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ORIGINAL

OPTIMUM PROFILE OF LOWER-LIMB MUSCLE FLEXIBILITY IN FEMALE FUTSAL PLAYERS

PERFIL ÓPTIMO DE FLEXIBILIDAD DEL MIEMBRO INFERIOR EN JUGADORAS DE FÚTBOL SALA

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ABSTRACT

The purpose of this study was to define the optimal lower-limb flexibility data for 20 female futsal players. Therefore, the flexibility of the major lower-limb muscles was evaluated throughout 7 different passive range of motion (ROM) assessment tests. The results of this study define the optimal ROM ranges for field players as: 43°-52° for the gastrocnemius, 48°-54° for the soleus, 148°-154° for the gluteus maximus, 99°-118° for the hamstrings, 46°-56° for the adductors, 12°-20° for the iliopsoas, and 116°-129° for the quadriceps. For goalkeepers have obtained the following ranges: 40°-46° for the gastrocnemius, 40°-47° for the soleus, 150°-155° for the gluteus, 94°-118° for the hamstrings, 45°-54° for the adductors, 8°-12° for the iliopsoas, and 115°-133° for the quadriceps. Keeping in mind that optimal ROM values were defined as >80th

percentile, only 4 field players and 2 goalkeepers presented this ROM values in each movement assessed.

KEY WORDS: Flexibility, range of motion, physical condition, sports.

RESUMEN

El objetivo fue definir cuantitativamente los valores del perfil óptimo de flexibilidad en 20 jugadoras de fútbol sala. Para ello, se valoró la flexibilidad de los principales grupos musculares del miembro inferior a través de 7 pruebas de rango de movimiento pasivo máximo (ROM). Los resultados del presente estudio definen como ROM óptimo los siguientes rangos para las jugadoras de campo: 43°-52° para gemelo, 48°-54° para sóleo, 148°-154° para glúteo mayor, 99°-118° para musculatura isquiosural, 46°-56° para aductores, 12°-20° para psoas iliaco y 116°-129° para cuádriceps. Para las porteras se han obtenido los siguientes rangos: 40°-46° para gemelo, 40°-47° para sóleo, 150°-155° para el glúteo mayor, 94°-118° para musculatura isquiosural, 45°-54° para aductores, 8°-12° para psoas iliaco y 115°-133° para cuádriceps. Teniendo en cuenta que se ha definido el percentil >80 como el ROM óptimo, sólo 4 jugadoras de campo y 2 porteras presentaban este ROM en cada movimiento evaluado

PALABRAS CLAVE: Flexibilidad, rango de movimiento, condición física, deportes.

1. INTRODUCTION

Flexibility, defined as the intrinsic ability of body tissues to determine the maximum range of movement without reaching a sports injury (Holt, Pelham and Holt, 2008), is one of the basic physical qualities for sports performance (Alricsson and Werner, 2004; Hahn, Foldspang, Vestergaard and Ingemann-Hansen, 1999). More specifically, Kraemer and Gomez (2001) claim that flexibility is an essential component of the physical condition of elite sportsmen.

The Range of motion (ROM) represents the indirect measurement (quantitative terms, in degrees) of muscle flexibility. In this regard, it has been reported that when a player shows normal and specific values of flexibility in each joint for a certain sport, he/she has the optimum ROM in order to promote the maximum physical-technical sports performance with a lower predisposition to sports injury (Riewald, 2004; Santana, 2004). Thus, several studies have observed that sports performance declines with both the extreme ROM "hypermobility" (Gannon and Bird, 1999; Snyder, McLeod and Hartman, 2006) and the limited ROM due to a lower muscle extensibility "muscle shortness" (Young, Clothier, Otago, Bruce and Liddell, 2003; Rahnama, and Lees, 2005; Zakas, Vergou, Zakas, Grammatikopoulou and Grammatikopoulou, 2002; Zakas, Vergou, Grammatikopoulou, Sentelidis and Vamvakoudis, 2003). In addition, muscle shortness was correlated with muscle injury (Bradley, Olsen and Portas, 2007; Dadebo, George and White, 2004; Ekstrand, Wiktorsson, Oberg and Gillquist, 1982; Rahnama et al., 2005; Witvrouw Danneels, Asselman, D'Have and

Cambier, 2003), the ligament injury and sprained ankle (Ekstrand et al, 1982; Pope, et al., 1998; Okamura et al, 2014) and the anterior cruciate ligament rupture (Ellera, Vieira and Becker, 2008), and injury caused by overuse such as plantar fasciitis, patellar and Achilles tendinopathy, tibial periostitis, iliotibial band syndrome and patellofemoral pain syndrome (Witvrouw, Mahieu, Roosen and McNair, 2007; Probst, Fletcher and Seeling, 2007; Johanson, Baer, and Phouthavong and Hovermale, 2008).

Therefore, the knowledge of the optimum ROM's values in sports can be a breakthrough in the world of physical and sport training, as it will achieve, together with the optimum values in other determining physical qualities for sports performance, sporting success. In addition, these benchmarks will be used to set specific and quantified objectives in training flexibility as basic physical quality to optimize the physical and technical sports performance.

However, in the scientific literature we have not found optimum ROM quantitative values for sportsmen. Most reference values used for the ROM are those published by the American Association of Orthopedic Academic [AAOA] (1965), the American Medical Association [AMA] (Gerhardt, Cocchiarella and Read, 2002) and the classic manuals for musculoskeletal assessment (Clarkson, 2003; Palmer and Epler, 2002) assigned to all joints of the body for the general population. These values have guided Sports and Health professionals to provide a joint ROM and an optimal function in a healthy joint. However, considering that the ROM is specific to each sport (Cejudo, Sainz de Baranda, Ayala and Santonja, 2014a,b; Gleim and McHugh, 1997), competitive level (Battista, Pivarnik, Dummer, Sauer and Malina, 2007; Gannon and Bird, 1999; Haff, 2006), joint, action or movement (Hahn et al., 1999; Zakas et al., 2002; Hedrick, 2002), gender (Canda, Heras and Gomez, 2004; Kibler and Chandler, 2003), body segment (dominant and non-dominant) (Chandler et al., 1990; Magnusson, Aagard, Simonsen and Bojsen-Møller, 1998; Probst et al, 2007) and tactical position (Cejudo, Sainz de Baranda, Ayala and Santonja , 2014th; Oberg, Ekstrand, Möller and Gillquist, 1984), applying this traditional approach does not allow the athlete to define the optimum flexibility profile.

Therefore, the main objective of this study is quantitatively define the reference values of the optimum profile of flexibility in 20 futsal players, measuring the flexibility of the main muscles of the lower limb through testing the maximum passive ROM.

2. MATERIAL AND METHODS

2.1. Participants

A total of 20 futsal players, with more than 10 years practicing this sport (4 weekly training sessions with a minimum of 1.5 hours per session), voluntarily participated in this study; 15 field players (age: 22.33 ± 4.94 years; weight: 57.71 ± 7.03 kg, size: 166.07 ± 4.67 cm) and 5 goalkeepers (age: 22.20 ± 6.22 ; weight: 64.80 ± 2.95 kg, size: 167.40 ± 5.18 cm). All players competed in the Women's Futsal Division of Honor (Honor Division Women futsal) in the

2009/10 season and two players were part of the National Futsal Team (Futsal National Selection).

The exclusion criteria established were the following: (a) having a clinical history of disorders of the musculoskeletal lower limb in the 6 months prior to this exploratory procedure; and (b) providing delayed onset muscle soreness (stiffness) at the time of being assessed, due to the fact of restricting the extensibility of the muscle-tendon unit and consequently the joint mobility (McHugh, Connolly, Eston and Gleim, 1999).

Both athletes and coaches were verbally informed of the methodology used and the purposes and potential risks of the study, and each of them signed an informed consent. This study was approved by the Ethics and Scientific Committee of the University of Murcia (Spain).

2.2. Procedure

A week before the start of the study, all participants completed a sports medical questionnaire (personal data, anthropometric data, sports data, injury history, experience with stretching and stressed muscle groups during the competition), as well as being subjected to a familiarization session in order to know the correct technical execution of the assessment tests through the practical performance of each of them. Similarly, another purpose of this familiarization session was the reduction of possible learning bias towards the results obtained in the different assessment tests (Ayala and Sainz de Baranda, 2011). In addition, during this session of familiarization, and in order to learn the dominant member, each player was asked to perform three tests: 1) jumping on one leg; 2) hitting a ball; and 3) climbing onto a stool with one leg, following the methodology of Wang, Whitney, Burdett and Janosky (1993). The member with which at least 2 of the 3 tests were executed was designated as the dominant member.

For the assessment process of the maximum passive ROM, the recommendations by the American Academic of Orthopedic Association (1965) and the American Medical Association [AMA] (Gerhardt, Cocchiarella and Lea, 2002) were followed.

All assessments were performed in the same environmental conditions and time slot to try to minimize the possible influence of the inter-examiner and circadian rhythms variability on the results (Atkinson, Nevill, 1988). Furthermore, athletes were encouraged to perform the assessment session on the same day and time slot in which they normally performed their training sessions to minimize the intra-subject variability (Hopkins, 2000).

Before applying the different assessment tests, all participants performed a standard warm-up that included 5-10 minutes of moderate race followed by 2 series of 30 seconds of standardized static stretching exercises, emphasizing the activity of the muscles of the lower limb under the strict supervision of examiners (Cejudo et al., 2015).

Once the warming up was finished, seven maximum angular passive tests were carried out to indirectly measure the extensibility of the main muscle groups of the lower limb [calf, soleus, quadriceps, iliopsoas, adductors, hamstring, gluteus maximus] (Wepler and Magnusson , 2010). The results of these measurements define the optimum profile of flexibility of the lower limb (Figure 1), which are part of the short version of the ROM-SPORT protocol. The hip flexion ROM was assessed with extended knee through the "Test of the Straight Leg Raising" (FCRE) for hamstrings, with bent knee (FC) for the gluteus maximus. The hip extension was assessed through the "Modified Thomas Test" (EC) for the iliopsoas and the hip abduction with knee extended (ABC) for the adductors. Regarding the knee, its flexion was measured by the "Modified Thomas Test" (FR) for the quadriceps. With regards to the ankle, the dorsi-flexion with the knee fully extended was used by the "Test of the modified stride" (DFTRE) for the calf, and dorsi-flexion with flexed knee through the "Test of the stride" (DFTRF) for the soleus (Cejudo et al., 2014a,b).

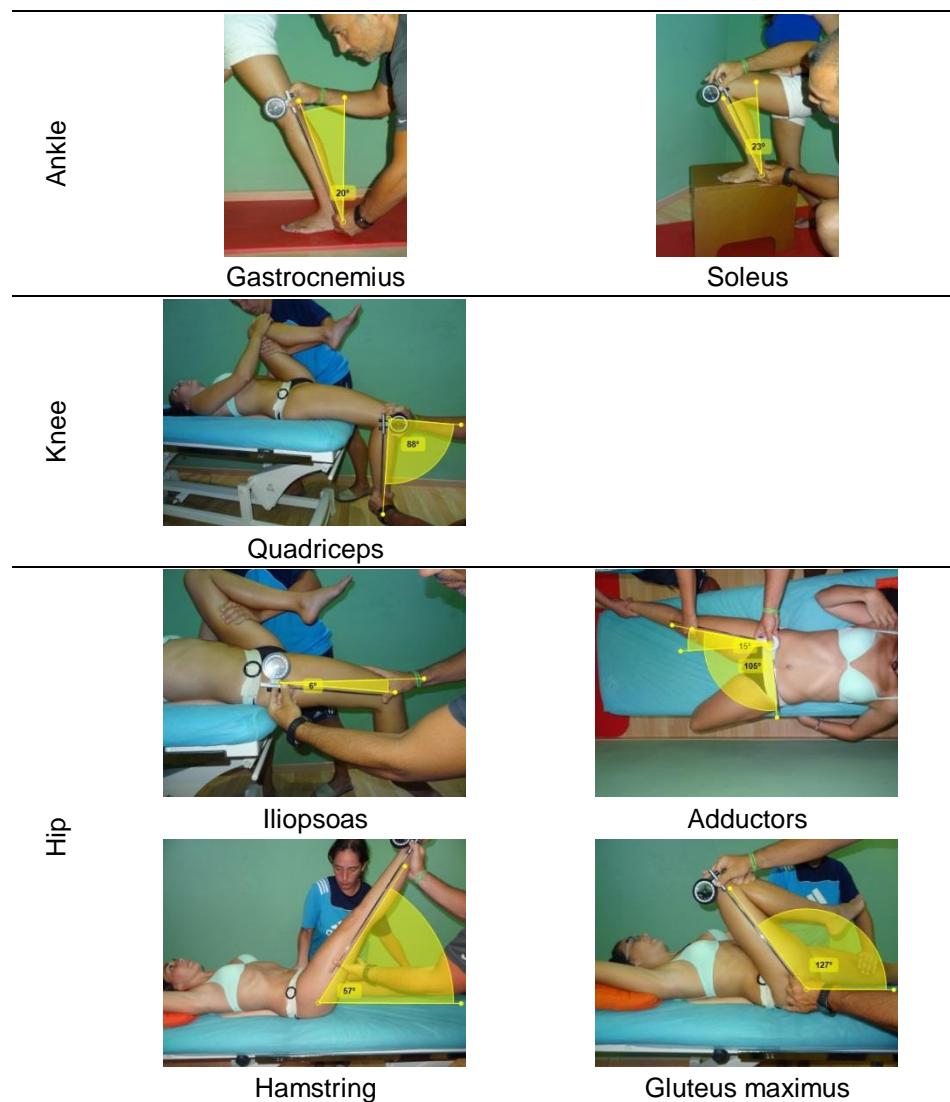


Figure 1: Graphical representation of the 7 assessment tests of the maximum passive range of motion used in the present study.

Participants were urged to make two maximum passive attempts for each of the assessment and body segment tests (dominant and non-dominant) in a random way in order to eliminate bias that could appear on the results in a specific sequence. However, when a difference bigger than 5% was observed between the value of each pair of attempts, a third attempt was made, and the average value of the two attempts whose results were closest to the subsequent statistical analysis were selected (Ayala, Sainz Baranda, 2011; Gabbe et al, 2004). Randomization in conducting assessment tests was carried out through the use of the computer software Research Randomizer (<http://www.randomizer.org>).

The assessment session was conducted by two experienced examiners. One of them led the test passively moving the assessed limb throughout the ROM for 3 consecutive cycles, while the other examiner provided a correct position of the participant during the whole exploratory process (stabilization of body segments), avoiding compensatory movements. Participants performed three consecutive cycles of passive movements throughout the ROM in order to be able to: (a) differentiate a possible occurrence of stretching myotatic reflex or involuntary muscle contraction; and (b) identify the end of the ROM in the last cycle as a result of a structural limitation of the muscle tissue (Stuberg, Miedaner and Fuchs, 1988).

For the measurement, an ISOMED Unilevel inclinometer (Portland, Oregon) was used with extendable telescopic rod (Gerhardt, 1994; Gerhardt, Cocchiarella, Lea, 2002), a metal goniometer with long arm (Baseline® Stainless) and "lumbosant" -lumbar support- to standardize the lumbar curvature (Santonja, 1995). Before each assessment session, the inclinometer was calibrated to 0° with either the vertical or horizontal. The angle between the longitudinal axis of the mobilized segment was recorded (following its bisector) with the vertical or the horizontal (Gerhardt, Cocchiarella, Lea, 2002; Cejudo et al, 2015.). On the other hand, for the assessment of hip abduction movement a metal goniometer of long arm (Baseline® Stainless) was used.

Each participant was assessed with sports clothes and barefoot. A period of about 30 seconds between each of the maximum two attempts, limb and test, was allowed to rest.

The final outcome of each maximum passive attempt for each of the assessment tests, was determined by one or more of the following criteria: (1) the examiner was unable to continue the joint movement evaluated due to the high resistance developed by the muscle or group of muscles stretched (American Academic of Orthopedic Surgeons, 1965; Zakas, 2005, Aalto et al., 2005); (2) the assessed participant warned about feeling a muscle stretching that entailed a major discomfort (Ekstrand et al, 1982; Zakas et al., 2003); and/or (3) both examiners appreciated some compensation movements that increased the ROM (Ekstrand et al.1982; Clark, Christiansen, Hellman, Winga and Meiner, 1999; Sainz de Baranda and Ayala, 2010) and/or (4) by the fact that allergies appeared in the explored joint.

The intra-session reliability of each of the variables was determined through the intraclass correlation coefficient (ICC_{2,1}) using the method previously described by Hopkins (2000). The ICC was above 0.90 in all assessment tests, demonstrating a high stability of the measurement (Cejudo, Sainz de Baranda, Ayala and Santonja 2015).

2.3. Statistical analysis

Prior to any statistical analysis, the normal distribution of data was verified through the Kolmogorov-Smirnov test. A descriptive analysis of each of the quantitative variables, including average and corresponding standard deviation, was performed. Moreover, a t-test for related samples was used to determine the existence of bilateral asymmetry of flexibility between the values of the dominant and non-dominant sides. In order to establish the categorization of flexibility the proposal adapted from Canda et al. (2004) and Cejudo et al. (2014a,b) was followed, considering the values above the percentile scale higher than 80 ($P > 80$) as "optimum" ROM (Table 1).

Table 1. Different flexibility categories according to percentiles.

Canda et al. (2004)		Present study (Cejudo et al., 2014a,b)	
$P > 95$	Very good	>80	Optimum
$P 95 - 85$	Very good		
$P 79 - 60$	Good		
$P 59 - 40$	Normal	20 – 80	Normal
$P 39 - 20$	Regular		
$P 19 - 5$	Low		
$P < 5$	Very low	<20	Limited

3. RESULTS

In Tables 2 and 3 the results of the assessment (ROM) of the 7 studied muscle groups flexibility are presented, differentiated the data found between the dominant and non-dominant member in both field players and goalkeepers. When differences between the dominant and non-dominant side were analyzed, no significant differences were found amongst goalkeepers ($p > 0.05$), while significant differences were found amongst field players regarding flexibility of calf, soleus and quadriceps between both body sides.

You can also appreciate the values defined for optimum ROM in each studied muscle flexibility and the number of players who presented this range. 3 out of the 15 field players obtained a limited ROM, 8 players a normal ROM and 4 players an optimum ROM in all evaluated movement, except from the flexibility of the gluteus maximus, which found five players. With regards to goalkeepers, there was one player with limited ROM, 3 players with a normal ROM and 2 players with optimum ROM in each evaluated movement.

Table 2. Mean and optimum values for maximum passive range of motion from 15 futsal field players.

Field players	Mean±SD		Optimum ROM (P>80)			
	Dominant	Non-Dominant	Dominant	N (%)	Non-Dominant	N (%)
Iliopsoas (EC)	7.2°±5.8°	8.2°±5.6°	12.3°-18°	4 (26.6%)	13.3°-20°	4 (26.6%)
Gastrocnemius (DFT _{RE})	40°±5.1°	41.9°±5.4°*	43.3°-49.9°	4 (26.6%)	45.6°-52°	4 (26.6%)
Soleus (DFT _{RF})	41.7°±5.9°	43.8°±6.3°*	48.6°-50.6°	4 (26.6%)	50°-53.3°	5 (27.8%)
Adductors (ABD)	44.4°±3.4°	46.1°±4.5°	46.6°-51°	4 (26.6%)	48.6°-55.3°	4 (26.6%)
Hamstrings (FC _{RE})	90.2°±14.1°	88.5°±13.7°	99.6°-118°	4 (26.6%)	99.3°-116°	4 (26.6%)
Quadriceps (FR)	105.6°±13.2°	112.5°±9.9°*	116.3°-124.6°	4 (26.6%)	118.6°-128.6°	4 (26.6%)
Gluteus maximus (FC)	147.6°±3.5°	146.9°±2.4°	150.6°-153°	5 (33.3%)	148°-151°	5 (33.3%)

* Significant differences between dominant and non-dominant sides.

Table 3. Mean and optimum values for maximum passive range of motion from 5 futsal goalkeepers.

Goalkeepers	Mean±SD		Optimum ROM (P>80)			
	Dominant	Non-Dominant	Dominant	N (%)	Non-Dominant	N (%)
Iliopsoas (EC)	6.6°±2.5°	7.8°±2.7°	8.3°-8.6°	2 (40%)	9.3°-11.3°	2 (40%)
Gastrocnemius (DFT _{RE})	38.2°±2.2°	39.3°±4.1°	40°-40.6°	2 (40%)	39.3°-46°	2 (40%)
Soleus (DFT _{RF})	40.1°±1.5°	41.8°±3.2°	40.6°-42.6°	2 (40%)	41.3°-47°	2 (40%)
Adductors (ABD)	44.5°±3.9°	47.3°±4.4°	45.3°-50°	2 (40%)	49.3°-54°	2 (40%)
Hamstrings (FC _{RE})	89°±7.92°	87.6°±10.1°	94.6°-97.3°	2 (40%)	94.6°-97.6°	2 (40%)
Quadriceps (FR)	114.4°±8.1°	116.6°±10.3°	115.3°-128°	2 (40%)	118.6°-133°	2 (40%)
Gluteus maximus (FC)	148.8°±3°	150°±4.1°	150°-151.3°	2 (40%)	152.6°-155.3°	2 (40%)

4. DISCUSSION

The main aim of this study was to quantitatively define the values of the optimum profile of lower-limb muscle flexibility in 20 female futsal players using the ROM-SPORT protocol. The importance of the optimum profile of flexibility is due to the fact that Sport and Health professionals have a very useful tool for the

prevention process of sports injuries and optimization of physical-technical sports performance.

After the statistical analysis it is observed that only four out of the 20 field players assessed in the present study and two goalkeepers had an optimum ROM ($P > 80$) in all assessed movements. In the scientific literature we have not found studies which define the optimum flexibility profile (using angular tests) in futsal, so it is just possible to compare the results of this study with the mean of flexibility values obtained in three scientific studies related to this sport (Table 4). The work developed by Ayala, Sainz de Baranda, Cejudo and De Ste Croix (2010) studies the hamstring flexibility of 10 players from the 1st Spanish National Division. The work carried out by Ayala et al. (2012) studies the hamstring flexibility of 46 players from the 1st and 2nd Spanish National Division and the work of Cejudo et al. (2014b) defines the flexibility profile of the lower limb of 20 players from the 2nd National Futsal Division. In general, the values of optimum ROM of this study are higher than the average values of flexibility. In addition, the field players from the present study show higher values in the flexibility of calf, soleus and gluteus maximus, while goalkeepers just present higher values in gluteus maximus flexibility.

Table 4. Mean and optimum values of range of motion from futsal players from the Spanish National Division.

	Iliopsoas	Gastrocnemius	Soleus	Adductors	Hamstrings	Quadriceps	Gluteus Maximus
Tactical position: field players							
Flexibility Optimum Profile							
Present study 1 st SND W (n=15)	>12.3°	>44.4°	>49.3°	>47.6°	>99.4°	>117.4°	>149.3°
Present study 1 st SND W (n=15)	7.7°	40.9°	42.7°	45.2°	89.3°	109.1°	147.3°
Ayala et al. (2010) 1 st SND W (n=10)					80.5°		
Ayala et al. (2012) 1 st + 2 nd SND M (n=46)					77.3°		
Cejudo et al. (2014b) 2 nd SND M (n=20)	12.4°	40°	39.7°	51.7°	91.6°	139°	143.4°
Tactical position: goalkeepers							
Flexibility Optimum Profile							
Present study 1 st SND W (n=15)	>8.8°	>39.6°	>40.9°	>47.3°	>94.6°	>116.9°	>151.3°
Present study 1 st SND W (n=5)	7.2°	38.7°	40.4°	45.9°	93.3°	115.5°	149.4°
Cejudo et al. (2014b) 2 nd SND M (n=3)	17.5°	48.3°	49.3°	47.3°	103.2°	146.4°	142.4°

ROM: range of motion; SND: Spanish National Division; M: men; W: women.

In addition, another fundamental objective of assessing flexibility is to detect muscle groups with smallness (limited ROM [$P < 20$]) and/or flexibility bilateral asymmetries for its correlation with an increase in the potential risk of sports injury (L'Hermette, Polle, Tourny-Chollet and Dujardin, 2006; Ellenbecker et al., 2007; Daneshjoo, Rahnama, Mokhtar and Yusof Halim, 2013). Statistical analysis has shown that from 20 players 4 (three field players and one goalkeeper) presented muscle shortness in each assessed movement, and therefore they have a higher probability of suffering from a sports injury. It has also been observed a bilateral asymmetry in the flexibility of calf, soleus and quadriceps amongst field players ($p < 0.05$) and showed lower values on the

dominant side, so players who present this significant difference suffer a higher risk of injury taking into account this risk factor (Ellenbecker et al, 2007; Young, Dakic, Stroia, Nguyen, Harris and Safran, 2014). In the case of calf and soleus assessment tests, there are only 2° of difference between the two body sides; however, it is noteworthy that in the individual analysis there are several players who present a difference between 5° and 7°.

To sum up, in order to correctly interpret the result of the assessed ROM it is necessary to compare it with the reference values of each sport. The definition of the optimum flexibility profile in a sport will enable Sport and Health professionals to accurately and quickly identify players who are more vulnerable to suffer a sports injury and be able to implement a program of stretching, which should be an important part of the prevention of musculoskeletal injury program with the aim of restoring or increasing the ROM to optimum values during the period established to rest (Witvrouw et al., 2003; Bradley and Portas, 2007). In addition, it will allow a greater physical-technical sports performance (Kolber and Fiebert, 2005; Riewald, 2004; Santana, 2004).

5. CONCLUSIONS

The results of this study define the optimum flexibility profile as the following ranges for field players: 43°-52° for the calf, 48°-54° for the soleus, 148°-154° for the gluteus maximus, 99°-118° for the hamstrings, 46°-56° for the adductors, 12°-20° for the iliopsoas and 116°-129° for the quadriceps. For goalkeepers the following ranges were obtained: 40°-46° for the calf, 40°-47° for the soleus, 150°-155° for the gluteus maximus, 94°-118° for the hamstrings, 45°-54° for the adductors, 8°-12° for iliopsoas and 133°-115° for the quadriceps. Provided that percentile >80 was defined as the optimum ROM, only 4 field players and 2 goalkeepers had this ROM in all the assessed movements.

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