) %SEM: SEM expressed as percentage according to the mean of the group; ROM: range of motion (0º= complete extension); ICC: intraclass correlation coefficient.

Maffiuletti et al. (2007) showed opposite results to those obtained by Dauty and Rochcongar (2001), since they determined the APT reliability of knee concentric and eccentric flexion and extension through different velocities (60º, 120º and 180º/s) in physically active young adults (n=30). Maffiuletti et al. (2007) reported moderate values of absolute reliability of the APT isokinetic strength parameter, without concerning the velocity of the movement execution (4-18.1% of variability), although the concentric mode and the knee extension action were the combinations which obtained the best reliability values (4-4.3% of variability)

4.3. Absolute reliability of the "average power" isokinetic strength parameter

There are few scientific studies which have tried to determine the absolute reliability of the AP isokinetic strength parameter (table 6). As a result, an exhaustive analysis of the influence that variables such as the type of muscle contraction and the magnitude of movement angular velocity have on intersession variability of the AP strength parameter would be hugely speculative and lacking in scientific base to establish rigorous judgments.

Along this argumental line, perhaps the only consideration regarding absolute reliability of the AP isokinetic strength parameter should be based on a general qualitative value derived from the results obtained in the studies with this aim. In this sense, absolute reliability of the AP isokinetic strength parameter seems to be moderate-high (<10-15% of intersession variation) (Hopkins, Marshall, Batterham & Hanin, 2009).

4.4. Absolute reliability of the "total work" isokinetic strength parameter

From a global perspective, and on the margins of the different exploratory procedures used by diverse studies to obtain it, the TW strength parameter presents a moderate absolute reliability with values around 10-15% of intersession variability (table 7).

The study of the possible influence that the type of muscle contraction (concentric and eccentric), the angular velocity (low: 0º-90º/s; moderate: 91º-150º/s; high: <150º/s) and the joint movement (knee flexion and extension) have on the valiability of the Total Work strength parameter shows similar conclusions to those obtained with PT strength parameter.

Along this line, studies which do direct comparisons between values of absolute reliability of the TW obtained through concentric and eccentric muscular actions show that generally the best results (less variability) are obtained by the concentric mode (Li et al., 1996; Maffiuletti et al., 2007; Sole et al., 2007; Tredinnick & Duncan, 1988). A clear example of this situation is the study made by Maffiuletty at al. (2007), who determined the TW absolute reliability in the concentric and eccentric mode at low velocity (60º/s) in physically active subjects (n=30). There authors reported variability values of 4.1% and 7.2% (SEM) for the concentric and eccentric contraction of knee extension respectively.

Table 6: Studies which determine absolute liability og average power strength parameter chronologically presented

Reference	Design	Exploratory procedures		Results
Population	Position of the evaluated subject	Process to warm-up	Evaluation process	
Perrin (1986) M (n = 15) Healthy Young adults	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (degree of hip flexion not indicated)	- 3 submaximal con/con cycles of KE and KF at 60º/s - 3 maximal con/con cycles of KE and KFat 60º/s - 1 min rest between warm-up and evaluation processes	- Both legs evaluated - 5 maximal con/con cycles of KE and KF at 60º/s - ROM: not specified - 2 min rest between the evaluation of one leg and another	Knee flexion - Con 180º FR left: 0.95 ICC - Con 180º FR right: 0.90 ICC Knee extension - Con 180º FR left: 0.94 ICC - Con 180º FR right: 0.90 ICC NS between legs: data show the average between both of them. NS between gender: data express the results of women
Li et al. (1996) M (n = 18) W (n = 12) Healthy Young adults	- 1 familiarization session - 2 evaluation sessions - 4-10 days between consecutive sessions - Sitting position with 110º of hip flexion	- 3 min stretching - 2 submaximal con/ecc cycles - 1 maximal con/ecc cycle	- Both legs evaluated - 5 maximal con/ecc cycles of KE and KF at 60º/s - 5 maximal con/ecc cycles of KE and KF at 120º/s - ROM: not specified - 2 min rest between velocities - 3 min rest between muscles - 5 min rest between dominant and non-dominant leg	Knee flexion - Con at 60º/s: 16.4 %diff; 0.77 ICC - Con at 120º/s: 11.7 %diff; 0.83 ICC - Ecc at 60º/s: 16.3 %diff; 0.76 ICC - Ecc at 120º/s: 14.6 %diff; 0.84 ICC Knee extension - Con at 60º/s: 11.2 %diff; 0.80 ICC - Con at 120º/s: 12.3 %diff; 0.82 ICC - Ecc at 60º/s: 16.9 %diff; 0.83 ICC - Ecc at 120º/s: 16.3 %diff; 0.83 ICC NS between legs: data show the dominant leg
Pincivero et al. (1997) M (n = 10) W (n = 11) Healthy Young adults	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (degree of hip flexion not indicated)	- 5 min of bicycle ergometer (60rpm) - Stretching exercises - 5 submaximal con/con cycles of KE and KF - 2-3 maximal con/con cycles of KE and KF	– Both legs evaluated – 5 maximal con/con cycles of KE and KF at 60º/s – 5 maximal con/con cycles of KE and KF at 180º/s – ROM: 0-90º	Knee flexion - Con 60º/s: 7.1 %SEM; 0.95 ICC - Con 180º/s: 7.6 %SEM; 0.95 ICC Knee extension - Con 60º/s: 2.0 %SEM; 0.92 ICC - Con 180º/s: 9.5 %SEM; 0.89 ICC
Symons et al. (2004) W (n = 25) Healthy old adults	- No familiarization session - 2 evaluation sessions - 2-10 days between consecutive sessions	- 5 min of bicycle ergometer (50 rpm) - 3 submaximal cont at 50-60% of MVC	- Both legs evaluated - 5 maximal ecc of KE at 90º/s - 5 maximal ecc of KE at 90º/s - ROM: 0-90º - 2 min rest between contr	NS between legs: data show the average of both legs Knee extension - Con 90º/s: 18.9%ETM; 52.37 RLOA and 0.84 ICC
Maffiuletti et al. (2007) M (n = 15)	- No familiarization session - 2 evaluation sessions	- 20 submaximal con (15º/s) and ecc (15º/s) contr of KE and KF	- 3 maximal con of KE and KF at 60º, 120º and 180º/s	Knee flexion - Con 60º/s: 8.4% CV and 0.92 ICC

W (n = 15) Young adult recreational athletes	- 7 days between consecutive sessions - Sitting position with 85º of hip flexion		- 3 maximal ecc of KF and KE at 60º/s - ROM: 10-80º - 1 min rest	- Con 120º/s: 6.9% CV and 0.96 ICC - Con 180º/s: 6.1% CV and 0.96 ICC - Exc 60º/s: 5.9% CV and 0.97 ICC Knee extension - Con 60º/s: 4.7% CV and 0.95 ICC - Con 120º/s: 3.4% CV and 0.98 ICC - Con 180º/s: 4.6% CV and 0.98 ICC - Ecc 60º/s: 7.3% CV ans 0.97 ICC

Contr: contractions; con: concentric; ecc : eccentric ; KF: knee flexion (hamstring) ; KE: knee extension (quadriceps); º: degrees; s: seconds; CV: coefficient of variation ([standard deviation of two assessments/mean of two assessments] x 100); SEM[3]: standard error of measurement (SD √(1-ICC)); %SEM: SEM expressed as percentage according to the mean of the group; 95% LoA[2]; limits of agreement (1.96x √2x SEM[3]); ROM: range of motion (0º= complete extension); ICC: intraclass correlation coefficient; %diff: percentage of the difference = {(result test 1 - result test 2) / result test 1)] x 100; RLoA: parameter of limits of agreement (%TEM x 2.77).

Table 7: Studies which determine the absolute reliability of Total Work isokinetic strength parameter chronologically presented

Reference Population	Design Position of the evaluated subject	Exploratory procedure Warm-up process	Evaluation process	Results
Perrin (1986) M (n = 15) Healthy young adults	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (degree of hip flexion not indicated)	- 3 submaximal con/con cycles of KE and KF at 60º/s - 3 maximal con/con cycles of KE and KF at 60º/s - 1 min rest between warm-up and evaluation processes	- Both legs evaluates - 5 maximal con/con cycles of KE and KF at 60º/s - ROM: not specified - 2 min rest between the evaluation of one leg and another	Knee flexion - Con 180º FR left: 0.94 ICC - Con 180º FR right: 0.96 ICC Knee extension - Con 180º FR left: 0.91 ICC - Con 180º FR right: 0.91 ICC
Tredinnick et al. (1988) M (n = 14) Healthy young adults	- 1 familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Supine position (degree of hip flexion not indicated)	- 4 submaximal con and ecc cont of KE at 60º, 120º and 180º/s - 1 maximal con and ecc contr of KE at 60º, 120º and 180º/s - 2 min rest between warp- up and evaluation process	- Right leg evaluated - 3 maximal con and ecc contr of KE at 60º, 120º and 180º/s - ROM: not specified - 5s rest between con and ecc contr - 3 min rest between velocities	Knee extension - Con a 60º/s: 0.85 ICC - Con a 120º/s: 0.95 ICC - Con a 180º/s: 0.80 ICC - Ecc a 60º/s: 0.68 ICC - Ecc a 120º/s: 0.72 ICC - Ecc a 180º/s: 0.86 ICC
Li et al. (1996) M (n = 18) W (n = 12) Healthy young adults	- 1 familiarization session - 2 evaluation sessions - 4-10 days between consecutive sessions - Sitting position with a hip flexion of 110º	- 3 min stretching - 2 submaximal con/ecc cycles - 1 maximal con/ecc cycle	- Both legs evaluated - 5 maximal con/ecc cycles of KE and KF at 60º/s - 5 maximal con/ecc cycles of KE and KF at 120º/s - ROM: not specified - 2 min rest between velocities - 3 min rest between muslces - 5 min rest between dominant and non-dominant leg	Knee flexion - Con a 60º/s: 15.3 %diff; 0.76 ICC - Con a 120º/s: 9.1 %diff; 0.84 ICC - Ecc a 60º/s: 17.7 %diff; 0.78 ICC - Ecc a 120º/s: 14.7 %diff; 0.82 ICC Knee extension - Con a 60º/s: 10.0 %diff; 0.81 ICC - Con a 120º/s: 10.0 %diff; 0.84 ICC - Ecc a 60º/s: 18.5 %diff; 0.80 ICC - Ecc a 120º/s: 14.9 %diff; 0.80 ICC
Pincivero et al. (1997) M (n = 10) W (n = 11) Healthy young adults	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions - Sitting position (degree of hip flexion not indicated)	- 5 min of bicycle ergometer (60rpm) - Stretching excersises - 5 submaximal con/con cycles of KE and KF - 2-3 maximal con/con cycles og KE and KF	– Both legs evaluated – 5 maximal con/con cycles of KE and KF at 60º/s – 5 maximal con/con cycles of KE and KF at 180º/s – ROM: 0-90º	NS between legs: data show the dominant leg Knee flexion - Con 60º/s: 7.4 %SEM; 0.95 ICC - Con 180º/s: 7.4 %SEM; 0.95 ICC Knee extension - Con 60º/s: 8.9 %SEM; 0.89 ICC - Con 180º/s: 9.6 %SEM; 0.88 ICC

Symons et al. (2004) W (n = 25) Healthy old adults	- No familiarization session - 2 evaluation sessions - 2-10 days between consecutive sessions	- 5 min of bicycle ergometer (50rpm) - 3 submaximal cont at 50-60% of MVC	- Both legs evaluated - 5 maximal con of KE at 90º/s - 5 maximal ecc of KE at 90º/s - ROM: 0-90º - 2 min rest between contr	NS between legs: data show the average of both legs Knee extension - Con 90º/s: 10.9%TEM; 30.2 RLOA y 0.91 ICC
Ordway et al (2006) M (n = 16) W (n = 17) Healthy old adults	- 1 familiarization session - 2 evaluation sessions - 7-10 days between consecutive sessions	- 3 submaximal con/con cycles og KE and KF	- Dominant leg evaluated - 5 maximal con/con cycles of KF and KE at 60º and 240º/s - ROM: not specified - 1 min rest between velocities	Knee flexion - Con 60º/s: 18 SEM[2]; 31 %SEM - Con 240º/s: 16 SEM[2]; 51.6 %SEM Knee extension - Con 60º/s: 24 SEM[2]; 18.5 %SEM - Con 240º/s: 18 SEM[2]; 24.2 %SEM
Maffiuletti et al. (2007) M (n = 15) W (n = 15) Young adult recreational athletes	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions	- 20 submaximal con (15º/s) and ecc (15º/s) contr of KF and KE	- 3 maximal con of KF and KE at 60º, 120º and 180º/s - 3 maximal ecc of KF and KE at 60º/s - ROM: 10-80º - 1 min rest	Knee flexion - Con 60º/s: 3.8% CV and 0.97 ICC - Con 120º/s: 5.5% CV and 0.97 ICC - Con 180º/s: 4.1% CV and 0.98 ICC - Ecc 60º/s: 5.7% CV and 0.97 ICC Knee extension - Con 60º/s: 4.1% CV and 0.96 ICC - Con 120º/s: 3.7% CV and 0.97 ICC - Con 180º/s: 4.0% CV and 0.98 ICC - Ecc 60º/s: 7.2% CV and 0.97 ICC
Sole et al. (2007) M (n = 11) W (n = 7) Athletes with different levels of performance	- No familiarization session - 2 evaluation sessions - 7 days between consecutive sessions	- 10 submaximal cona and ecc contr - 2 maximal con and ecc contr	-Dominant leg evaluated -2 maximal con/ecc cycles of KE at 60º/s -3 maximal con/ecc cycles og KF at 60º/s -ROM: 0-85º -15s rest between cycles	Knee flexion - Con 60º/s: 6.5 SEM[3]; 7.7 %SEM[3]; 18.1 95% LoA[2]; 21.4 RLoA[2]; 0.91 ICC - Ecc 60º/s: 7.8 SEM[3]; 7.8 %SEM[3]; 21.6 95% LoA[2]; 21.7 RLoA[2]; 0.93 ICC Knee extension - Con 60º/s: 5.1 SEM[3]; 4.4 %SEM[3]; 14.2 95% LoA[2]; 12.3 RLoA[2]; 0.96 ICC - Ecc 60º/s: 6.8 SEM[3]; 4.3 %SEM[3]; 19.0 95% LoA[2]; 12.1 RLoA[2]; 0.96 ICC

Contr: contractions; con: concentric; ecc : eccentric ; KF: knee flexion (hamstring) ; KE: knee extension (quadriceps); º: degrees; s: seconds; CV: coefficient of variation ([standard deviation of two assessments/mean of two assessments] x 100); SEM[3]: standard error of measurement (SD √(1-ICC)); %SEM: SEM expressed as percentage according to the mean of the group; 95% LoA[2]; limits of agreement (1.96x √2x SEM[3]); RLoA[2]: 95% LoA[2] expressed according to the percentage of the mean of the group; %TEM: Typical error of measurement expressed in % (([antilog {SD (test 1 - test 2) / √ 2}] x 100) - 100).
.

Regarding the effect of angular velocity on the magnitude of intercessions variability, it is possible that there was no relationship between these two variables, so that TW reliability could not be influenced by the angular velocity used during the evaluation process (table 7).

Finally, table 7 shows a slight tendency to achieve better results of absolute reliability of TW during the knee extension movement compared to knee flexion joint movement, no matter the angular velocity used during the exploratory process.

It is important to highlight the theoretical character of all previously mentioned considerations, due to the high heterogeneity present in the exploratory procedures of the different studies selected for the analysis.

5. LIMITATIONS OF THE ISOKINETIC EVALUATION ACCORDING TO SCIENTIFIC LITERATURE

5.1. Importance of the different isokinetic strength parameters in the scientific literatura

There are many scientific studies aimed to determine absolute reliability of the different isokinetic strength parameters. Most of them are focused on the analysis of PT (n=17) and TW (n=8) isokinetic strength parameters, while less are aimed to determine the error of measurement of the AP isokinetic strength ratio (n=5), and those studies which evaluate the reproducibility of the APT isokinetic strength ratio (n=2).

5.2. Importance of the different angular velocities in the scientific literature

The telescopic boom of modern isokinetic dynamometers can move at angular velocities ranging from 30º to 500º/s. Sports actions generally require quick and explosive movements with a short time of force application (200-500 ms) (Cronin, McNair & Marshall, 2001).

Therefore, theoretically, isokinetic evaluation should use moderate-high angular velocities (180º-300º/s) if the aim is to reflect the reality of sports actions and with that to increase the ecologic validity of the exploratory procedure.

However, only Iga et al. (2006) and Ordaway et al. (2006) used angular velocities higher than 180º/s in their exploratory procedures (240º/s in both studies). The evaluation of isokinetic strength parameters using moderate and high angular velocities (180º-300º/s) could be very helpful for doctors, trainers and other members of the physical activity and sports field, since it could (theoretically) provide data which reflect strength values closer to the sports reality, and which help to prevent the main disadvantage of the isokinetic evaluation: little contextualization of its evaluation actions.

Therefore, there is a clear need of studies which determine the reproducibility of quick isokinetic actions as an essential previous requirement to justify its use in exploratory procedures.

5.3. Aspects related to the procedures for isokinetic evaluation

A measurement reliability may be affected by several factors, such as the following: (a) the complexity of the movement evaluated (learning bias), (b) if the assessment is carried out by one examiner (intra-examiner reliability), (c) environmental factors such as temperature and the moment of the day, (d) previous warm-up exercises or not, (e) and even the characteristics of the population evaluated (scholars, healthy young adults, people with pathologies) (Hopkins, 2000).

In this sense, and in the context of isokinetic exploration, Keating and Matyas (1996) consider that the learning bias, the position adopted by the subject and the range of motion evaluated could be three of the main aspects to control for obtaining a stable measurement to isokinetic strength parameters.

As a result, in the following there is an analysis of the effect that learning bias, the subject’s position and the range of motion could have on the results obtained in an isokinetic evaluation.

5.3.1. The learning effect

Isokinetic tests require the cooperation of the patient during the evaluation procedure, which could obtain better results after the repetition of the test a short period of time later. This is known as learning effect. If learning effect appears, this means that the evaluated subject is able to obtain better isokinetic strength results in the last measuring (compared to the first one) provided that they have been measured two or more times separated by a few minutes. Learning effect could negatively affect in the evaluation of the measurement reliability (Thomas y Nelson, 1990).

Despite the specific, and new in many occasions, neuromuscular demands that the isokinetic evaluation requires from the evaluated subject, few studies have researched the number of repetitions needed to obtain stable values of the measurement during the evaluation session (intra-session stability) (Lund et al., 2005; Madsen, 1996; Madsen & Lauridsen, 1995).

Lund et al. (2005) studied the learning effect of the isokinetic test during 4 maximal repetitions of knee flexion and extension, separated by 20 minutes with healthy young adults (n=33). These authors reported that no learning effect appears between the first four repetitions of knee flexion and extension, even though they realize that the best results for knee flexion (non significant) were obtained in the first repetition.

The conclusions obtained by Lund et al. (2005) were not supported by several previous studies (Burdett and Swearingen, 1987; Friedlander, Block, Byl, Tubbs, Sadowsky & Genant, 1991; Kues, Rothstein & Lamb, 1992; Murray, Gardner, Mollinger & Sepic, 1980), although they were by some more recent ones (Madsen, 1996; Madsen & Lauridsen, 1995). Therefore, there are several studies which showed that the results obtained in the second and following repetitions are statistically higher than those obtained in the first measurement (systematic bias). Along this line, Kues, Rothstein and Lamb (1992), based on a visual analysis of the data obtained in the knee evaluation, concluded that subjects should be evaluated using four maximal repetitions and selecting the highest result obtained (quantitatively) as the measurement in maximal effort.

Keatin and Matyas (1996) after analyzing in minute detail the factors that could have an influence on the measurement stability, claim that to control certain aspects on the exploratory procedure may decrease its variability: (a) a familiarization session of the exploratory procedure several days before its start-up; (b) a previous warm-up process; (c) an appropriate stabilization of the subject to be evaluated; (d) a correct alienation of the axis of rotation of the joint with the axis of rotation of the dynamometer; (e) and an exact length selected for the telescopic boom.

Along this line, Keatin and Matyas (1996) consider that if the previous requirements are respected, two repetitions could be necessary to obtain measurement stability if low angular velocities are used (0º-90º/s), three repetitions for moderate-high velocities (90º-180º/s) and four for high velocities (> 180º/s).

On the other hand, studies which analyze the learning effect of isokinetic measurements (mainly the Peak Torque) during several days (inter-session) report, generally, the non-existence of learning bias in the obtained results (Dauty and Rochcongar, 2001; Deighan, De Ste Croix & Armstrong, 2003; Iga et al., 2006; Impellizzeri et al., 2008; Kellis et al., 1999; Li et al., 1996; Maffiuletti et al., 2007; Sole et al., 2007). However, knee flexion and extension movements and the evaluation under high velocities seem to be the variables more susceptible to alteration from one session to another (learning bias) (Iga et al., 2006; Maffiuletti et al., 2007).

Glesson & Mercer (1992), after evaluating the inter-session variation (5 days between consecutive sessions) of the performance of the isokinetic strength in physically active women and men they concluded that after a familiarization session, measurement variability could be related to biological and technological variation and to the error of measurement connected to learning effect.

5.3.2. Position adopted by the evaluated subject

The position of the person is one of the most important aspects that a doctor must bear in mind when designing his or her exploratory procedures (Keating & Matyas, 1996). In this sense, isokinetic devises allow to evaluate muscle function of the knee joint by adopting different positions, for instance the sitting position with a hip flexion of 80º-100º (Kellis et al., 1999; Li et al., 1996;

Maffiuletti et al., 2007; Lund et al., 2005), although certain studies prefer supine position (Worrell, Denegar, Armstrong & Perrin, 1990; Worrell, Perrin & Denegar, 1989), or prone position (Worrell, Perrin & Denegar, 1989).

Studies which have determined the effect of the body position on the results obtained in the isokinetic evaluations of knee flexion and extension movements report that the production of concentric and eccentric strength is influenced by the body position (Curner, 1977; Figioni, Christ & Massey, 1988; Lunnen, Yack, Leveau, 1981; Gordon, Huxley, Julian, 1986; Worrell, Denegar, Armstrong & Perrin, 1990; Worrell, Perrin & Denegar, 1989).

Figure 1: main participant testing positions adopted during an isokinetic kne flexion and extensión strength assessment: a) seated, b) lying prone and c) lying supine

These studies' results show that the maximal strength of knee flexors and extensors was significantly lower in prone and supine positions than in a sitting position (Figioni, Christ & Massey, 1988; Lunnen, Yack & Leveau, 1981; Worrell, Perrin & Denegar, 1989). Therefore, Lunne, Yack and Leveau (1981) studied the maximum isometric force of the knee flexor muscles at 60º of knee flexion, and adopting positions of hip flexion at 0º, 45º, 90º and 135º. These authors discovered that the isometric force of knee flexor muscles was significantly lower in the position of 0º of hip flexion than the obtained with positions of 90º and 135º of flexion. Worrell, Perrin and Denegar (1989) compared the isokinetic strength of concentric knee flexion and extension in sitting and supine positions with university students (n=12). These authors also found higher strength values of knee flexion and extension movements in a sitting position rather than a supine position.

The mechanism that could explain this strength decrease according to the body position may be related to the force-position curve, which describes the optimum length where a muscle can develop the maximum force (Gordon, Huxley & Julian, 1986). Along this line, Worrell, Perrin and Denegar (1989) suggest that in hip flexions lower than 60º and higher than 135º, both knee flexor and extensor muscles are in an unfavorable position to allow actin and myosin cross-bridges slide efficiently.

Worrell, Perrin and Denegar (1989) discovered that the decrease in the strength of knee flexors was double to that suffered by knee extensors when comparing sitting and lying positions. These authors consider that a possible explanation could lie in the fact that if quadriceps are considered the main knee extensors and hamstrings the main knee flexors, three of the muscles that form the quadriceps do not cross the hip joint, while the three muscles that form the hamstring cross both the hip joint and the knee. Therefore, Worrell, Perrin and Denegar (1989) claims that hamstring muscles could be more susceptible to suffer variations in the magnitude of its strength when modifying the hip position.

From the ecological validity perspective, several studies suggest to evaluate the knee muscles function by using lying positions, since this position reflects with higher accuracy the hip position when a sportsman is running at the highest speed (main injury mechanism of the hamstring muscle and the ACL) (Worrell et al., 1990; Worrell, Perrin & Denegar, 1989).

Worrell et al. (1990) studied the effect of prone and supine positions on maximal concentric and eccentric isokinetic strength of knee flexors with lacrosse players (n=12). The results showed that supine position had a decrease of 36% and 31% of the maximal concentric and eccentric strength respectively compared to the prone position. Worrell et al. (1990) suggest that a possible explanation for this phenomenon could lie in the influence of certain postural reflexes (vestibular labyrinthine reflex, neck symmetric and asymmetric reflex) on the hamstring muscle tone. This study finally suggests that the evaluation of the knee muscles function should be in prone position, since it is the closest to the sports reality of actions and it facilitates an optimal force generation.

Surprisingly, only Tredinnick and Ducan (1988) use the lying position to evaluate the absolute reliability of the PT isokinetic strength ratio. Therefore, the need to address the study of absolute reliability of the different isokinetic strength parameters adopting different positions seems clear in order to try to determine what position of the evaluated subject allow to obtain the best measurement stability over time.

5.3.3. Range of motion evaluated

The joint range of motion to be evaluated is one of the most relevant variables of the exploratory procedure. Scientific studies which analyze absolute reliability of the different isokinetic strength parameters of knee flexion and extension generally use two types of range of motion: (a) from 0º (total knee extension) to 90º-100º of knee flexion (Arnold, Perrin & Hellwing, 1993; Dauty & Rochcongar, 2001; Deighan, De Ste Croix & Armstrong, 2003; Dervisevic et al., 2006; Kellis et al., 1999; Lund et al., 2005; McCleary & Andersen, 1992; Pincivero, Lephart & Karunakara, 1997; Sole et al., 2007; Symons et al., 2004); and (b) from 10º to 80º-90º of knee flexion (Iga et al., 2006; Impellizzeri et al., 2008; Maffiuletti et al., 2007).

In addition, most of isokinetic strength ratio reliability studies take the variables to evaluate from the whole joint range of motion, without focusing on neither specific ranges of motion or specific angles.

The study of the magnitude of isokinetic strength parameters obtained during ranges of motion and/or specific angles seem to be gaining importance in the last years, especially in the field of injury rehabilitation and prevention. For instance, it is well known that knee flexor muscles act as synergistic muscles (active ligament) and as protective structures of the anterior cruciate ligament (ACL). This last function is of vital importance in angles from 0º to 40º of knee flexion during quick dynamic actions, where the ACL has to support the maximum stress, due to the tensile strength executed by knee extensors (Beymnnon, Johnson, Abate, Fleming & Nichols, 2005; Solomonow, Baratta & D´Ambrosia, 1989). Therefore, the study of the magnitude of isokinetic strength parameters taken from the range of motion from 0º to 40º could provide very interesting information to doctors and other professionals in the field of physical and sports rehabilitation about the dynamic knee stability (Kellis & Katis, 2007).

However, only Arnold, Perrin and Hellwing (1993) and Dervisevic et al. (2006) focus on studying absolute reliability of isokinetic strength parameters in specific angles and ranges of motion. In this sense, Arnold, Perrin and Hellwing (1993) determine the reproducibility of the PT in angles 30º, 60º and 75º of knee flexion, while Dervisevic et al. (2006) focus on the range from 30º to 60º of knee flexion.

Therefore, the lack of scientific information related with absolute reliability of isokinetic strength parameters in specific ranges of motion and angles show the clear need of scientific studies which focus in this matter.

6. CONCLUSIONS

Despite the generalized use of isokinetic devises to evaluate and monitor knee muscle functions after using intervention programs, the scientific evidence related to the magnitude of the change needed in the different isokinetic strength parameters that express a real change beyond the measurement error bias is quite limited.

Therefore, it is important to carefully consider the following conclusions:

- PT and TW isokinetic strength parameters seem to present a moderate-high absolute reliability (SEM and TE < 10%), no matter the evaluated muscle contraction (concentric and eccentric), the angular velocity selected (low, moderate and high) and the joint movement (knee flexion and extension). In addition, it seems to be a tendency that suggests that concentric muscle contraction presents a lower inter-session variability compared to eccentric contraction.

- AP isokinetic strength ratio seems to have moderate absolute reliability (SEM and TE ≈ 10-15%). There is not enough scientific evidence to allow the evaluation of the influence of variables such as the type of contraction, angular velocity and muscle action on the measurement stability.

- APT absolute reliability has not been appropriately established. The few studies with this aim (n=2) show very controversial results. Therefore, doctors, physical coaches and other members of the physical and sports field must use it cautiously.

- More scientific studies which evaluate absolute reliability of AP and APT are needed.

- There is a clear scientific gap in relation to the effect that different positions (supine, prone and sitting positions) could have on the degree of inter-session variability.

- It is essential to study absolute reliability of isokinetic strength parameters using high angular velocities, since they reflect with more accuracy the physical and sports reality, and it would improve the ecological validity of the results obtained.

7. REFERENCES

Anderson, M.A., Gieck, J.H., Perrin, D., Weltman, A., Rutt, R. & Denegar, C. (1991). The relationships among isometric, isotonic and isokinetic concentric and eccentric quadriceps and hamstring force and three components of athletic performance. *Journal of Orthopaedic and Sports Physical Therapy*, 14(3), 114-119.

Arnold, B.L., Perrin, D.H. & Hellwig, E. (1993). The reliability of three isokinetic knee-extension angle-specific torques. *Journal of Athletic Training*, 28(3), 227-229.

Ashley, C.D. & Weiss, L. (1994). Vertical jump performance and selected physiological characteristic of women. *Journal of Strength and Conditioning Research*, 8, 5-11.

Atkinson, G. & Nevill, A.M. (1998). Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Medicine*, 26, 217-238.

Baumgarter, T.A. (1989). *Norm-referenced measurement: reliability*. En: Safrit MJ, Wood TM, editors. Measurement concepts in physical education and exercise science. Champaign (IL): Human Kinetics, p. 45-72.

Beynnon, B.D., Johnson, R.J., Abate, J.A., Fleming, B.C. & Nichols, C.E. (2005). Treatment of anterior cruciate ligament injuries, part 1. *American Journal of Sports Medicine*, 33, 1579-1602.

Brown, L.E. (2000). *Isokinetics in human performance*. Champaign, IL: Human Kinetics.

Brown, L.E., Whitehurst, M. & Buchalter, D.N. (1994). Comparison of bilateral isokinetic knee extension/flexion and cycle ergometry tests of power. Journal of Strength and Conditioning Research, 83(3), 139-143.

Brown, S.L. & Wilkinson, J.G. (1983). Characteristics of national, divisional, and club male alpine ski racers. *Medicine & Science in Sports & Exercise*, 15(6), 491-495.

Burdett, R. & Swearingen, J.V. (1987). Reliability of isokinetic muscle endurance tests. *Journal of Orthopaedic & Sport Physical Therapy*, 8, 484-488.

Cronin, J., McNair, P.J. & Marshall, R. (2001). Developing explosive power: A comparison of technique and training. *Journal of Science and Medicine in Sports*, 4(1), 59-70.

Curner, D. (1977). Positioning for knee strengthening exercising. *Physical Therapy*, 57, 148-151.

Dauty, M. & Rochcongar, P. (2001). Reproducibility of concentric and eccentric isokinetic strength of the knee flexors in elite volleyball players. *Isokinetics and Exercise Science*, 9, 129-132.

Deighan, M.A., De Ste Croix, M.B.A. & Armstrong, N. (2003). Reliability of isokinetic concentric and eccentric knee and elbow extension and flexion in 9/10 year old boys. *Isokinetics and Exercise Science*, 11, 109-115.

Dervisevic, E., Hadzic, V., Karpljuk, D. & Radjo, I. (2006). The influence of different ranges of motion testing on the isokinetic strength of the quadriceps and hamstring. *Isokinetics and Exercise Science,* 14, 269-278.

Dvir, Z. (2004). *Isokinetics muscle testing: interpretation and clinical applications* (2nd edition) London: Churchill Livingstone, 1-50.

Figoni, S., Christ, C. & Massey, B. (1988). Effect of speed, hip and knee angle, and gravity on hamstring to quadriceps torque ratios. *Journal of Orthopaedic and Sports Physical Therapy*, 9, 287-291.
Friedlander, A.L., Block, J.E., Byl, K.N., Tubbs, H.A., Sadowsky, H.S. & Genant, H.K. (1991). Isokinetic limb and trunk muscle performance testing: short-term reliability. *Journal of Orthopaedic & Sport Physical Therapy*, 14, 220-224.
Gleeson, N.P. & Mercer, T.H. (1995). Reliability of relativised angle torque and angle-specific torque indices of isokinetic leg strength in women, *Medicine & Science in Sports & Exercise*, 27(5), S209.
Gordon, A.M., Huxley, A.F. & Julian, F.J. (1986). The variation in isometric tension with sarcomere length in vertebrate muscle fiber. *Journal of Physiology (Lond)*, 170-192.
Haymes, E.M. & Dickinson, A.L. (1980). Characteristic of elite male and female ski racers. *Medicine and Science in Sports and Exercise*, 12(3), 153-158.
Hislop, H.J. & Perrine, J.J. (1967). The isokinetic concept of exercise. *Physical Therapy*, 2, 114-117.
Hopkins, W.G. (2000). Measures of reliability in sports medicine and science. Sports Medicine, 30(1), 1-15.
Hopkins, W.G., Marshall, S.W., Batterham, A.M. & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*. 41, 3-12.
Iga, J., George, K., Lees, A. & Reilly, T. (2006). Reliability of assessing indices of isokinetic leg strength in pubertal soccer players. *Pediatric Exercise Science*, 18, 436-445.
Impellizzeri, F.M., Bizzini, M., Rampinini, E., Cereda, F. & Maffiulet, N.A. (2008). Reliability of isokinetic strength imbalance ratios measured using the Cybex NORM dynamometer. *Clinical Physiology and Functional Imaging*, 28(2), 113-119.
Keating, J.L. & Matyas, T.A. (1996). The influence of subject and test design on dynamometric measurements of extremity muscles. *Physical Therapy*, 76, 866-889.
Kellis, E., Kellis, S., Gerodimos, V. & Manou, V. (1999). Reliability of isokinetic concentric and eccentric strength in circumpubertal soccer players. *Pediatric Exercise Science*, 11, 218-228.
Kues, J.M., Rothstein, J.M. & Lamb, R.L. (1992). Obtaining reliable measurements of knee extensor torque produced during maximal voluntary contractions: an experimental investigation. *Physical Therapy*, 72, 492- 504.
Li, R.C., Wu, &., Maffulli, N., Chan, K.M. & Chan, J.L. (1996). Eccentric and concentric isokinetic knee flexion and extension: a reliability study using the Cybex 6000 dynamometer. British Journal of Sports Medicine, 30. 156-160.
Lund, H., Søndergaard, K., Zachariassen, T., Christensen, R., Bülow, P., Henriksen, M., Bartels, E.M., Danneskiold-Samsøe, B. & Bliddal, H. (2005). Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers. *Clinical Physiology and Functional Imaging*, 25(2), 75-82.
Lunnen, J.D., Yack, J. & Leveau, B.F. (1981). Relationship between muscle length, muscle activity, and torque of the hamstring muscles. *Physical Therapy*, 61, 190-195.

Madsen, O.R. (1996). Torque, total work, power, torque acceleration energy and acceleration time assessed on a dynamometer: reliability of knee and elbow extensor and flexor strength measurements. *European Journal of Applied Physiologic*, 74, 206-210.

Madsen, O.R. & Lauridsen, U.B. (1995). Knee extensor and flexor strength in elderly women after recent hip fracture: assessment by the Cybex 6000 dynamometer of intra-rater inter-test reliability. *Scandinavian Journal of Rehabilitation Medicine*, 27, 219-226.

Maffiuletti, N.A., Bizzini, M., Desbrosses, K., Babault, N. & Munzinge, U. (2007). Reliability of knee extension and flexion measurements using the Con-Trex isokinetic dynamometer. *Clinical Physiology and Functional Imaging*, 27, 6, 346-353.

McCleary, R.W. & Andersen, J.C. (1992). Test-retest reliability of reciprocal isokinetic knee extension and flexion peak torque measurements. *Journal of Athletic Training*, 27(4), 362-365.

Moffroid, M., Whipple, R., Hofkosh, J., Lowman, E. & Thistle, H. (1969). A study of isokinetic exercise. *Physical Therapy*, 49, 735-744.

Murray, P.M., Gardner, G.M., Mollinger, L.A. & Sepic, S.B. (1980). Strength of isometric and isokinetic contractions. *Physical Therapy*, 64, 412-419.

Ordway, N.R., Hand, N., Brings, G. & Ploutz-Snyder, L.L. (2006). Reliability of knee and ankle strength measures in an older adult population. *Journal of Strength and Conditioning Research*, 20(1), 82-87.

Perrin, D.H. (1986). Reliability of isokinetic measures. *Athletic Training*, 21, 319-321.

Pincivero, D.M., Lephart, S.M. & Karunakara, R.A, (1997). Reliability and precision of isokinetic strength and muscular endurance for the quadriceps and hamstrings. *International Journal of Sports Medicine*, 18(2), 113-117.

Sole, G., Hamrén, J., Milosavljevic, S., Nicholson, H. & Sullivan, J. (2007). Test-retest reliability of isokinetic knee extension and flexion. *Archives of Physical Medicine and Rehabilitation*, 88, 626-631.

Solomorrow, M., Baratta, R. & D´Ambrosia, R. (1989). The role of hamstrings in the rehabilitation of the anterior cruciate ligament-deficient knee in athletes. *Sports Medicine*, 7, 42-48.

Symons, T.B., Vandervoort, A.A., Rice, C.L., Overend, T.J. & Marsh, G.D. (2004). Reliability of isokinetic and isometric knee-extensor force in older women. *Journal of Aging and Physical Activity*, 12, 525-537.

Thistle, H.G., Hislop, H.J., Moffroid, M. & Lowman, E.W. (1967). Isokinetic contractions: A new concept of resistive exercise. *Archives of Physical Medicine and Rehabilitation*, 6, 279-282.

Thomas, J.R. & Nelson, J.K. (1990). Introduction to research in health, physical education, recreation and dance. 2nd ed. Champaign (IL): Human Kinetics.

Tredinnick, T.J. & Duncan, P. (1988). Reliability of measurements of concentric and eccentric isokinetic loading. *Physical Therapy*, 68(5), 656-659.

Van Tulder, M., Furlan, A., Bombardier, C. & Bouter, L. (2003). Updated method guidelines for systematic reviews in the Cochrane collaboration back review group. *Spine,* 28, 1290-1299.

Worrell, T.W., Denegar, C.R., Armstrong, S.L. & Perrin, D.H. (1990). Effect of body position on hamstring muscle group average torque. *Journal of Orthopaedic and Sports Physical Therapy*, 11(10), 449-452.

Worrell, T.W., Perrin, D.H. & Denegar, C.R. (1989). The influence of hip position on quadriceps and hamstring peak torque and reciprocal muscle group ratio values. *Journal of Orthopaedic and Sports Physical Therapy*, 11(3), 104-107.

Wrigley, T.V. (2000). *Correlations with athletic performance*. En: Brown L, editor. Isokinetics in Human Performance. Champaign, Illinois: Human Kinetics, 42-73.

Yong-Hao, P., Bryant, A.L., Steele, J.R., Newton, R.U. & Wrigley, T.V. (2008). Isokinetic dynamometry in anterior cruciate ligament injury and reconstruction. *Annals Academy of Medicine Singapore*, 37, 330-340.

Referencias totales / Total references: 52 (100%)
Referencias propias de la revista / Journal's own references: 0 (0%)