



# Isokinetic muscle evaluation of the knee joint in athletes of the Under-19 and Under-21 Male Brazilian National Volleyball Team

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## ABSTRACT

The vertical jump is a basic volleyball practice that demands a high ability to generate strength and work in the muscles involved, mainly in the quadriceps muscle. Due to such demand, muscle imbalances between extensor and flexor muscles may be present, causing an overloading on the muscle-tendinous structures of the knee joint. Thus, the establishment of normal parameters for the muscle function related to that joint in volleyball athletes is necessary. Therefore, the purpose of this study was to assess through isokinetic dynamometry the peak torque, work peak, agonist/antagonist ratio, and fatigue index of the flexor and extensor of the knee among both volleyball athlete population. The isokinetic flexion and extension tests of the knees were performed in the concentric-concentric seat mode at 60 and 300°/sec. velocity in thirty-six athletes (20 under 19-under 21, and 16 under 21). The data allowed to set the parameters for the muscle function of the knee joint among athletes of the 2003 Under 19-Under 21 and Under 21 Brazilian National Team Selection of Male Volleyball. Athletes presented peak torque and work peak values normalized by the body mass to the upper quadriceps to the mean normal values for the athletes and non-athletes populations. Compared to other categories, the under 21 athletes presented significantly higher values for the agonist/antagonist ratio, and peak work ratio of the knee flexors at 60°/sec. velocity. Furthermore, the agonist/antagonist ratio was lower than the reference value expected for both categories, thus characterizing predominance in the extensor musculature over the flexor musculature. The fatigue index was close to what would be expected for the majority of athletes. The present study may be useful as comparison basis for future studies aiming evaluate the isokinetic muscle function in volleyball players.

**Keywords:** Knee injuries. Torque. Athletic injuries. Knee joint.

## INTRODUCTION

The vertical jump has been mentioned as one of the major basic components to the volleyball practice<sup>(1-3)</sup>. Thissen-Milder *et al.*<sup>(3)</sup> consider the jumping ability a differentiating factor to the volleyball players' performance, as the jump is the component of the attack and defense movement required in that sport, such as spike, serve and block. Thus one of the training goals to perform higher vertical jumps. The resistance training as well stretch-shortening cycle exercises has been used to attain this goal<sup>(1,4)</sup>.

The vertical jump, which is characterized by a ballistic movement consisted by a quick eccentric muscle action followed by a maximal concentric action demands a high ability to generate strength and work to the musculature involved mainly in the quadriceps muscle<sup>(5)</sup>. This basis of the sports demands two main functions from the extensor mechanism: the accelerating function with a concentric contraction, such as the impulsion phase in a jump; and the decelerating function with an eccentric contraction observed in the phase of landing<sup>(6)</sup>. Due to such demand on the extensor mechanism, imbalances between the extensor and flexor muscles may be present, causing an overloading to the muscle-tendinous structures around the knees joint<sup>(6,7)</sup>.

This specific volleyball demand on knee joint may be related to high incidence of injuries in such joint<sup>(4,5)</sup>. Some authors mention the knee joint injuries as one of the major causes for the absence occurrences in this sport<sup>(1,8-10)</sup>. Ferretti *et al.* report a higher than 40% incidence in the patellar tendinopathy in the elite players, and this injury is the main cause of anterior pain in knee joint<sup>(2,4)</sup>; the increase the likelihood of muscle and/or joint injuries has been clinically pointed out as consequence of abnormal torque differences between the agonist/antagonist and/or contralateral muscle groups<sup>(11)</sup>. Another factor related to the increase in overload of muscle-tendinous structures of the knee joint may be the increasing training intensity and volume in players from different categories. As a consequence, athletes from more advanced categories may present a higher ability to generate knee extensor and flexor strength compared to younger players<sup>(11,12)</sup>. This fact emphasizes the need to identify differences between athletes from different training levels of practice in the sports.

The demand imposed to the knee joint through the sports practice results in specific muscle adaptations that may generate strength imbalances that has a static and dynamic action around this joint<sup>(13)</sup>. Such muscle imbalances may predispose athletes to injuries, as they produce high stress levels into the tissues<sup>(11,13)</sup>. Being so, it is necessary to set the parameters for the muscle function related to that joint in athletes. For this, the isokinetic dynamometry allows a quick and reliable quantification of variables related to the muscle performance at several speeds, including the torque, work, agonist/antagonist ratio, and fatigue index<sup>(11,14)</sup>.

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Furthermore, isokinetic assessment allows identify muscle strength deficits both between the legs and between the agonist and antagonist muscles group in the joint evaluated<sup>(11-13)</sup>.

There are several studies focusing the use of the isokinetic dynamometer in different populations<sup>(11-15)</sup>. Nevertheless, there is few little information available about these measurements in volleyball athletes, especially related to lower limbs<sup>(16,17)</sup>.

Therefore, the purpose of this study was to established for knee joint muscle function of the knee joint in high level male volleyball athletes through the isokinetic dynamometry, and to assess the differences on muscles performance of such joint and on the training volume between the under 19-under 21 and under 21 categories.

## MATERIALS AND METHODS

### Sample

Thirty-six elite Brazilian volleyball athletes were assessed: twenty from the Under 19 Male Brazilian National Team, with mean age 17 years ( $\pm 0.46$ ), body mass 86.3 ( $\pm 9.1$ ), and height 1.97 ( $\pm 0.05$ ), and sixteen from Under 21 Male Brazilian National Team, with mean age 19.5 ( $\pm 0.63$ ), mass 91.6 ( $\pm 6.6$ ), and height 1.97 ( $\pm 0.06$ ). All subjects provided written informed consent term to participate in the tests that were composed by an assessment program promoted by the Center of Sports Excellence (CENESP-UFMG).

### Instrumentation

The Isokinetic Dynamometer *Biodex 3 System Pro*<sup>®</sup> was used to assess the peak work variables, the peak torque of the flexor and extensor of the knees normalized through the body mass, the agonist/antagonist ratio at 60°/sec and 300°/sec. velocity, and a fatigue index at 300°/sec. The isokinetic assessment is characterized by the accomplishment of muscle contractions, keeping the limb moving under a constant and predetermined velocity<sup>(18)</sup>. The isokinetic dynamometer applies a accommodative resistance along the whole magnitude of the movement<sup>(18)</sup>. Thus, an increase in the muscle strength performed by the subject being evaluated produces an increase in the resistance, but no increase in the velocity, similar to what happens in isotonic exercises.

### Procedure

Athletes performed a 5 minute warming up in an ergonomic bicycle before beginning the isokinetic testing. Next, athletes seat on the dynamometer, having the chair positioned at an 85° hip flexion, and the movement axis of the equipment was aligned to the side epicondyle of the femur. Athletes were belt-stabilized around their trunks and thigh, in order to avoid compensatory movements. The magnitude of the movement was limited between an 110° flexion and 0° extension, and 0° was defined as the whole extension.

Before starting the test, athletes performed previously three submaximal repetitions, in order to be familiarized with the procedures.

During the test, athletes performed five maximal flexion and extension repetitions of the knee in the concentric-eccentric mode at 60°/sec. velocity, and thirty repetitions at 300°/sec.<sup>(18)</sup>. This procedure was bilaterally performed, and the first limb to be tested was randomly chosen. It was chosen the angle velocity of 60°/sec., since the muscle strength assessed at low velocities allow to gather a higher number of motor units<sup>(13)</sup>, thus allowing a better representation of the maximal work performed by the musculature to be assessed. The 300°/sec. velocity was selected in order to assess every variable in the most functional velocity available, and the number of repetitions performed at such velocity allowed to assess the fatigue index of the athletes<sup>(18)</sup>. Every athlete received verbal stimulation during the tests.

## Data Reduction

The isokinetic variables analyzed were: peak work (J), and peak torque (Nm) of the knee flexor and extensor normalized through the body mass (J/Kg and Nm/Kg, respectively), agonist/antagonist ratio at 60°/sec. and 300°/sec. velocity, and muscle fatigue index at 300°/sec. The work variable was calculated as the total area under the torque curve during the maximal repetition of the test.

Thus, the peak work is the most representative variable of the muscle function, compared to the peak torque variable, since the peak work informs the production of the torque during the whole magnitude of the contraction, while the peak torque informs only the peak in just one spot of the whole magnitude. The peak torque and peak work values were divided by the body mass and multiplied by 100, allowing normalize the data to compare and gather the subjects. The variable agonist/antagonist ratio was calculated dividing the peak torque of the flexor of the knees (hamstring) by the peak torque of the extensor of the knee (quadriceps), multiplied by 100. The fatigue index variable was calculated as the percentage difference between of the production of work between the ten first and ten last repetitions at the 300°/sec. velocity<sup>(18)</sup>.

## Data Analyses

Independent *t*-test was used to compare groups in the training hours variables per week and time of the volleyball practice. The two-way factorial analysis of variance (ANOVA) was used to evaluate the main affects of group affiliation (categories: under 19 and under 21), limb dominance (dominant and non-dominant), and their interaction effect on the dependent variables: knee extensor and flexor peak torque and peak work normalized by body mass, of the flexor and extensor of the knee, the agonist/antagonist ratio at both velocities and the muscle fatigue index.

The analysis of the contrasts was used to locate specific pairs between which the difference was significant. The significance level was set at  $\alpha = 0.05$ .

## RESULTS

The results found in this study showed a statistically significant difference ( $p < 0.0001$ ) between the under 19-under 21 and under 21 categories to the hours of training per week variable. The time variable of the volleyball practice did not present that difference ( $p > 0.05$ ). Values are described on table 1.

**TABLE 1**  
Training characteristics (mean  $\pm$  standard deviation)

	Under 19-Under 21	Under 21	p Value
Practice time (years)	5.95 $\pm$ 2.85	5.62 $\pm$ 1.67	> 0.05
Training hours/week	18.4 $\pm$ 8.75	30.3 $\pm$ 5.63	< 0.0001

The variance analysis showed no statistically significant difference ( $p > 0.05$ ) between groups, legs, or leg x group interaction to the peak torque and work peak variables normalized by the body mass of the extensor of the knee at 60°/s and 300°/s, and fatigue index of the knee extensor (table 2).

To the variable agonist/antagonist ratio at 60°/s it was found statistically significant differences between the dominant and non-dominant limbs in the under 21 category ( $p = 0.0426$ ), and between both categories only to the dominant limb ( $p = 0.0247$ ) (table 3).

Besides, it was found statistically significant differences between the under 19-under 21 and under 21 categories (group factor) to the peak torque ( $p = 0.0031$ ), and peak work ( $p = 0.0040$ ) of the flexor muscles of the knees at 60°/s variables, and statistically significant differences between dominant and non-dominant limbs (leg factor) to the peak torque ( $p = 0.0077$ ) and peak work ( $p = 0.0221$ ) variables of the flexor of the knee at 60°/s. For the interac-

**TABLE 2**  
Mean and standard deviation of the peak torque and peak work normalized by the body mass of the extensor of the knee, and the extensor of the knee fatigue index at 60°/s e 300°/s in the dominant and non-dominant limbs in each category

Extension	Under 19-Under 21				Under 21			
	60°/s		300°/s		60°/s		300°/s	
	D	ND	D	ND	D	ND	D	ND
Peak torque (Nm/Kg)	340.4 ± 42	342.8 ± 37.3	192.9 ± 21.8	190.1 ± 18.1	356.8 ± 47.7	356.1 ± 30.7	309 ± 29.3	200 ± 19.6
Peak work (J/Kg)	422.1 ± 46.4	427.5 ± 42.1	205.3 ± 29.5	206.1 ± 20.6	429.1 ± 70.1	434.3 ± 41.2	205 ± 31.6	205.4 ± 19
Fatigue index (%)	-	-	48.5 ± 7.6	48.5 ± 5.4	-	-	47.1 ± 11.7	50.3 ± 6.0

**TABLE 3**  
Mean and standard deviation of the agonist/antagonist ratio (flexor/extensor) at 60°/s and 300°/s of the dominant and non-dominant limbs in each category

AG/ANT RATIO (%)	Under 19-Under 21				Under 21			
	60°/s		300°/s		60°/s		300°/s	
	D	ND	D	ND	D	ND	D	ND
	49.0 ± 5.2 <sup>b</sup>	47.2 ± 6.2	67.7 ± 12.0	66.8 ± 11.8	53.7 ± 9.5 <sup>a,b</sup>	49.3 ± 6.1 <sup>a</sup>	66.4 ± 13.2	66.6 ± 8.6

a = p < 0.05 between dominant and non-dominant limbs in the under 21 category; b = p < 0.05 between both categories in the dominant limb.

**TABLE 4**  
Mean and standard deviation of the peak torque and peak work normalized by the body mass of the flexor muscles of the knee, fatigue index of the flexor muscles of the knee at 60°/s e 300°/s of the dominant and non-dominant limbs in each category

Flexion	Under 19-Under 21				Under 21			
	60°/s		300°/s		60°/s		300°/s	
	D	ND	D	ND	D	ND	D	ND
Peak torque (Nm/Kg)	165.2 ± 12.8	160.8 ± 20.0	128.8 ± 16.4	125.8 ± 17.2	188.2 ± 19.3	176.7 ± 26.0	140 ± 25.0	134.7 ± 22
Peak work (J/Kg)	214.6 ± 17.5 <sup>b</sup>	214.8 ± 32.2 <sup>c</sup>	109.3 ± 19.9	108.7 ± 20.7	250.3 ± 27.1 <sup>a,b</sup>	229.0 ± 31.1 <sup>a,c</sup>	122 ± 21.6	116.8 ± 21.2
Fatigue index (%)	-	-	60.2 ± 7.9	63.7 ± 9.4	-	-	60.1 ± 10.9	62.4 ± 10.9

a = p < 0.05 between dominant and non-dominant limbs in the under 21 category; b = p < 0.05 between both categories in the dominant limb; c = p < 0.05 between both categories in the non-dominant limb.

tion effect (leg x group), it was a statistically significant difference only to the work peak (p = 0.0200) variable of the flexor of the knee 60°/s.

The analysis of the contrast for the interaction effect (leg vs. group) revealed a statistically significant difference to the peak work in the flexor of the knee between both categories (p = 0.0001) for the dominant limbs; p = 0.0291 for non-dominant limbs), and between the dominant and non-dominant limbs in the Under 21 category at 60°/sec. (p = 0.0026) (table 4).

## DISCUSSION

Characterization studies of the isokinetic performance are frequently found in the sports literature<sup>(11,13-15)</sup>. Nevertheless, despite the high incidence of injuries in the lower limbs in volleyball athletes and the importance of the jumps in the acquisition of a high level performance in this sport, it was found few studies on the isokinetic variables in the lower limbs for such population<sup>(16,17)</sup>.

Thus, data of this study allowed set the parameters for the muscle function of the knee joint through the isokinetic dynamometry in Male Volleyball Under 19-Under 21 and Under 21 Athletes from the Brazilian National Team, and it can be used as reference for future comparisons. In both groups, the peak torque variable of the extensor of the knees normalized by the body mass presented higher values than those from the normative data for the non-athlete population supplied by the manufacturer of the isokinetic dynamometer used in this study<sup>(18)</sup>. These results are in accordance to what was found in the literature on the comparison of the isokinetic variables between athletes and non-athletes<sup>(11-13)</sup>. In the specific case of the volleyball, these results can be explained

by the great quantity of jumps inherent to the sports practice. Some authors mention a mean sixty maximum jumps per hour during a match<sup>(5,12)</sup>. Furthermore, Lian *et al.*<sup>(5)</sup> have proposed that more than 50% of the work produced in a jump is attributed to the knee extensors of the knee, and this would cause a muscle demand capable to cause adaptations, thus differentiating athletes from non-athletes. Parallel to this, high level athletes are submitted to physical preparation schedules that beyond the jumps, they involve in muscle strengthening programs, such as resistance training.

This study analyzed differences in the isokinetic variables between two different volleyball categories (Under 19-Under 21, and Under 21). Results of this analysis has pointed out significant differences of the peak work normalized by the body mass of knee flexor of the knees between volleyball Under 19-Under 21 and Under 21 teams, that were not followed by significant differences in the peak work normalized by the body mass of knee extensors of the knees. Similar to this, Hewet *et al.*<sup>(16)</sup> have found an increase in the peak torque only in the knee flexor muscles after a six-week plyometric training in young female volleyball players. Furthermore, Herzog *et al.*<sup>(19)</sup> showed that the peak torque in the knee joint was kept approximately constant after successive raisings starting from 40% of the peak load during the squat exercise, while in the hip and ankle joints it was detected a raise in the torque generated. These results seem to indicate that despite the extensor musculature is considered the major generator of strength to the jump<sup>(5,6)</sup>, the variations in the load or training volume may also lead to a raise in the ability to generate strength in the flexor muscles. According to these data, differences found in the present study may be related to a higher training volume of the Under 21 category

(mean = 30.3 h/week) compared to the Under 19-Under 21 (mean = 18.4 h/week,  $p < 0.0001$ ).

Another factor that may be related to the significant difference between the Under 19-Under 21 and Under 21 categories found in the peak work variable normalized by the body mass of the flexor of the knee may be a change in the training methodology, as only athletes from the under 21 category had been submitted to some specific work giving priority to the flexor of the knee. Besides, many athletes assessed in this study had already suffered injuries related to the knee joint (Under 21 = 31.3%, and Under 19-Under 21 = 17.3% - data yet to be published) what is in agreement to the data found in the literature<sup>(1,4,5,8,9)</sup>. Thus, it is possible that before the presence of injuries, athletes have developed compensatory strategies to keep their performance level, as a way to give priority to the flexor muscles as the momentum generator to the jump. In order to properly answer such cause and effect relationship, it is necessary to perform longitudinal studies. Thus, these questions deserve further clarifications, and it should be aimed further researches in this area.

Also, it was found a significant difference in the peak flexion work at 60°/s between the dominant and non-dominant limbs among the Under 21 category, thus characterizing a deficit between legs, as the dominant limb presented a higher work than the non-dominant one in those athletes. Such deficit has been reported in some studies as a risk factor for the muscle-tendinous injuries of the knee joint<sup>(11,13)</sup>. The possible causal factors for such difference in the flexor work between limbs in the under 21 category may be characteristic of the jump in which the strength generated and absorbed, respectively in the impulsion and landing can be uneven between lower limbs due to the specific characteristic of the sports attack movement<sup>(20)</sup>.

The methods used to attain the agonist/antagonist ratio are widely discussed in the literature<sup>(4,21)</sup>. Traditionally, the agonist/antagonist ratio is calculated as the ratio between the peak values of the concentric torque of the flexor muscles, and the concentric peak torque of the extensor of the knee. Some authors consider that this method is not representative of the muscle function, since the antagonist musculature (flexor of the knee) would actuate in an eccentric way during the concentric action of the agonist muscles<sup>(11,21)</sup>. Nevertheless, Baratta and Solomonow<sup>(22)</sup> showed that the hamstring action as antagonist is directly proportional to its ability to generate concentric strength.

Thus, this study considered the measurement of the agonist/antagonist ratio in the concentric/concentric mode due to its ability to provide information on the relationship of the strengths around the knee joint<sup>(22)</sup>. Besides, in order to compare it with other studies, this work uses as normality parameters the reference values the 64% at 60°/s, and 80°/s at 300°/s agonist/antagonist ratio supplied by Reid<sup>(23)</sup>. Despite the values supplied by Reid<sup>(23)</sup> are not specific for volleyball athletes, its use was chosen due to the absence of more appropriate parameters in the literature.

The variable agonist/antagonist ratio in the assessed athletes in this study presented lower values than foreseen for both categories, besides of significant differences between them, comparing dominant limbs, and comparing between dominant and non-dominant limbs only for the under 21 category, thus reflecting the previously mentioned difference between legs. The low agonist/antagonist ratio indicates predominance of the extensor musculature or a deficit in the flexor musculature, which can represent a muscle imbalance of the knee. Such imbalance has been reported as a possible cause for the increase in the overloading in this joint, making it susceptible to injuries in the muscle-tendinous insertions<sup>(2,4,8-10,24)</sup>.

Colonna *et al.*<sup>(17)</sup> assessed the peak torque and the agonist/antagonist ratio of the flexor and extensor of the knee in eleven volleyball players in Italy. Similar to what was done in this study, it was used the 60°/s velocity, and the normalization of the peak

torque variable was performed by the body mass. For the agonist/antagonist variable (flexor/extensor) in Italian athletes, it was found means of 54% for right leg, and 53.7% for the left leg. In Brazilian athletes of the under 19-under 21 and under 21 categories, respectively, the means found were: 49%, and 53.7% for the right leg (dominant), and 47.2%, and 49.3% for the left leg (non-dominant). Both studies found agonist/antagonist ratio means below 64%, indicating a possible muscle imbalance of the knee joint.

The fatigue index variable did not present any significant difference between groups or limbs in a same group. It is expected that such index is kept below 50% both to the extensor and the flexor of the knee<sup>(18)</sup>, as this percentage indicates that the musculature was able to keep at least 50% of its initial ability in generating work along thirty repetitions. However, the mean of athletes was kept around that value for the quadriceps and above that figure to the hamstring. This result can indicate a lower flexor's resistance to the fatigue related to the extensor of the knee, raising the risk for injuries after long training or competition periods. It was found no study aiming to analyze such variable for comparisons.

One limitation in this study was not to assess the peak work and peak torque variables normalized by the body mass of the flexor and extensor of the knee at 60 and 300°/s in an eccentric mode, the agonist/antagonist ratio at both velocities, and the muscle fatigue index of the flexor and extensor of the knee, once the jump, a basic activity to the volleyball practice consists of eccentric contraction followed by a concentric contraction<sup>(5,6,15)</sup>. This protocol was not used, as several athletes were able to generate eccentric torques higher to that produced by the dynamometer, thus disabling to conduct the tests.

Still, there is some controversy in the literature concerning the ability of the isokinetic test to be a good predictor of the sports performance, since several studies did not find any relationship between the isokinetic variables of the knee joint and the height reached by athletes in the vertical jumping<sup>(15,17,25)</sup>. Nevertheless, the isokinetic tests are widely used by studies in populations of athletes, because they supply objective, reliable and reproducible values of the muscle function of several joints<sup>(11,12,14)</sup>.

Thus, these tests allow assessing the parameters related to the muscle performance, such as strength, work, power, and imbalances between the agonist and antagonist muscles<sup>(11,12)</sup>. Therefore, these measurements attained through isokinetic assessment may be quite effective in detecting muscle-skeletal changes, guidance to preventive measures, implementation of specific training programs to each athlete and to improve the sports performance<sup>(13)</sup>.

## CONCLUSION

The data allow the settings of parameters for knee joint muscle function of the knee joint through the isokinetic dynamometry in athletes from the 2003 Brazilian Under 19-Under 21 and Under 21 National Male Volleyball Team. The assessed athletes presented peak torque and peak work values normalized by the body mass for the upper quadriceps to the mean athlete and non-athlete populations. Comparing the categories, under 21 athletes presented significantly higher agonist/antagonist ratio and peak work values of the flexor muscles of the knee at 60°/s. Nevertheless, the agonist/antagonist ratio was lower than the reference value expected for both categories, thus characterizing the predominance of the extensor over the flexor musculature. The fatigue index was found close to the expected value for the majority of athletes. The present study can be used as basis for comparisons in future studies assessing the isokinetic muscle function for volleyball athletes.

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