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Isokinetic Assessment of Muscle Imbalances and Bilateral Differences between Knee Extensores and Flexores' Strength in Basketball, Footbal, Handball and Volleyball Athletes

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Abstract The imbalance of muscle strength indicators is harmful for elite sport and, in case of significant asymmetries, it increases the probability of muscular injuries or the deterioration of the athletic performance. So it's essential the evaluation of these imbalances in Handball, Basketball, Soccer and Volleyball athletes'. **Objective:** The aim of this study was to verify the existence of Isokinetic muscle imbalances in the profile of professional athletes from various modalities and examine their relationship with the sport practiced. **Design:** Through an observational, analytical and cross study were evaluated 86 athletes (Handball=14; Basketball=27; Football=25; Volleyball=20) using an isokinetic dynamometer Biodex Medical System 4 ®. The evaluated parameters were the Bilateral Differences and Hamstrings/Quadriceps Ratio at angular velocities of 60 °/s (4 repetitions) and 180 °/s (6 repetitions). **Results:** The Bilateral Differences (found) between the lower limbs are within the respected normal values (<10%). The Hamstrings / Quadriceps Ratio were higher in Football athletes and were lower in Volleyball athletes comparatively to other modalities. **Conclusion:** However, the motor skills of each sport do not seem to induce to significant muscular imbalances but each sport requires a specific isokinetic profile.

Keywords Sports, Muscle Weakness, Muscle Strength Dynamometer, Hamstring / Quadriceps Ratio, Bilateral Differences

1. Introduction

The high competition sports stand out by its popularity and by the phenomenon around them, although this is threatened by the great number of injuries due to its practice [1,2].

Generally, sports are of quiet demanding because it requires a lot of muscle and joint strength through high-level dynamic tasks[3].

This sport practice and the respective workout may lead to a bigger request of specific muscles groups, mainly in asymmetric sports[4]. However, this muscle specialization may result in an imbalance of the forces applied in the joint being able to expose the athletes to injuries, which bring (carries) major economic damages for the teams[5,6].

Besides the economic damages, the decline of sports performance is also a consequence of these kinds of injuries and the departure resulting of the same. For this reasons, the evaluation of muscular strength in Quadriceps and Hamstrings muscles assumes a major importance in a sooner perception of this type of imbalances[1,2,7].

The most used method to establish the functional standard and muscular balance is the isokinetic evaluation. This method shows an increasing utilization in sports to identify athletes with an high risk of injuries, allowing to reduce their incidence and recurrence, being also useful to provide a proper rehabilitation after an injury[3,8,9,10].

The muscular imbalances are one of the predisposing factors most cited in literature about sports injuries[11]. These can be observed through the differences of strength between agonist/antagonist muscles and the bilateral differences[11,12]. In knee joint, the relationship among agonist/antagonist used is the ratio Hamstrings/Quadriceps ($R_{H/Q}$)[9,13,14,15].

Although there a is low consensus on normative values for the $R_{H/Q}$, the value between 50-69% to the angular velocity of 60º/s and the value concerning 70-80% to the velocity of 180º/s seems to have gained some general acceptance[15, 16].

Furthermore, the existence of Bilateral Differences (BD) between the dominant limb and the non-dominant still

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remains controversial. However, the asymmetrical character of some modalities makes the bilateral comparison of strength, a good indicator of possible deficits in muscular system[2,9].

Some authors suggest that BD of strength between 10 a 15% are considered significant asymmetries. A bigger deficit may indicate a muscular imbalance[9,17,18].

In sports to detect the muscular imbalance and to identify a regular adaptation to sports versus a pathological condition, after an injury, is very important, making the studies that aboard this subject quiet pertinent[6,19].

Thereby, the purpose of the present study was to identify the existence of muscular imbalances in the Isokinetic profile of the thigh muscles of professional athletes, of various modalities, and to analyze its relationship with each sport practiced, through the analyses of BD and $R_{H/Q}$.

2. Methods

In this study were included athletes with ages understood between 18 and 32 years old, with a sports practice of at least 5 years with a frequency of workouts between 6 to 7 sessions per week and with one weekly session of strength work.[2]

Were defined as exclusion criteria (1) any type of injury in the evaluation moment (pain, swelling and inflammation) or in a phase of rehabilitation of the lower limbs [20]; (2) history of a surgery and instability of the lower limbs[21,22]; (3) sense of pain during the isokinetic evaluation[9,20,22] and (4) values of BD superior to 15%, because these are considered pathological.[9] This last criterion was applied after the isokinetic evaluation.

Therefore the sample was constituted by 14 Handball athletes of the 1st division, 25 of the Football League Zon Sagres, 27 of the Basketeball Portuguese League and 20 individuals from the Nation Championship of Volleyball A1 as shown in Table 1.

2.1. Instruments

To assess body weight and height were used, respectively (respectably), Digital Weighing Machine Soehnle Fitness Scale 7850® (Soehnle Professional GmbH & Co., with establishment in Backnang, German) and stadiometer Seca 214® (Seca, with establishment in Vila Verde, Sintra, Portugal).

The Bilateral Differences and the Hamstring/Quadriceps Ratio were quantified using a dynamometer Biodex System 4® (Biodex Medical Systems, Inc., Shirley, NY, EUA), which represents a high validity and viability[23].

2.2. Procedures

Initially, the athletes were submitted to an inspection and a functional evaluation of the knee, in order to verify the existence of surgical scars, observe the skin and its general behavior[22].

The athletes started with an warming up in a Cycloergometer Monark Ergomedic 894E® (Monark Sports and Medical, established in Sweden), during 5 minutes and with a charge equivalent of 2% of its body weight, followed by stretches of Quadriceps and Hamstrings. This stretch was bilateral and static in 4 series of 20 seconds[18,24].

Table 1. Characterization of sample, in accordance with the modalities practiced mean results ($\bar{X}$), standard deviation (S), median (me), interquartile deviation (ID), minimum, maximum, p value and F)

Modality		$\bar{X} \pm S$	**me ± ID**	**Minimum**	**Maximum**
Handball n=14	Age (years)	23,29±2,55	22,5±2,50	19	27
	Weight (Kg)	85,5±4,90	85,5±3,40	79	96
	Height (cm)	188,07±6,11	187±3,75	180	201
Modality		$\bar{X} \pm S$	**me ± ID**	**Minimum**	**Maximum**
Basketball n=27	Age (years)	24,63±4,24	24±3,50	18	30
	Weight (Kg)	89,76±11,40	91±10,0	72	109
	Height (cm)	192,6±6,47	193±6,50	182	203
Modality		$\bar{X} \pm S$	**me ± ID**	**Minimum**	**Maximum**
Football n=25	Age (years)	23,32±2,12	23±1,50	19	27
	Weight (Kg)	73,16±6,29	73±3,75	63	89
	Height (cm)	180±7,59	181±5,00	167	198
Modality		$\bar{X} \pm S$	**me ± ID**	**Minimum**	**Maximum**
Volleyball n=20	Age (years)	24,8±2,12	25±1,50	20	29
	Weight (Kg)	85±9,07	83,5±8,40	73	102
	Height (cm)	189,1±7,11	190±5,25	177	205
F/ p value	Age	(Years)	F = 1,532	p = 0,213	
	Weight	(Kg)	F = 16,834	p = 0,000*	
	Height	(Cm)	F =15,169	p = 0,000*	

* Significant differences among modalities (p<0, 05)

Subsequently, the participants were positioned in the dynamometer chair (Figure 1) with 100º of inclination, with rotation axe of lever arm of the dynamometer aligned with the lateral part of the femoral condyle with stabilization in torso, abdomen and thighs, in order to prevent compensatory movements. The point of application of the resistance was positioned in the distal third of the leg, 3 centimeters above the tibial malleolus and, then fixed with adjacent strips[18, 20].

The angular velocities used in this study were 60º/s (4 repetitions) and (of) 180º/s (6 repetitions), on a range of motion among 0º – 100º and with a break between the different velocities, of 2 minutes[9,13,24].

The gravitation factor of the arm lever and of the studied limb were measured and automatically offset during the measurements. It was provided an adequate familiarization with the dynamometer through a workout composed by sub-maximal isokinetic repetitions in the angular velocities that will be evaluated[24,25].

All the subjects were instructed to place their arms comfortably, crossed in chest, in order to isolate the action of the muscle groups in test (Figure 1)[9].

Thus allow determining its laterality[26].

The order of evaluation of the limbs was random. However, the Quadriceps was always evaluated before Hamstrings[18]. During the test was given an auditory stimulus similar for every athlete[20,24].

Figure 1. Positioning in isokinetic dynamometer Biodex *System* 4 Pro®

2.3. Ethics

This study was approved by ESTSP ethics commission and each athlete read and signed the Informed Consent, according to the Declaration of Helsinki, dated of 1964.

Statistics

For all statistics procedures it was used the software (do) PASW® Statistics 18 (Predictive Analytics Software) for Windows 7, considering a level of significance of 0.05 (confidence interval of 95%) across all study.

Sample characterization was made using mean and median, as measures of central tendency, and with standard deviation, interquartile deviation and maximum and minimum values as measures of dispersion. Homogeneity between groups was ensured by one-way ANOVA test.[27]

For "Bilateral Differences" variable, since normality were not found, it was used Kruskal-Wallis Test[27].

3. Results

3.1. Bilateral Differences (BD)

The mean BD presented are among the parameters considered normal by the literature, in other words, the values are below 10%, in every analyzed variables'. However, some athletes have BD considered as significant asymmetrical (Table 2). The several modalities do not exhibit statistical significant differences of BD, in both muscles and velocities evaluated.

3.2. Hamstrings/Quadriceps Ratio (R H//Q)

The Table 3 shows that the mean values of $R_{H/Q}$ at 60º/s are among the normative values for functional balance ($R_{H/Q}$ - 50%-69%). However, to 180º/s into all modalities the values were lesser to those referenced in the literature ($R_{H/Q}$ - 70%-80%), except Football. The percentage of individuals, in each modality, with functional imbalances is represented in table 2.

In the comparison between limbs, Football players have shown superior mean values of $R_{H/Q}$ in D limb comparatively with ND, at 60º/s (p=0,018).

Comparing modalities, in both limbs and velocities, the values of $R_{H/Q}$ were significantly superiors in Football players relatively to Basketball and Volleyball players, except in the ND limb at 60º/s where there is no statically significant differences. Basketball – D 60º/s – p=0,027 and 180º/s - p=0,010; ND 180º/s – p=0,020; Volleyball – D 60º/s – p=0,000 and 180º/s- p=0,000; ND 180º/s – p=0,004).

4. Discussion

Over the years, several studies, involving a wide range of sports evaluated variables like Peak Torque (PT), Peak Torque to Body Weight (PTBW), Bilateral Differences (BD) and Hamstrings/Quadriceps (RH/Q). These studies highlightened the scholars concern to provide data about the adequate muscle balance at (e) knee joint, even as the relationship of muscular imbalance and injuries.[21,28] However, there are few published studies that compare different modalities and provide data about the consequences of their practice in males muscular balance[21, 22].

The fact that does not exist any (none) standard protocol to evaluate the athletes' strength and the isokinetic equipment is different between investigations, it can cause complex and doubtful comparisons[6, 9].

4.1. Bilateral Differences (BD)

The present study examined, also, the bilateral asymmetries of thigh muscles in several modalities.

Despite of some individuals of the sample have BD in PT and PTBW between limbs and show superior BD than (those) recommended by literature, the mean of bilateral asymmetry of this study is below the reference value (< 10%).

Furthermore, were not verified (a) significant effects of the sport practiced in the bilateral asymmetries of those athletes shown.

Studies from Carvalho and Cabri[25], Hadzic, et al.[2], Iga, et al.[26] and Magalhaes, et al.[29] found similar results to this one and concluded that, despite of some specific skills used in the practice of these modalities be fulfilled with lateral preferences, the values of isokinetic test suggest that these athletes are functionally balanced.

This balance may be justified by the training method of these modalities, once it is accomplished bilaterally and not with the aim to reinforce just one of the limbs[30]. On the other hand, the active participation and differentiated of contractile ND limb, in actions like pass and shoot as support leg in Football and in actions of running and reception actions in Handball, Basketball and Volleyball, also seem to contribute for this balance[6,18].

Tabel 2. Percentage of individuals with BD above normal and mean of Quadricipes (Q) e Hamstrings (H) in angular velocities of 60º/s and 180º/s, of athelets of diferent modallities (results in percentage, median (me), interquartile deviation (ID) and p value)

Sample	Modality	Velocity 60º/s			Velocity 180º/s		
		%	BD (%) me ± DI	P value	%	BD (%) me ± DI	P value
Bilateral Differences – Q	Handball (n=14)	21,4	5,25±3,10	0,640	21,4	5,55±3,35	0,260
	Basketball (n=27)	29,6	6,80±2,85		14,8	6,50±2,55	
	Football (n=25)	24,0	6,50±4,55		40,0	8,40±4,15	
	Volleyball (n=20)	25,0	6,95±3,20		45,0	9,45±4,30	
Bilateral Differences – H	Handball (n=14)	21,4	4,25±2,45	0,191	35,7	4,95±4,85	0,266
	Basketball (n=27)	37,0	7,50±4,50		29,6	6,80±4,40	
	Football (n=25)	36,0	7,50±3,60		36,0	5,50±5,40	
	Volleyball (n=20)	30,0	7,20±4,75		15,0	3,10±2,40	

Table 3. Percentage of individuals with Hamstrings/Quadriceps Ratio($R_{H/Q}$) above normal values and mean values of $R_{H/Q}$ in angular velocities of 60º/s and 180º/s, of individuals os various modalities (results in percentage, of mean ($\overline{X}$), standard deviation (S) , p value, t and F)

	Modality	H/Q D Ratio	H/Q ND Ratio	Value p
Velocity 60º/s	Handball (n=14)	59,64±4,69	58,99±4,79	t=0,354 p=0,729
	Basketball (n=27)	57,94±8,11	56,02±7,32	t=1,472 p=0,153
	Football (n=25)	62,75±4,57	60,33±6,22	t=2,227 p=0,018 [a]*
	Volleyball (n=20)	55,23±5,27	56,60±5,75	t=-1,345 p=0,195
	F/ p value	F = 6,084 p = 0,001*	F = 2,477 p = 0,067*	
Velocity 180º/s	Handball (n=14)	70,74±8,43	67,68±5,50	t=1,337 p=0,204
	Basketball (n=27)	65,19±6,20	64,19±6,70	t=0,867 p=0,395
	Football (n=25)	71,01±5,44	69,72±7,15	t=1,060 p=0,299
	Volleyball (n=20)	60,66±6,48	62,70±6,87	t=-1,405 p=0,176
	F/ p value	F = 11,528 p = 0,000*	F = 5,131 p = 0,003*	

* D significantly higher than ND (p<0,05)
Ψ At least one group of differences statistically significant (p<0,05)
a- t test unilateral for paired

Thereby, the results of the present study seem to conclude that the preferential use of one of the lower limbs, for the motor skills of one's own modality, are not susceptible to urge a bilateral muscular imbalance found through an isokinetic evaluation.

4.2. Hamstrings/Quadriceps Ratio RH/Q

During the jump, the call action entails a high risk of injury in Football. While in Basketball and Volleyball, the moment of soil reception is that increases this risk[31].

In these actions the co-activation of Hamstrings and Quadriceps protects the knee joint, which is very important in evaluation and balance of RH/Q in sports[32].

The mean RH/Q presented by the evaluated athletes are in agreement with the literature about angular velocity of 60º/s (among 50%-69%). Devan et al,. (2004) noted that the prevalence of injuries on knee were higher in athletes that have RH/Q lower than normal for 60º/s, so it can be concluded that the athletes who composed the sample have a lower propensity to have an injury, when this factor is considered individually.

However, at 180º/s the functional balance (RH/Q - 70%-80%) was just verified in Football players. This fact may enhance the predominant work of Quadriceps in several specific actions in Football and the insufficient compensatory work of the Hamstrings in other modalities[25, 29].

Football athletes presented higher values of RH/Q in ND limb at 60º/s. Similar results were referenced by literature by Holcomb, et al.[33] and Voutselas, et al.[34].

The Football athletes show higher values of RH/Q comparing with Basketball and Volleyball players in both limbs and velocities, except in ND limb at 60º/s. These results may be explained, by the motor skills inherent to Football, as sprints by long periods with sudden direction changes. However, it is the notion of shooting a ball, which contrasts with other modalities and more requests the Quadriceps[13,21]. The lower RH/Q values in Volleyball players comparably to other modalities was also concluded by Bamaç, et al.[21], although, were only found differences at 300º/s. Magalhaes, et al.[29], they also verified that at 90º/s, Volleyball players have a lower RH/Q than Football athletes.

Although there are differences between the sports represented in this study, most of them implicate similar actions (run, jump, direction changes) and the different workout plans, according to the modality, may be responsible for the differences in RH/Q among the evaluated sports[21].

4.3. Implications

An imbalance of strength may affect the performance of athletes, either to increase the risk of an injury or to promote their dominant side. Such limitation or preferences are understood as prejudicial in modalities like Basketball, Handball, Football and Volleyball, where the capacity to use both limbs may improve their performance.

The use of isokinetic tests may help to realize what re the exercises to improve the muscular balance and may also be useful to monitor a rehabilitation program in the recovery of an injury and lower limbs surgeries.

Besides, the "normalization" of the isokinetic parameters may also reduce the relapse of injuries. However, that does not suggest that all the athletes with imbalances have the same deficits and they require the same intervention. Therefore, the intervention programs should be compatible with the personal needs of each athlete.

It is suggested other future studies, of longitudinal nature, allowing to withdraw conclusions in the relation of cause and effect of the differences and observed imbalances, as well as in the muscular disorders which result in injuries, during the competitive period, in equal proportions in each evaluated modality.

5. Conclusions

The mean from bilateral differences is among the normal values quoted in the literature, therefore the training and competition in these modalities do not seem to induce muscular imbalance.

The Hamstrings/Quadriceps ratio was higher in Football athletes and lower in Volleyball players. These results may be relevant (factors) in the interaction with the necessities of each modality.

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