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Review Article

CORRELATIONS BETWEEN THE STRENGTH OF KNEE EXTENSOR AND FLEXOR MUSCLES AND JUMP PERFORMANCE IN VOLLEYBALL PLAYERS: A REVIEW

RELAÇÃO ENTRE A FORÇA DOS MÚSCULOS EXTENSORES E FLEXORES DE JOELHO E O DESEMPENHO DE SALTOS EM JOGADORES DE VOLEIBOL: UMA REVISÃO

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ABSTRACT
Jump tests and isokinetic dynamometer assessments are widely used in sports to identify parameters of strength and power development. Understanding the relationship between these variables can help in the selection of more specific parameters to assess the strength of knee joint muscles on isokinetic dynamometer in volleyball players. The objective of this literature review was to summarize studies that have analyzed the relationship between performance in jump tests with strength generation capacity in knee isokinetic dynamometry assessments among volleyball players, besides investigating whether muscle imbalances of the knee joint can interfere with jump performance. The reviewed studies resulted from a search on PubMed and Scielo databases. A total of 106 articles were found, 6 of which were used for final analysis. The capacity to generate strength in knee isokinetic dynamometry assessments correlates with jump performance. Strength imbalances from one limb to another do not seem to interfere with jump performance. Strength imbalances between knee flexors and extensors may be related to the functionality of volleyball players.
Keywords: Peak torque. Collective sports. Muscle power. Strength imbalance. Muscle balance.

RESUMO
Os testes de saltos e as avaliações no dinamômetro isocinético são amplamente utilizados no esporte para a identificação dos parâmetros de desenvolvimento de força e potência. A compreensão da relação entre essas variáveis pode auxiliar nas escolhas de parâmetros mais específicos na avaliação da força dos músculos da articulação do joelho no dinamômetro isocinético para os jogadores de voleibol. O objetivo da presente revisão de literatura foi reunir estudos que analisaram as relações entre o desempenho dos testes de saltos com a capacidade de geração de força em avaliações de dinamometria isocinética de joelho em jogadores de voleibol, além de investigar se os desequilíbrios musculares da articulação do joelho podem interferir no desempenho dos saltos. Os estudos revisados são provenientes da busca realizada nas bases de dados *PubMed* e *Scielo*. Foram encontrados 106 artigos dos quais 6 artigos foram utilizados para a análise final. A capacidade de gerar força nas avaliações de dinamometria isocinética de joelho é relacionada com o desempenho de salto. Os desequilíbrios de força de um membro para outro parecem não interferir no desempenho dos saltos. Os desquilíbrios de força entre os flexores e extensores de joelho podem ter relação com a funcionalidade dos jogadores de voleibol.
Palavras-chave: Pico de torque. Esporte coletivo. Potência muscular. Desequilíbrio de força. Equilíbrio muscular.

Introduction

A volleyball player's performance is directly influenced by power production capacity. Power is determined by the product of strength by speed, and maximum power is achieved by the optimal relationship between these variables[1]. Therefore, the most powerful player is one who can reach good strength levels in a short time. One of the main characteristics of volleyball is the need for the player to jump great heights in attack and block movements; thus, a great power production is necessary, especially in the lower limbs[2].

Jump tests and the analysis of strength production capacity on isokinetic dynamometer are widely used in sports to identify parameters of strength and power development in the lower limbs[3]. The Countermovement Jump (CMJ) and the Squat Jump (SJ), for instance, enable a more specific analysis in relation to strength analysis performed on isokinetic dynamometer, since the motor gesture of jumps are similar to game actions[4]. However, jump analysis does not seem to be enough to identify all performance determinants in volleyball players. In their turn, data obtained on isokinetic dynamometer allow for a more detailed observation of the functioning of muscles involved in the flexion and extension of the knee joint[3] and can serve as a complement to determine volleyball players' performance.

Considering that jumps are multi-joint movements with total work contributions of 49% for the knees, 28% for the hips and 23% for the ankles[5], it is possible that a test performed on isokinetic dynamometer involving knee flexion and extension may relate to jump performance in volleyball players. We hypothesize that these relations may be different according to the speed of the movement on an isokinetic dynamometer, as well as to the different types of jumps, muscles and muscular contractions analyzed, since they directly interfere with the relationship between strength production and speed[1]. In addition, we believe that resulting imbalances on isokinetic dynamometer can also be related to jump performance[6,7], because the technical gesture of jumps requires a coordinated action of knee extensors and flexors, and a joint action between the lower limbs[8]. Understanding the relationship between these variables may be helpful in the selection of more specific parameters to assess the strength of knee joint muscles on isokinetic dynamometer for the needs of volleyball players.

The relationship between strength production capacity on isokinetic dynamometer and jump performance is not clear in the literature. Moreover, the influence of muscle imbalance observed by means of isokinetic dynamometry tests on volleyball players' jump performance is not well established. Therefore, the objective of the present literature review was to gather studies that have analyzed correlations between performance in jump tests and strength generation capacity in knee isokinetic dynamometry assessments in volleyball players, as well as to investigate whether muscle imbalances of the knee joint can interfere with jump performance.

Methods

The reviewed studies result from a search on PubMed and Scielo databases. Terms in English and their respective translations into Portuguese were used in the following search strategy: (((((“isokinetic” OR “peak torque” OR “strength imbalance” OR “bilateral strength asymmetry” OR “*isocinético*” OR “*pico de torque*” OR “*desequilíbrio de força*” OR “*assimetria de força bilateral*”)))) AND ((((“relationship” OR “correlation” OR “association” OR “*relação*” OR “*correlação*” OR “*associação*”))))) AND (((“jumping” OR “jump” OR “vertical jump” OR “volleyball” OR “*saltando*” OR “*salto*” OR “*salto vertical*” OR “*voleibol*”))).

Selection Criteria

The studies were included according to the following eligibility criteria: (a) primary articles, (b) studies with volleyball players in the sample, and (c) studies analyzing the relationship between strength generation capacity by knee extensors and flexors assessed on isokinetic dynamometer with performance in jump tests. By the eligibility criteria, the articles were initially analyzed by title and abstract. If there was doubt about the content of the article, it was read in its entirety.

Data Included in the Tables

The sample characterization data included in Table 1 were number of participants, gender, players' level, sports played by the sample, and any sample condition that could interfere with results, such as reconstruction of the anterior cruciate ligament of the knee. The variables analyzed on isokinetic dynamometer were included, as well as the variables analyzed in the different jumps. The results in Tables 2 and 3 presented significant correlations ($p<0.05$) according to the studies; r values represent the result of the correlations, and R^2 values represent regression coefficient values.

Results

In total, 106 articles were found and 105 articles were analyzed after the exclusion of 1 duplicate. They were chosen in the following order: primary articles (101), studies with volleyball players (18) and studies analyzing correlations between strength generation capacity by knee extensors and flexors assessed on isokinetic dynamometer and performance in jump tests (6). The search was completed on 05/01/2018.

Table 1. Synthetizing sample characteristics of the studies that have analyzed correlations between strength of knee extensors and flexors and imbalances assessed on isokinetic dynamometer and jump performance of volleyball players

Studies	Sample (number and gender, level and sport)	Isokinetic Dynamometer Assessment	Jump Assessment
Bosco et al.[9]	12 (M); Professionals (Volleyball)	PT normalized by CON body mass of the dominant leg's knee EXT at 30, 60, 120, 180, 240 and 300°.s^{-1}	Anaerobic POW in 15 and 60s of Jumps, and SJ, CMJ and DJ HGT
Yapici et al.[10]	10 (F) and 20 (M); College Students (Volleyball)	CON PT and TW of the dominant leg's knee EXT and FLE at 60, 120 and 240°.s^{-1} and ECC PT and TW of EXT at 60°.s^{-1}#.	SJ and CMJ POW
Sattler et al.[11]	67 (F) and 9 9 (M); Professionals (Volleyball)	PT normalized by CON and ECC body mass of knee EXT and FLE at 60°.s^{-1}	BJ and AJ HGT
D' Alessandro et al.[12]	8 (F) and 22 (M); Professionals (Volleyball)	PT, TW and CD of CON PT and TW of knee EXT and FLE at 60 and 300°.s^{-1}	Hop Test distance, and CD of the Hop Test distance
Laudner et al.[13]	17 (F) and 16 (M); Level of participants not reported (Volleyball, Basketball and Football) with reconstruction of the anterior cruciate ligament of the knee	PT normalized by body mass and CON CD of knee EXT and FLE at 180 and 300°.s^{-1}	HGT of unilateral jump, bilateral jump and 4 consecutive unilateral jumps. CD in unilateral jump and 4 consecutive unilateral jumps. Ground contact time and air time proportion divided by ground contact time in the 4 consecutive unilateral jumps
Li et al.[14]	18 (F) and 28 (M); Recreational (Volleyball, Basketball, Soccer, Tennis, Table Tennis, Dance and Track and Field), with complete rupture of the anterior cruciate ligament	ΔPT, ΔPT normalized by body mass, ΔPT acceleration energy ΔTW, ΔH:Q and mean CON ΔPOW of knee EXT and FLE at 60 and 180°.s^{-1}	ΔFQ (Modified Cincinnati rating scale tests): Pain, swelling, persistence in activities, general activity level, walking, climbing stairs, running, jumping or spinning

Legend: F= Female, M= Male, PT= Peak Torque, TT= Total Work, CD= Contralateral Deficit H:Q= Conventional ratio, CON= Concentric, ECC = Eccentric, POW= Power, HGT= Height, SJ=Squat jump, CMJ= Countermovement Jump, DJ= Drop jump, BJ= Block Jump, AJ= Attack Jump, and FQ= Functionality Questionnaire. # Test performed on isokinetic dynamometer in an ECC way of EXT and in a CON way of FLE. Δ The results obtained concern variations of pre- and post-strength training variables as to knee EXT and FLE on isokinetic dynamometer.
Source: The authors

Table 2. Summary of significant results (p<0.05) of studies that have analyzed correlations between the strength of knee extensors and flexors assessed on isokinetic dynamometer and jump performance of volleyball players

Studies	Isokinetic dynamometer assessment	Jump assessment													
		POW Jumps in 15s (W)	POW Jumps in 60s (W)	SJ HGT (cm)	CMJ HGT (cm)	DJ HGT (cm)	SJ POW (W)	CMJ POW (W)	BJ HGT (cm)	AJ HGT (cm)	*Hop Test* Right Leg (cm)	Unilateral Jump HGT (cm)	Bilateral Jump HGT (cm)	4 Consecutive Unilateral Jumps HGT (cm)	ΔFQ
Bosco et al.[9]	PT 180°.s^{-1} (N.m.kg^{-1})	(r=0.70)^{PC}	(r=0.68)^{PC}												
Bosco et al.[9]	PT 240°. s^{-1} (N.m.kg^{-1})			(r=0.71)^{PC}	(r=0.74)^{PC}	(r=0.60)^{PC}									
Yapici et al.[10]	CON PT EXT 60°.s^{-1} (N.m)						(r=0.80)^{PC}	(r=0.82)^{PC}							
Yapici et al.[10]	CON PT FLE 60°.s^{-1} (N.m)						(r=0.74)^{PC}	(r=0.71)^{PC}							
Yapici et al.[10]	CON TW EXT 60°.s^{-1} (J)						(r=0.78)^{PC}	(r=0.77)^{PC}							
Yapici et al.[10]	CON TW FLE 60°.s^{-1} (J)						(r=0.67)^{PC}	(r=0.67)^{PC}							
Yapici et al.[10]	CON PT EXT 120°.s^{-1} (N.m)						(r=0.83)^{PC}	(r=0.84)^{PC}							
Yapici et al.[10]	CON PT FLE 120°.s^{-1} (N.m)						(r=0.66)^{PC}	(r=0.64)^{PC}							
Yapici et al.[10]	CON TW EXT 120°.s^{-1} (J)						(r=0.74)^{PC}	(r=0.74)^{PC}							
Yapici et al.[10]	CON TW FLE 120°.s^{-1} (J)						(r=0.63)^{PC}	(r=0.60)^{PC}							
Yapici et al.[10]	CON PT EXT 240°.s^{-1} (N.m)						(r=0.87)^{PC}	(r=0.89)^{PC}							
Yapici et al.[10]	CON PT FLE 240°.s^{-1} (N.m)						(r=0.70)^{PC}	(r=0.66)^{PC}							
Yapici et al.[10]	CON TW EXT 240°.s^{-1} (J)						(r=0.82)^{PC}	(r=0.84)^{PC}							
Yapici et al.[10]	CON TW FLE 240°.s^{-1} (J)						(r=0.58)^{PC}	(r=0.53)^{PC}							
Yapici et al.[10]	EXC PT EXT 60°.s^{-1} (N.m) #						(r=0.50)^{PC}	(r=0.48)^{PC}							
Yapici et al.[10]	CON PT FLE 60°.s^{-1} (N.m) #						(r=0.54)^{PC}	(r=0.54)^{PC}							
Yapici et al.[10]	CON TW FLE 60°.s^{-1} (J) #						(r=0.42)^{PC}	(r=0.43)^{PC}							
Sattler et al.[11]	PT 60°.s^{-1} (N.m.kg^{-1}) - (M)								(R^2=0.37)^{LR}	(R^2=0.36)^{LR}					
Sattler et al.[11]	PT 60°.s^{-1} (N.m.kg^{-1}) - (F)								(R^2=0.42)^{LR}	(R^2=0.39)^{LR}					
D' Alessandro et al.[12]	Right Leg PT 60°. s^{-1} (N.m) - (M)										(r=0.54)^{PC}				
D' Alessandro et al.[12]	Right Leg TW 60°. s^{-1} (J) - (M)										(r=0.56)^{PC}				
D' Alessandro et al.[12]	Right Leg PT 60°. s^{-1} (N.m) - (F)										(r=0.72)^{PC}				
D' Alessandro et al.[12]	Right Leg TW a 60°. s^{-1} (J) - (F)										(r=0.80)^{PC}				
Laudner et al.[13]	EXT PT 180°. s^{-1} (N.m.kg^{-1})											(r=0.71)^{MRA}	(r=0.64)^{MRA}	(r=0.63)^{MRA}	
Laudner et al.[13]	EXT PT 300°. s^{-1} (N.m.kg^{-1})											(r=0.74)^{MRA}	(r=0.63)^{MRA}	(r=0.73)^{MRA}	
Laudner et al.[13]	FLE PT 180°. s^{-1} (N.m.kg^{-1})											(r=0.53)^{MRA}	(r=0.58)^{MRA}	(r=0.39)^{MRA}	
Laudner et al.[13]	FLE PT 300°. s^{-1} (N.m.kg^{-1})											(r=0.49)^{MRA}	(r=0.45)^{MRA}	(r=0.56)^{MRA}	
Li et al.[14]	ΔFLE PT a 30° 180°.s^{-1} (N.m)														(r=0.46)^{PC}
Li et al.[14]	ΔFLE PT 30° 60°.s^{-1} (N.m)														(r=0.45)^{PC}
Li et al.[14]	ΔFLE PT 180°.s^{-1} (N.m.kg^{-1})														(r=0.42)^{PC}
Li et al.[14]	ΔFLE PT 60°.s^{-1} (N.m)														(r=0.41)^{PC}
Li et al.[14]	ΔFLE PT 60°.s^{-1} (N.m.kg^{-1})														(r=0.40)^{PC}
Li et al.[14]	ΔFLE PT acceleration energy														(r=0.35)^{PC}

Legend: F= Female, M= Male, PT= Peak Torque, TW= Total work, CON= Concentric, ECC= Eccentric, POW= Power, HGT= Height, SJ= Squat jump, CMJ= Countermovement Jump, DJ= Drop Jump, BJ= Block Jump, AJ= Attack Jump, and FQ= Functionality Questionnaire. # Test performed on isokinetic dynamometers in an ECC way of EXT, and in a CON way of FLE. Δ The results obtained concern variations of pre- and post-strength training variables as to knee EXT and FLE on isokinetic dynamometer. Statistical analysis used - CP = Pearson's correlation, LR= Linear regression and MRA= Multiple Regression Analysis.
Source: The authors

Table 3. Summary of significant results ($p<0.05$) of studies that have analyzed correlations between knee muscle strength imbalances assessed on isokinetic dynamometer and jump performance of volleyball players

Studies	Isokinetic dynamometer assessment	Jump assessment			
		Hop Test CD (cm)	Bilateral Jump HGT (cm)	4 Consecutiv Unilateral Jumps – contact time (s)	ΔFQ
D' Alessandro et al.[12]	CD PT 60°. s^{-1}	(r=0.44)[PC]			
D' Alessandro et al.[12]	CD TW 60°. s^{-1}	(r=0.61)[PC]			
Laudner et al.[13]	CD PT FLE 180°. s^{-1}		(r=0.39)[MRA]		
Laudner et al.[13]	CD PT FLE 300°. s^{-1}			(r=0.37)[MRA]	
Li et al.[14]	ΔH:Q at 30° 180°.s^{-1}				(r=0.62)[PC]
Li et al.[14]	ΔH:Q PT acceleration energy 180°.s^{-1}				(r=0.47)[PC]
Li et al.[14]	ΔH:Q PT 180°.s^{-1}				(r=0.44)[PC]
Li et al.[14]	ΔH:Q TW				(r=0.41)[PC]
Li et al.[14]	ΔH:Q at 30° 60°.s^{-1}				(r=0.37)[PC]
Li et al.[14]	ΔH:Q PT 180°.s^{-1}				(r=0.37)[PC]
Li et al.[14]	ΔH:Q PT 60°.s^{-1}				(r=0.34)[PC]

Legend: PT= Peak Torque, TW= Total work, CD= Contralateral deficit H:Q= Conventional ratio, HGT= Height and FQ= Functionality Questionnaire. Δ The results obtained concern variations of pre- and post-strength training variables as to knee EXT and FLE on isokinetic dynamometer. Statistical analysis used - PC= Pearson's correlation and MRA= Multiple Regression Analysis.
Source: The authors

Discussion

The objective of the present literature review was to gather studies that have analyzed correlations between performance in jump tests and strength generation capacity through isokinetic dynamometry assessments of the knee in volleyball players, besides investigating whether muscle imbalances of the knee joint can interfere with jump performance. To meet the investigation's objectives, 6 studies were selected, whose results were used for discussion. The discussion was separated into topics according to the similarity of the results obtained in the studies analyzed.

Correlation Between Speeds in Isokinetic Dynamometer Assessments and Jump Performance

The isokinetic dynamometer test involves the measurement of strength, torque and power through the performance of joint movements at constant speed[15]. The selected studies choose different execution speeds in the isokinetic dynamometry test. The speeds used in isokinetic dynamometry assessments with volleyball players range from low angular speeds (30 and 60°.s^{-1}), allowing for greater torque production, up to higher angular speeds, such as 300°.s^{-1}, in order to be closer to the speed of muscle contraction performed by knee joint muscles in sports practice[12].

Among the studies selected for analysis, only Laudner et al.[13] did not use isokinetic dynamometry at low speed to assess knee muscle strength. Bosco et al.[9] used isokinetic dynamometry at low speed, but found no correlation between slow knee muscle contraction speeds and jump performance. In the other studies, the authors identified positive correlations of (r= 0.40)[14] to (r= 0.82)[10] between the assessment of knee muscle strength at slow speed (60°.s^{-1}) and jump performance. In those studies in which isokinetic dynamometry assessments are applied at more than one speed, correlation values between variables analyzed on isokinetic dynamometer and jump performance raise with the increase of angular speeds of the isokinetic dynamometry of the knee[9,10,13,14]. Considering that power is determined by the product of strength by speed, with maximum power being reached by the optimal relationship between these variables[1], and that jump height and power relate to capacity of generating good levels of strength and speed[16], higher speeds in the analysis performed on isokinetic dynamometer possibly allow volleyball players to perform strength actions more similar to jump movement needs, which might explain greater correlations with increased speed. However, the high speed of 300°.s^{-1} in isokinetic dynamometry does not correlate with jump variables equally in all studies. Although Bosco et al.[9] have found higher correlations (r= 0.71 to r= 0.74)[9] at higher speeds (240º.s^{-1}), the speed of 300°.s^{-1} showed no correlation with height in vertical jump tests, corroborating with the findings of D'Alessandro et al.[12], who observed correlations with the distance of unilateral horizontal jumps only at a speed 60°.s^{-1} on isokinetic dynamometer (r= 0.54 to r= 0.80)[12], not identifying correlations with the speed of 300°.s^{-1}. Bosco et al.[9] justify that angular speeds between 180 and 240°.s^{-1} might have a closer relationship with jump performance, since these speeds are closer to the angular speeds used in jumps. In fact, the study by Yapici et al.[10] has identified stronger correlations (r= 0.87 to r= 0.89)[10] between jump power and knee extensors strength at a speed of 240°.s^{-1} . Laudner et al.[13] have identified the greatest correlation (r= 0.74)[13] between knee extensors strength analyzed on isokinetic dynamometer at an angular speed of 300°.s^{-}1 and height of unilateral jumps. The fact that the study by Laudner et al.[13] included players from other sports with reconstruction of the knee cruciate ligament may not reflect what occurs in the population of uninjured volleyball players. However, this result is important as it does not rule out the use of this speed in the isokinetic test when, for instance, the goal is to transfer strength gains obtained on isokinetic dynamometer for the performance of jumps in volleyball players.

Thus, because not all studies that have tested the correlation between isokinetic test variables and jump performance in volleyball players have used the angular speed of 300°.s^{-1}, it is not possible to draw conclusions about this variable. However, the analysis of these studies allows us to infer that the use of intermediate angular speeds in the isokinetic dynamometry test may better reflect the strength-generating needs of volleyball players for jumping.

Relationship Between Variables Assessed on Isokinetic Dynamometer and SJ, CMJ, DJ, Block Jump and Attack Jump

Control over the ability to jump is usually executed by means of specific jump tests, such as SJ, CMJ and DJ[9,17], for their similarities with the motor gestures of attacking and blocking[4], as well as the use of attack and block jumps themselves to analyze volleyball players' ability to jump[2,11]. Different jump gestures mean the use of different mechanisms, changing the height and power generated in each action. Thus, the results of the relationship between jump tests and strength performance of knee joint muscles measured on isokinetic dynamometer may vary by type of jump chosen.

Bosco et al.[9] used the height of SJ, CMJ and DJ as one way to assess jump performance. Regarding these three jumps, the greatest correlation found between the strength of knee extensors assessed on isokinetic dynamometer occurred with the CMJ (r= 0.74), followed by the SJ (r= 0.71) and DJ (r= 0.60). We were expecting that the SJ would have the highest correlation value, since it is a jump performed through concentric contractions of the lower limb muscles[17], similar to the type of muscle contraction analyzed on isokinetic dynamometer in this study[9], but the CMJ, which uses energy from the stretch-shortening cycle (SSC) as an aid to muscle contraction[16], presented a slightly higher correlation value than the SJ did. As for the DJ, the lower values found in the correlation can be explained by the fact that it is performed with great contribution of energy from the SSC, so the height variations between the volleyball players are less related to the strength of the concentric contraction of the knee extensors assessed on isokinetic dynamometer. The study by Yapici et al.[10] also used SJ and CMJ tests for jump performance analysis, but the performance data chosen was maximum power. Both jumps correlated with the different performance results achieved on isokinetic dynamometer[10] (Table 2). Similar to Bosco et al.[9], differences between SJ and CMJ correlations are discrete, and it is not possible to infer whether the SJ and the CMJ have different correlations with the strength of the knee muscles analyzed on isokinetic dynamometer.

Unlike Bosco et al.[9] and Yapici et al.[10], Sattler et al.[11] used for jump performance assessment block jumps and attack jumps. To identify the relationship between the variables obtained on isokinetic dynamometer with the jumps, a regression model was employed to explain this relationship. The female group and the male group presented higher regression coefficient values between the knee muscle strength obtained on isokinetic dynamometer and block jump height (R^2= 0.42 and R^2= 0.37, respectively) compared to the attack jump [11] (R^2= 0.39 and R^2= 0.36, respectively). The block jump is less complex as to motor gesture, and sometimes similar to CMJ and SJ gestures, with less utilization of the arms in comparison with the attack jump gesture. This lower complexity of the gesture and lower utilization of the arms for impulsion may be an explanatory factor for the higher regression coefficient value found between the variables analyzed on isokinetic dynamometer and the block jump in relation to the attack jump. In addition, similar to the DJ, the attack jump also has great contribution from the SSC to perform the movement, which may also explain these smaller regression coefficient values found for the attack jump. It is worth emphasizing that the difference between regression coefficient values for the male group was discrete, requiring further studies to confirm this justification.

The SJ and the CMJ appear to relate similarly to muscle knee strength analyzed on isokinetic dynamometer. In its turn, the DJ seems to correlate less with knee muscle strength analyzed on isokinetic dynamometer due to the contribution of other factors to the performance of this jump. The block jump seems to be more related to the knee muscle strength analyzed on isokinetic dynamometer in relation to the attack jump. The lower correlation between knee muscle strength and attack jump is due to the greater complexity of the attack gesture involving other mechanisms to perform the jump, therefore decreasing this correlation.

Relationship Between the Strength of Knee Extensors and Flexors and Different Muscle Contractions Assessed on Isokinetic Dynamometer and Jump Performance

The complexity of the mechanisms of each jump is characterized by different requests of muscle activations, besides different forms of contraction used in the jumps. Jumps that use mechanical energy from SSC have the participation of eccentric contractions in the first phase of the gesture[18] and, conversely, jumps that do not use SSC mechanical energy require a great deal of energy from concentric muscle contractions[19]. Therefore, the relationship between knee muscle strength analyzed on isokinetic dynamometer and jumps depends not only on jump speed or type, but also on which muscles will be analyzed in isokinetic dynamometry and types of muscle contractions.

The influence of the strength of knee extensors on jump performance is evidenced when we observe the high correlation values found in studies with volleyball players[9,10,12,13] (Table 2). On the other hand, knee flexor muscles seem to exert less influence on the performance of jumps. In the study by Yapici et al.[10], for instance, the peak torque and total work of knee flexors showed significant correlations (r= 0.42 to r= 0.74) with jump power, but the correlations are smaller than those found with concentrically analyzed knee extensors. In a study by Laudner et al.[13], the correlation of knee flexors torque peak normalized by body mass also showed lower correlation values (r= 0.39 to r= 0.58) with jump height compared to the knee extensors that presented higher correlation values (r= 0.63 to r= 0.74) with height of unilateral and bilateral jumps and four consecutive jumps. These results suggest that the strength of the muscles responsible for the knee extension motion is of greater importance to jump performance compared to flexors. This finding can be explained by the fact that the extensors are working agonistically for the knee joint in the impulsion phase, exerting much of the strength required to reach higher power and height values in the jumps.

The type of contraction analyzed in isokinetic dynamometer assessments should also be taken into account to understand its relationship with the variables of jump tests. Jumps such as CMJ and the attack jump have the beginning of the gesture at knee flexion with posterior extension of this joint for impulsion[4,16]; thus, there is a transition from eccentric to concentric contractions[18]. Yapici et al.[10] identified that for the speed of $60°.s^{-1}$ the power of SJ and CMJ presented higher correlation values with the concentric peak torque of the knee extensors (SJ – r= 0.80 and CMJ – r= 0.82) compared to the eccentric peak torque of the knee extensors (SJ – r= 0.50 and CMJ – r= 0.48), allowing to infer that the concentric action of knee extensors are more associated with power generation in SJ and CMJ. Although SJ and CMJ differ by the use of eccentric contraction in the movement, this study showed that concentric and eccentric peak torque correlations versus both jumps were rather close, suggesting that the type of muscle contraction performed by knee muscles did not differ as to performance in SJ and CMJ.

According to the studies analyzed, the evidence indicates that the peak torque values of knee extensors obtained in the isokinetic dynamometer assessments show higher values of association with jump performance in volleyball players compared to the peak torque of knee flexors. About the different types of muscular contraction, the concentric action of knee extensors is more associated with performance in SJ and CMJ than the eccentric one, and there is no difference in relation to the contribution of concentric and eccentric contractions for the two jumps.

Relationship Between Muscle Imbalances Assessed on Isokinetic Dynamometer and Jump Performance

A great potential for application of results from assessments conducted on isokinetic dynamometer is the identification of muscle torque imbalances from one limb to another and torque imbalance of muscles involved in the movement of a certain joint[6]. Muscle imbalance from one limb to another, called contralateral deficit, is obtained by calculating the peak torque percentage difference of the dominant and non-dominant limbs, in which the reference value for percentage calculation is that of the limb which had a higher peak torque value, that is, the dominant limb[20]. The great importance of this analysis lies on the fact that contralateral deficit values that are higher than 15% may pose a greater risk of injury to the individual[21].

In addition to risk of injuries, these imbalances can negatively influence the performance of volleyball players[6,7], considering that the technical gesture of jumps requires a coordinated action of knee extensors and flexors, and a joint action between the lower limbs[8]. D'Alessandro et al.[12] analyzed the correlation of peak torque contralateral deficit data and the work of knee extensors and flexors performed on isokinetic dynamometer at speeds of 60 and $300°.s^{-1}$ with the contralateral deficit obtained in the Hop Test (unilateral jump test that compares the distance jumped between limbs). The results showed significant correlations between contralateral deficits of peak torque and work at 60°.s^{-1} with the deficit of jumped distance between the lower limbs in the Hop Test (r= 0.44 and r= 0.61, respectively), with no correlations with the highest angular speed. However, the interference of the contralateral deficit with the jump height performance variable does not seem to be clear. In the study by Laudner et al.[13] with volleyball players and other athletes with reconstruction of the knee cruciate ligament, only one correlation was found with the peak torque contralateral deficit of knee flexors assessed on isokinetic dynamometer and bilateral jump height (r= 0.39), not reflected on the height of the unilateral jumps and on the height of the four consecutive jumps. The contralateral deficit of peak torque and work at 60°.s^{-1} seems to be related to the deficit of the jumped distance between the lower limbs in the Hop Test[12]; however, performance measures, such as jump height, do not seem to be related to the contralateral deficit of knee extensors and present small values of correlation with the contralateral deficit of knee flexors[13].

The analysis of imbalances of muscle forces involved in the motion of a single joint is also of great importance to prevent injuries. In the knee joint, one way to achieve this result is by calculating the conventional ratio. This calculation is done by dividing the concentric peak torque of the flexors (hamstrings) by the concentric peak torque of the extensors (quadriceps) of one same limb[22,23]. The result of this division brings relevant information as well, since studies establish a standard value of 0.6 as ideal for joint balance when isokinetic assessment is done at the speed of 60°.s^{-1}, taking into account that individuals who present this value have a reduced risk of injuries in the knee joint[24]. Although differences in strength from one limb to another, obtained on isokinetic dynamometer, do not appear to interfere with jump performance in volleyball players, the imbalance between knee flexors and extensors of one same joint seems to be related to the functionality of volleyball players and other athletes[14]. Li et al.[14] found a positive correlation (r= 0.35 to r= 0.62) between increased conventional ratio and knee flexors torque values with improved functionality measured by means of a functionality questionnaire (ability to jump, walk, etc.) in volleyball players and athletes undergoing rehabilitation for anterior cruciate ligament injury, with strength training of knee flexors and extensors on isokinetic dynamometer. Even though the research by Li et al.[14] did not analyze jump gesture, this study suggests that the balance between the peak torque of knee joint extensors and flexors is important for the functionality of players in sports activities.

Thus, the studies cited here indicate that muscle imbalance values obtained in the isokinetic dynamometry of the knee, such as contralateral deficit, do not seem to interfere with the jump performance of volleyball player. On the other hand, the imbalance analyzed by calculating the conventional ratio may be related to the players' functionality in sports activities. Due to the lack of studies on the interference of muscle imbalances obtained on isokinetic dynamometer and jump performance, it was not possible to draw further conclusions. Furthermore, studies on the relationship between functional ratio and jump performance may present more specific results, as the functional ratio analyzes the relationship between concentric contractions of knee extensors and eccentric contractions of flexors[24], similar to that performed in jump actions.

Conclusions

The use of intermediate angular speeds on isokinetic dynamometer seems to better reflect power generation needs of volleyball players for jumping. The SJ and CMJ seem to be similar in relation to the knee muscle strength analyzed on isokinetic dynamometer, jumps that are performed with the aid of other components, such as the SSC and use of the arms, seem to correlate less. The peak torque of knee extensors are more associated with jump performance than flexors are. The concentric contraction of knee extensors is more associated with performance in SJ and CMJ than the eccentric is, with no difference as to the contribution of concentric and eccentric contractions for both jumps. Contralateral deficit values do not seem to interfere with the jump performance of volleyball players; on the other hand, conventional ration values may relate to the players' functionality in sport activities.

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