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ORIGINAL

ABSOLUTE RELIABILITY OF TWO TESTS FOR ASSESSING TRICEPS SURAE FLEXIBILITY

FIABILIDAD ABSOLUTA DE DOS PRUEBAS PARA LA ESTIMACIÓN DE LA FLEXIBILIDAD DEL TRÍCEPS SURAL

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ABSTRACT

The purpose of this study was to examine the absolute reliability of both ROM-soleus and ROM-gastrocnemic tests for estimating triceps surae flexibility throughout a repeated measures design. 40 professional futsal players completed 3 evaluation sessions of ankle dorsiflexion ROM with the knee flexed (ROM-soleus) and extended (ROM-gastrocnemic) with a two-week interval between consecutive sessions. Absolute reliability was examined through estimating the following percentages: change in the mean (CM), typical percentage error (CV_{TE}) and intraclass correlation coefficients (ICC). The results of the current study showed that both ROM-soleus and ROM-gastrocnemic present high absolute reliability measures (CM < 2%; CV_{TE} < 6.5%; ICC > 0.8).

KEY WORDS: coefficient of variation, reproducibility, measurement error, range of motion, variability.

RESUMEN

El objetivo de este estudio fue examinar la fiabilidad absoluta de las pruebas de estimación de la flexibilidad de la musculatura del tríceps sural ROM-sóleo y ROM-gemelo a través de un diseño de medidas repetidas. 40 jugadores profesionales de fútbol sala completaron 3 sesiones de evaluación del ROM articular de la dorsi-flexión del tobillo con rodilla flexionada (ROM-sóleo) y extendida (ROM-gemelo) con un intervalo de 2 semanas entre sesiones consecutivas. La fiabilidad absoluta fue examinada mediante el cálculo de los estadísticos cambio en la media (CM) entre sesiones de valoración, porcentaje del error típico (CV_{ET}) e índice de correlación intraclase (ICC). Los resultados del actual estudio demuestran que las pruebas ROM-sóleo y ROM-gemelo presentan una elevada fiabilidad absoluta (CM < 2%; CV_{ET} < 6.5%; ICC > 0.8).

PALABRAS CLAVE: Coeficiente de variación, reproducibilidad, error de la medida, rango de movimiento, variabilidad.

1. INTRODUCTION

Estimating the triceps surae flexibility (gastrocnemic and soleus) is a common practice in the field of physical and sports health, since the lower values of triceps surae flexibility, the higher probability of suffering injuries due to overuse of the lower limb, such as the following: plantar fasciitis, chronic Achilles tendinopathy, medial tibial stress syndrome, iliotibial band syndrome and patellofemoral pain syndrome (Alter, 2004; Johanson, Baer, Hovermale & Phouthavong, 2008; Radford, Burns, Buchbinder, Landorf & Cook, 2006; Zito, Driver, Parker & Bohannon, 1997).

The effective assessment of the state of muscles requires a selection of diagnostic tests with a high level of reliability and validity, as well as reduced human and material costs. The tests for estimating triceps surae flexibility which examine the range of motion (ROM) in degrees of ankle dorsiflexion with the knee flexed (ROM-soleus) and extended (ROM-gastrocnemic) in standing position are probably the most common tools in order to estimate triceps surae flexibility in the research and physical and sports field (American Academic of Orthopedic Association, 1965; Ekstrand, Wiktorsson, Oberg & Gillquist, 1982, Sady, Wortman & Blanke, 1982; Möller, Öberg & Gillquist, 1985). This is mainly due to its easy use and scarce need of materials for its performance and, to a lower extent, to the scientific evidence that exist regarding its level of validity and reliability.

The evaluation of the absolute reliability (defined as the stability of the measure over the time) of triceps surae flexibility estimation tests (ROM-soleus and ROM-gastrocnemic) should be determined before they are legitimately used in the clinical and scientific field (Ayala & Sains de Baranda, 2011). In this sense, to know ROM-soleus and ROM-gastrocnemic tests' absolute reliability is very important for clinicians and specialists in the physical and sports area, since they may be used to determine sensibility and estimate the required magnitude in the variation of its initial levels. This could be considered as a "real change" beyond the measure's error (due to technical and biological variation). On a practical level, the analysis of absolute reliability allows to value the "real efficiency" of intervention programs about initial values of flexibility of patients and sportsmen triceps surae, as well as a better interpretation of the results obtained in previous studies where these exploratory tests are used. In the same way, another important use of absolute reliability is the possibility to compare between different diagnostic tests and even clinicians and researchers may use this information to determine the sample size of their studies (Atkinson & Nevill, 1998; Hopkins, 2000; Hopkins, Marshall, Batterham & Hanin, 2009).

However, despite the extensive use that ROM-soleus and ROM-gastrocnemic tests currently has as tools to estimate triceps surae flexibility, there are surprisingly no scientific studies (as far as authors' knowledge is concerned) which had determined their absolute reliability. Therefore, it is clear the need of scientific studies regarding the analysis of absolute reliability of these triceps surae flexibility estimation tests.

As a result, the main object of this study was to examine the inter-session absolute reliability of triceps surae flexibility estimation tests ROM-soleus and ROM-gastrocnemic with professional futsal players.

2. METHOD

2.1. Participants

A total of 40 professional futsal players (20 men and 20 women) fulfilled this study (4-7 training sessions per week with a minimum duration of 1.5 hours per session) (Table 1).

Table 1: Statistical description of participants' Age, Weight, Size and Body Mass Index (BMI).

Mean \pm SD	Men (n=20)	Women (n=20)
Age (years old)	20.1 \pm 2.8	22.4 \pm 5.3
Weight (kg)	73.3 \pm 7.7	59.4 \pm 7.5
Size (cm)	173 \pm 6.1	166.2 \pm 4.9
BMI (kg/cm ²)	24.5 \pm 2.5	21.4 \pm 2.1

Kg: kilograms; cm: centimetres

All participants were high level futsal players with more than 8 years of sports training who competed in the feminine first division and men football silver leagues of the National Futsal League (NFSL) of Spain. The study was carried out during the sports year 2010-2011.

The exclusion criteria established were the following: (a) to present musculoskeletal disorders such as tears in the triceps surae and Achilles tendon during the last 6 months previous to the exploratory procedure; (b) to present delayed-onset muscle soreness (stiffness) during any of the three evaluation moments; and (c) not to attend one or more sessions of assessment throughout the data collection process.

All inclusion and exclusion criteria were evaluated by two investigators with extensive experience in the scientific and clinical field (Bachelor of Medicine and Bachelor of Surgery with over 10 years experience). They used a questionnaire of medical and physical and sports assessment. All participants were informed (orally and through an information sheet) of the methodology used, as well as the aims and the study's possible risks, and an informed consent was signed by each of them. The present study was approved by the Ethical and Scientific Committee of the University of Murcia (Spain).

2.2. Procedure

The study of the absolute reliability of ROM of ankle dorsiflexion with the knee flexed (ROM-soleus) and extended (ROM-gastrocnemius) assessment tests was carried out through a repeated measured design and according to the recommendations established by Hopkins et al. (2009).

Therefore, a week before the experimental phase, all participants performed a familiarization session with the aim of knowing the appropriate technical execution of all the exercises of the exploratory procedure. At the same time, another aim of this performance was to reduce the possible learning bias in the results obtained in different assessment tests. After the familiarization session, each participant was examined a total of 3 times, with a two-week interval between consecutive sessions.

Each of the assessment sessions was held by the same two experienced clinicians (one controlled the correct position of the participant during the whole exploratory process [stabilization of body segments] and the other directed the test) under the same environmental conditions and times in order to try to minimize the possible influence of the inter-examiner variability and circadian rhythms on the results (Atkinson & Nevill, 1998). Both examiners were blinded to the results obtained by participants in the different evaluation sessions (blind reviewers). In addition, participants were encouraged to perform each of the assessment sessions during the same days and times that they normally perform their physical sport sessions in order to minimize intra-subject variability (Hopkins, 2000).

Before each assessment session, all participants performed 5 minutes of aerobic warm-up (light race) together with a series of standardized stretching exercises (Gabbe, Bennell, Wajswelner & Finch, 2004), emphasizing the activity of calf and soleus muscles, under the strict supervision of examiners. In this sense, two stretching exercises were selected, imitating each of them the position adopted in the two selected assessment tests. Previous studies suggest that the changes caused by stretching on the viscoelastic properties of the muscles remain stable for at least 20 minutes after the application of stretching volumes of 120-150 seconds (Ford & McChesney, 2007; Power, Behm, Cahill, Carroll & Young, 2004). Therefore, in order to ensure muscles' properties stability during the whole assessment process, the stretching exercises sequence presented a total volume of 180 seconds (6 sets of 30 seconds per exercise and leg).

Aerobic warm-up and standardized stretching sequence were carried out due to the following reasons: (a) all assessment tests submit calf and soleus muscles to maximum tension forces; and (b) to try to minimize variability and standard error of the measurement by reducing the effect that different muscular stretching and temperature have on the viscoelastic properties of the soft tissue (Dixon & Keating, 2000).

After completing the warm-up and stretching exercises, participants were urged to make two maximum attempts for each of the assessment tests and body segment (left and right) in a random way in order to eliminate bias that a specific sequence could present on the results obtained. The mean value of each pair of attempts for each assessment test was selected for the subsequent statistical analysis (Ayala & Sainz de Baranda, 2011; Khan et al., 2000; Gabbe et al., 2004). Randomization in conducting the evaluation tests are carried out through the blind extraction by each participant of a card from a Spanish deck, so that the first test to be performed was determined by the number of the selected card, being equivalent even numbers to ROM-soleus test and odd numbers to ROM-gastrocnemic test.

Each participant was examined wearing sports clothes without footwear (Castro-Piñero, Chillon, Ortega, Montesinos, Sjostróm & Ruiz, 2009).

2.3. Assessment Tests

ROM-soleus and ROM-gastrocnemic assessment tests were held under methodological guidelines established by the American Academic of Orthopedic Association (1965) and the American College of Sports Medicine (2001). An inclinometer ISOMED Unilevel with telescopic extendable rod was used for both exploratory tests. Before each assessment session the inclinometer was calibrated at 0° from vertical.

Tables 2 and 3 present the description and the graphical representation of ROM-soleus and ROM-gastrocnemic tests respectively.

Table 2: ROM of ankle dorsiflexion with the knee flexed (ROM-soleus) assessment test.



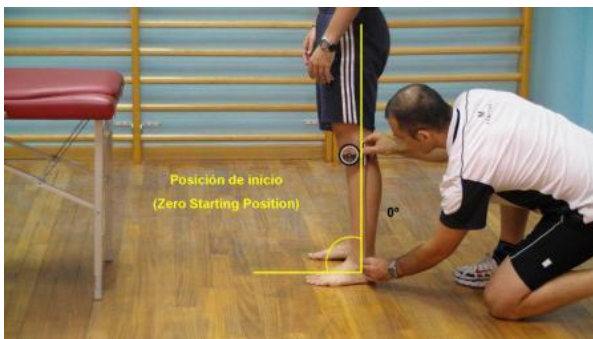
Starting Position	The subject stands with feet parallel and hip width apart. The explored leg was placed on a box to maintain knee flexion between 90°-120°. The inclinometer was situated on the fibular head and the inclinometer's extension "rod or branch" was placed on the bisector of the leg.
Stabilization (auxiliary explorer)	The auxiliary explorer ensured that the rotational motion of the hip and ankle was avoided, besides controlling the heel did not lose contact with the ground.
Movement (main explorer)	The subject performed a movement of ankle dorsiflexion doing a knee forward bend slowly and gradually keeping the heel in contact with the box
Final Position	Established through the maximum tolerable stretching sensation by the subject and/or the detection by the auxiliary explorer of the start of any compensation motion that increases the ROM or causes pain.
Graphical representation	
	
Starting Position	Final Position

Table 3: ROM of ankle dorsiflexion with the knee extended (ROM-gastrocnemic) assessment test.

Starting Position	The subject stands face to the wall with feet parallel and hip width apart. The inclinometer was placed on the lateral epicondyle of the femur and the extension of the inclinometer "rod or branch" was placed on the bisector of the leg.
Stabilization (auxiliary explorer)	The auxiliary explorer ensured that the knee was always extended, the hip and the ankle were in anatomical position and the heel did not lose contact with the ground.
Movement (main explorer)	The subject performed a step forward resting his/her hands on the wall and immediately after that a heel dorsiflexion slowly and progressively "approaching" the gluteus to the wall.
Final explorer	Established through the maximum tolerable stretching sensation by the subject and/or the detection by the auxiliary explorer of the start of any compensation motion that increases the ROM or causes pain.

Graphical Representation



Starting Position



Final Position

2.4. Statistical Analysis

Prior to any statistical analysis, the normal distribution of data was checked by the Kolmogorov-Smirnov test. A descriptive analysis was performed for each of the quantitative variables; it included the mean and its standard deviation. In addition, a Student's *t*-test was used to determine significant differences between the values of right and left lower extremity tests.

The absolute reliability of each of the assessment tests (ROM-soleus and ROM-gastrocnemic) was determined by calculating the statistics, the change in the mean between assessment sessions expressed in percentage terms (CM), the typical percentage error (expressed as the coefficient of variation [CV_{ET}] and through the intraclass correlation coefficient (ICC) using the method previously described by Hopkins (2000) and Hopkins et al. (2009). Thus, the absolute reliability was calculated by using the average value of all reliability values of each two consecutive sessions (2-1 and 3-2) in each of the assessment sessions (Hopkins, 2000).

Two (ROM-gastrocnemic and ROM-soleus) x 3 (assessment session 1-3) repeated measures analysis of variance (RMANOVA) was used to identify the change in the average values (systematic bias) and the standard deviation of the difference between two consecutive assessment sessions for each of the variables tested (Bonferroni post hoc test). The sphericity of the data was confirmed through the Mauchly's test.

The CM was calculated through the RMANOVA model as the difference between the means obtained in consecutive sessions, taking the logarithm of the values achieved by participants.

The CV_{ET} was calculated through the use of logarithms using the following equation:

$$100 (e^s - 1)$$

In this equation, *s* represents the standard error (standard deviation of the difference between consecutive assessment sessions / $\sqrt{2}$). Transforming the data to logarithms was performed as a means to successfully minimize the possible presence of heterocedasticity in them (Atkinson & Nevill, 1998; Hopkins, 2000). In order to interpret the results obtained through the calculation of CV_{ET} the following arbitrary idea was considered: variability less than 10-15% for a measurement tool is "acceptable" for the scientific literature (Atkinson & Nevill, 1998; Castro-Piñero et al., 2009; Hopkins, 2000; Stokes, 1985).

On the other hand, the sample's ICC was calculated following the equation below:

$$(F - 1) / (F + k - 1)$$

In this equation, *F* is the within-subjects F-ratio, and *k* (3) in the total number of assessment sessions (Hopkins et al., 2009; Schabert, Hopkins & Hawley, 1998). Hopkins et al. (2009) categorize the magnitude of ICC obtained values through a qualitative scale, so that values close to 0.1 are considered low values, those close to 0.3 are moderate values, the values close to 0.5 are high values, those close to

0.7 very high values and the values close to 0.9 are considered extremely high values.

The statistical analysis was performed using SPSS (Statistical Package for Social Sciences, v. 16.0 for Windows; SPSS Inc, Chicago) and Microsoft Excel 2003.

3. RESULTS

The Student's t-test for related samples showed significant differences ($p < 0.05$) in the results obtained in the right and left legs ROM-soleus and ROM-gastrocnemic tests. Therefore, the results of both legs were used to analyze the absolute reliability.

Table 4 shows the descriptive statistics (mean of each assessment session [$k = 3$] \pm standard deviation) and the absolute reliability statistics (mean and 90% confidence interval) of the sample study for each of the exploratory tests. There were no significant differences between the results obtained in the two consecutive sessions ($p > 0.05$).

Table 4: Absolute reliability statistics for ROM-soleus and ROM-gastrocnemic.

Degrees	Mean and standard deviation			Mean and 90% CI		
	Measurement 1	Measurement 2	Measurement 3	CM	CV _{ET}	ICC
Right calf	39.8 \pm 6.1	37.5 \pm 6.1	39.47 \pm 5.96	0.36 (-1.94/-2.67)	4.02 (3.13-5.70)	0.90 (0.79-0.96)
Left calf	41.4 \pm 4.94	39.6 \pm 4.8	41.47 \pm 5.45	-0.16 (-2.32/2)	3.75 (2.92-5.32)	0.88 (0.75-0.95)
Righ soleus	41.2 \pm 5.1	39.2 \pm 5.9	39.79 \pm 5.77	-0.49 (-1.77/2.75)	3.92 (3.06-5.56)	0.90 (0.79-0.96)
Left soleus	42.8 \pm 6.3	39.5 \pm 6.3	41.47 \pm 5.92	1.76 (-0.67/4.19)	4.22 (3.29-5.99)	0.91 (0.81-0.96)

CM: Change in the mean; CV_{ET}: coefficient of variation according to the mean standard error; ICC: intraclass correlation coefficient; CI: confidence interval

All the analyzed exploratory tests presented high values of absolute reliability (CM: -0.16-1.76%; CV_{ET}: 3.76-4.22%; ICC: 0.88-0.91) and there were no clinically relevant differences between their inter-session variability levels. Furthermore, similar values of absolute reliability were found per each of the assessment tests according to the limb evaluated (left and right).

4. DISCUSSION

The absolute reliability is an essential component to justify the use of fitness assessment techniques in the field of Sport Science (Peeler & Anderson, 2008). In this sense, the assessment tests ROM-soleus and ROM-gastrocnemic are frequently used as clinical tests for estimating the triceps surae muscles flexibilities.

In addition, nowadays there is incipient scientific evidence that suggests the evaluation and later monetarization of the triceps surae flexibility as tools: (a) to

identify sportsmen with high injury risk of the lower limb (Bozic, Pazin, Berjan, Planic, Cuk, 2010; Bradley, Olsen & Portas, 2007; Dadebo, White & George, 2004; Kibler & Chandler, 2003; Shellock & Prentice, 1985; Wang, Whitney, Burdett & Janosky, 1993; Weerapong, Hume & Kolt, 2004); and (b) to quantitatively assess the impact of certain therapeutic interventions and/or the effect of a training program on their initial mobility level.

However, there is no scientific studies (as far as the authors are concerned) which analyze the inter-session absolute reliability of the ROM-soleus and ROM-gastrocnemic assessment tests, so that their usefulness is unknown. Therefore, the main aim of this study was to examine the inter-session absolute reliability of the ROM-soleus and ROM-gastrocnemic triceps surae muscles flexibility estimation tests in futsal players.

In order to determine the absolute reliability of these assessment tests, the present study used the statistics CM, CV_{ET} and ICC, as well as their confidence intervals of 90%. These statistics were chosen based on the recent suggestion made by Hopkins et al. (2009) about the analysis in reproducibility studies.

The CM specifically reflects the change in the average value of each variable between assessment sessions (Hopkins, 2000). It is especially important when a group of athletes perform a series of assessment sessions as part of the process of monitoring the effectiveness of an intervention program, since the general trend of the measure tends to be different in a direction in particular (positive or negative) between assessment sessions (Hopkins, 2000; Cameron, Adams, Maher, 2003). It is important to use simple familiarization sessions and exploratory procedures that minimize the possible influence that the learning bias could have on the magnitude of the results of an assessment test, which could influence the CM statistical (Iga, George, Lees & Reilly, 2006).

When it is desired to make an interpretation of the changes in a variable after an intervention, clinicians and professionals in the field of Sport Sciences must decide whether these changes are real or only reflect the magnitude of the measurement error used. In this sense, if a change in the initial values of a variable established for a group of people presents a magnitude lower than the CV_{ET} of the measure is very likely (68% certainty) that this change reflects the measurement error and therefore it is not clinically relevant (Hopkins, 2000). Similarly, Hopkins (2000) suggests that a threshold around 1.5-2 times the magnitude of the standard error may also be appropriate to indicate that there has been a real change in the person's individual previous levels (80-90% chance) .

Finally, the ICC reflects the degree of proximity or correlation between values obtained at different times after applying the same assessment test. It shares with the CV_{ET} the advantage of being dimensionless, and therefore it allows its comparison with other reliability studies that use different exploratory procedures, assessment tools and study populations (Hopkins, 2000).

The results of the assessment tests used in the present study (ROM-soleus and ROM-gastrocnemic) regarding the CM show no significant differences ($p > 0.05$) and lower than 2% between assessment sessions. These results tentatively suggest that

the familiarization session was carried out effectively so as to eliminate possible systematic bias associated with the technical learning of exploratory tests by participants.

Considering the arbitrary idea commonly accepted that an inter-session variability lower than 10% for a given assessment tool can be considered acceptable to use in the scientific and clinical fields (Atkinson & Nevill, 1998, Hopkins, 2000; Hopkins, 2009; Vincent, 1994), then the analysis of the absolute reliability carried out in this study shows acceptable levels of intra-subject variability (expressed through the CV_{ET}) for both ROM-gastrocnemic test (4.02% and 3.75 % right and left legs respectively) and the ROM-soleus test (3.92% and 4.22% right and left legs respectively), after 3 measurement sessions (with an interval of two weeks between consecutive sessions).

Similarly, the values obtained in the ICC for both estimation of triceps surae flexibility tests ranged from 0.88 to 0.91, which results in a qualitative rating of "very high" on the measuring scale recently established by Hopkins et al . (2009).

Therefore, the overall interpretation of the results of this scientific study shows that estimation of the triceps surae muscles flexibility tests ROM-soleus and ROM-gastrocnemic are measurement tools with a large absolute reliability.

From a practical point of view, the results of absolute reliability on both assessment tests performed in this study provide useful information, since it allows taking decisions based on whether there was a "real change" between assessment sessions after treatment application (e.g. muscles stretching program) or, on the contrary, the observed change is simply the result of the standard measurement error. Therefore, if Hopkin's proposal (2000) is used as the threshold for application (1.5-2 times the standard error), a change in flexibility higher than 6.03% (right ROM-gastrocnemic), 5.6% (left ROM-gastrocnemic), 5.88% (right ROM-soleus), 6.33% (left ROM-soleus), after performing an intervention program could indicate a possible real change.

Unfortunately, the comparison between the results obtained in this study and those observed in other studies was not possible because, from our present knowledge, the current study is the first to analyze the absolute reliability of the ROM-soleus and ROM-grastrocnemic tests using contemporary statistical methods as those proposed by Hopkins (2000).

One of the potential limitations of this study was the population used. Although the design contained 40 participants and 3 assessment sessions, which could respond to what Hopkins et al (2009) demand (50 participants and 3 assessment sessions), all them were homogeneous in age and level of fitness, and it may slightly limit the external validity of the results. In addition, in order to promote consistency amongst assessment tests, the stretching level during the maximum ankle's dorsiflexion motion was determined by participants instead of by clinicians. Future studies should consider establishing a stretching criterion regulated according to participants' weight in order to apply the same stretching strength (Davis, Quinn, Whiteman, Williams & Young, 2008), as well as the use of a greater number of subjects and assessment sessions.

5. CONCLUSIONS

The results of the present study show that the ROM of ankle dorsiflexion with the knee flexed (ROM-soleus) and extended (ROM-gastrocnemic) have large absolute reliability ($CV_{ET} < 10\%$; $ICC > 0.8$) estimated through the recent method described by Hopkins et al. (2009). Therefore, ROM-soleus and ROM-gastrocnemic tests are recommended to monitor triceps surae muscles flexibility levels.

From a sports training point of view, a change in the initial flexibility level of triceps surae flexibility higher than 6% for ROM-gastrocnemic and ROM-soleus tests after performing an intervention program, could indicate that a “real change” happened (80-90% probability) and not only due to the measurement error.

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