Analysis on the association between isokinetic dynamometry of the knee's articulation and one-leg horizontal jump, hop test, in volleyball athletes

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ABSTRACT

The isokinetic dynamometer has been widely used to assess the muscle performance. Due to its high cost, the use of such device in clinical practice becomes unfeasible. The one-leg hop is a test to evaluate the strength and reliance on lower limbs that may be used in routine clinical trials at low cost, being no time-consuming. The present study aimed to assess whether there is any association between the hop test and the muscular function data provided by the knee evaluations at the isokinetic dynamometer in professional athletes. **Materials and methods:** Thirty volleyball players (8 women and 22 men) were evaluated by means of isokinetic dynamometer at speeds of 60º/s and 300º/s, and through the hop test at distance. **Results:** It was observed a low correlation between the deficit of the peak torque (r = 0,441) and the work (r = 0,610) at 60º/s, with a deficit for hopped distance between lower limbs. Moreover, it was found a low correlation between the muscle performance and the distance reached during the hop test, except for women in the right lower limb. **Conclusion:** The current study has shown that the hop test cannot be used to replace isokinetic dynamometric tests for functional tests.

Keywords: Hop test. Isokinetic. Sports. Performance.

INTRODUCTION

The isokinetic dynamometer has been frequently used to study the muscular function in the research environment[1,2], mainly to evaluate the post-lesion of muscles around the knees' articulation[3]. Besides of having good validity and reliability, the isokinetic dynamometer allows to evaluate the maximum torque produced by muscles throughout the endurance of the movement (ADM)[3]. The main application of the isokinetic dynamometer has been in monoarticular tests for several articulations of the human body[3,4]. These tests supply information on the muscular function, such as torque, work, and potency among others[3]. The evaluation of those variables has allowed setting comparisons between agonist and antagonist muscles, and between counter-lateral limbs[5], with the purpose to determine possible risk factors for sprains. Besides of having low values of the muscular function below the reference values in some populations, asymmetries between limbs and the unbalance between agonists and antagonists are among those variables supplied by the dynamometer[6], and they have been considered as risk factors for sportive sprains in the specialized literature[7,8]. However, due to the high cost of the equipment, the isokinetic dynamometer still is subutilized equipment in the clinic practice.

To compensate the difficulty to have access to such equipment, other simplest tests or methods of evaluation have been commonly employed by physiotherapists, doctors, trainers, among other sports' professional in the clinical practice[9-11]. However, it is necessary further scientific studies to give a base aiming to use these tests, since most of them cannot prove to be valid.

The validation of simplest tests to evaluate the muscular function could grant other methods able to select those individuals who need a more detailed evaluation using sophisticated equipments, such as the isokinetic dynamometer. These classification methods shall include easy-to-handle and no-time-consuming instruments, and able to supply valid information on the muscular function. The use of such classification methods to identify the muscle deficits would allow the selection of individuals with potential for muscular sprain[7,8], and furthermore, it would facilitate a preventive therapeutic approach.

A simple test commonly employed in the physiotherapeutic practice to evaluate the performance of a sprained lower limb (LL) related to the non-sprained LL is the one-leg horizontal hop at distance (hop test). The hop test was proposed by Daniel *et al.* (1982)[12] to evaluate the muscular strength and the reliance on the lower limbs (LL) involved in a sprain. The hop test has psychometric properties which are set to identify sprains in the LL[10,11]. The hop test and its variations have been widely used to evaluate the returning to the functional level of the sprained knee, mainly after reconstruction of the anterior crossed ligament (LCA)[9-11]. Although the hop test does not allow performing a detailed analysis on the LL's function similar to that obtained using more sophisticated devices, it allows a general classification for the sprained LL's evaluation in the clinical practice[10]. Other advantages of the hop test on other evaluation methods are the low wasting of time, minimum financial demand, and use of the counter-lateral limb as control[10].

However, as it is used mainly in situations upon the return to the activity after sprains, there is no further study on the possibility to apply this test to evaluate possible strength deficits between LL and healthy individuals.

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Dimensions measured by the hop test are not quite defined in the literature, that is, it is not clear if such test is more related to the strength of the LL or to the reliance or skill on the tested lower limb, but some authors have already evaluated associations between this test or similar tests and those variables related to the muscular performance. Dauty *et al.* (2002)[13] found a mild association between the vertical hop and the isokinetic dynamometer at 180º/s to the extension of the knees in non-sprained soccer players. Petschnig *et al.*[11] observed the association between the torque peak at 15º/s of the knee's extension in hopped distance during the hop test of LL with and without sprain, and in the symmetry between non-sprained LL. However, in those knees without sprain history, it was not found in the researched literature any direct association between the hopped distance in the hop test and the maximum torque and work in the knee extension movement in isokinetic dynamometer[11]. Therefore, in the event it would be found a strong association between the isokinetic dynamometer and the hop test, it could be of big use to the sports' professionals, since it would set the ground to the use of the hop test as a classification method to the variables studied in non-sprained individuals.

Thus, the purpose of this study was to verify the existence of an association between the hop test and data on the muscular function supplied by the evaluation of the knee's articulation at the isokinetic dynamometer in non-sprained professional volleyball athletes of high level.

MATERIALS AND METHODS

Sampling

It participated in the study 30 volleyball athletes (eight women and 22 men) with average ages of 18.25 ± 1.25 years, average height of 194 ± 8.37 cm, average weight of 85.22 ± 10.19 kg, integrants of national selections, being two German world champions, and one world's vice-champion in the male juvenile and childish-juvenile, and female juvenile of 2003, same year when the data collection was performed. To be included in this study, the athletes could not present sprains in the knees, hips or ankles. Every athlete voluntarily signed the term of consent to participate in the tests, whose data are part of an evaluation program promoted by the Center of Sportive Excellence (CENESP-UFMG) in convention with federations and selections through the Ministry of the Sports. The evaluation was approved by the technical-scientific coordination of the CENESP.

Instruments

The isokinetic dynamometer *Biodex 3 System Pro* (Biodex Medical System, Inc, New York, USA) was used to accomplish every measurement of the muscular function (maximum torque and maximum work at the speeds of 60º/s and 300º/s). To measure the hopped distance in the hop test, it was used a millimeter metric tape.

Procedures

Athletes were evaluated using the isokinetic dynamometer, and the hop test. Every athlete was wearing shorts, T-shirts, and appropriated shoes to perform the tests. The test sequence was accomplished as to follow the convenience criteria and the lab operationalization. Voluntaries were allowed to have enough recovering time from a test to another.

Hop test

Athletes were tested in a previous marked area using meters. Upon the beginning of the test, athletes' anterior extremity of the right foot was positioned on the first mark. All athletes were informed on the hop procedure, and they were asked to hop the largest distance possible using each of their lower limbs. Athletes could use their upper limbs (UL) to help the impulsion, in order to performing it as close as possible to the UL movement in the sports. Upon the execution of the hop, it was performed an eccentric phase before the test began.

Those hops allowing such eccentric phase along with the UL movement, also follow functional aspects related to the modality[15] thus allowing a higher generation of strength due to physiologic and biomechanical aspects. Athletes were oriented to keep their foot at the same site of the fall after landing. The distance from the fastest posterior point of the heel up to the first mark was measured using the millimeter tape, and it was considered as the distance reached in the hop.

Every hop was performed three times using each LL. Next, the procedure was reproduced using the left LL. The best hop with each member was used for statistical purposes.

Isokinetic dynamometer

The isokinetic dynamometry was performed by an isokinetic dynamometer *Biodex System 3-Pro* (New York, USA). After the test, athletes performed a warm up in ergometric-bicycle for ten minutes, followed by four stretching series of 20 seconds each for the ischiotibial muscles and the femoral quadriceps muscles. After the stretching, athletes performed a series of three repetitions at each speed using the dynamometer, to be familiarized with the test. Tests were performed at two speeds: 60º/s and 300º/s to the eccentric flexion/extension of the knee, in order to obtain variables of torque and work peak. It was chosen the speed of 60º/s, once at low speeds[17] it is obtained a higher torque generation, which is closest to the athletes' maximum muscular performance[18]. The speed of 300º/s was chosen, since it represents more functionally the high contraction speed performed when practicing the sports[17]. Athletes were positioned seat on the dynamometer seat. The angulation of the chair's with the dynamometer's axle. The popliteal fossa of the tested knee was five centimeters apart to the seat, and the isokinetic arm was held five centimeters above the lateral malleolus of the ankle. The five centimeters in relation to the seat, and the isokinetic arm was held five centimeters above the lateral malleolus of the ankle. The magnitude of the test was limited to 100º, beginning with a 110º flexion, and a 10º knee's flexion. The magnitude of the whole extension was limited to avoid the passive insufficiency effect of the ischiotibials.

Testes were performed in the concentric mode, with five repetitions at 60º/s, and five repetitions at 300º/s. When comparing both speeds, it was allowed a 30 seconds of resting interval. Every test was performed upon verbal stimulation, in order to motivate the athletes' maximum strength during the accomplishment of the tests. Tests were performed in varied order of LL, according to the lab's convenience criteria.

Data reduction

To the muscular asymmetry analysis between LL it was calculated the deficits between LL among the tested variables. The lower value was subtracted from the higher, and the remainder was divided by the higher value. Then, this quotient was multiplied by 100, reaching a result as the deficit percentage. These calculations were made for the hop index, and for the torque and work peak of the isokinetic dynamometer. The hop index calculations were performed manually, and the calculations of the variables related to the isokinetic performance are shown after the calculation performed by the analysis software of the dynamometer.

Statistical analysis

The Pearson correlation test was used to perform the analysis of the association between the deficit in the isokinetic and the deficit in the hop test, and to analyze the relationship between the maximum torque and work, and the maximum hopped distance separated by gender and by right and left side, with significance level (α) equal to 0.05.

The statistical software *Minitab Release* 13.20 (Minitab, Inc, Pennsylvania, USA) was used to perform this analysis.

RESULTS

The average values of the tested variables and their standard deviations are presented in table 1.

TABLE 1
Average and standard deviation (Tmax 60º – maximum torque at 60º/s, W 60º – work performed at 60º/s, Tmax 300º – maximum torque at 300º/s, W 300º – work performed at 300º/s, D hop – maximum distance hopped in the hop test)

Variable	Average	Standard deviation
Tmax 60º	287.53 N.m	61, 93 N.m
W 60º	352.48 J	72.75 J
Tmax 300º	160.04 N.m	35, 83 N.m
W 300º	164.09 J	34.89 J
D hop	195 cm	30 cm

Associations between the deficit of the hopped distance between LL, and the deficit of the torque and work peak at 300º/s were not significant. It was observed a significant association between the deficit of the torque and the work peak at 60º/s with the deficit of the hopped distance between LL. The association between the work deficit and the deficit of the hopped distance presented better result (r = 0.610; p = 0.0001). Other data are presented in table 2.

TABLE 2
Values to the correlation (r) and significance level (p) for the deficits. (Tmax 60º DEFICIT – deficit of the maximum torque between LL at 60º/s, W 60º DEFICIT – work deficit performed between LL at 60º/s, Tmax 300º DEFICIT – deficit of the maximum torque between LL at 300º/s, W 300º DEFICIT – work deficit performed between LL at 300º/s, hop DEFICIT – deficit of the maximum distance hopped between LL in the hop test, significant values for * – p < 0.05 and ** p < 0.001, (ns) – non-significant values)

Variables	Value of r	Value of p	
Tmax 60º Deficit x hop Deficit	0.441	0.015	*
Deficit W 60º x Deficit hop	0.610	0.000	**
Tmax 300º Deficit x hop Deficit	0.126	0.507	(ns)
W 300º Deficit x hop Deficit	0.343	0.064	(ns)

Compared to the results of the isokinetic dynamometer separate by gender and LL, it was found a decreasing in the association value, and a difference in the association between left and right LL as well. It was noted that in significant associations between genders, women presented higher *r* values. Male individuals presented a higher number of significant associations (table 3).

DISCUSSION

Despite the increasing proliferation of the isokinetic dynamometers in Brazil, this test is still financially unviable to become part of the medical assessment routine, the physiotherapy or the physical preparation in the major part of clinics, sports clubs, and universities. The interpretation of the results found in the evaluation at the kinetic dynamometer requires experience by the appraiser, as well as it demands time to execute the test and the data analysis. On the other hand, the use of the hop test in the clinical practice does not demand any further financial support it is easy to apply and to interpret its results. The existence of the association between the hop test and the isokinetic dynamometer would be of great applicability to the clinical practice.

Results showed no significant association between the deficits of the variables torque and work peaks evaluated at 300º/s, and the deficit between LL of the maximum hopped distance in the hop test between LL. This absence of significant association surprises due to the fact that the speed of 300º/s is closest to the angular speed of the knee when performing the hop movement[15]. It was observed at 60º/s a low but significant association both in the maximum torque with hopped distance (r = 0.441) and to the work with hopped distance (r = 0.610). Such low association can be explained by the influence of other hop factors, such as neuromuscular coordination and trust[11,12].

The execution of the hop test in this study can partially explain these results, since it allowed an eccentric muscular action previous to the hop. Such pre-hop eccentric activity could raise the power of the hopped distance[16], and the same did not occur in the isokinetic test performed only in the concentric mode. Due to the fact that the hop occurs in closed kinetic chain, athletes can use compensatory strategies, such as the use of ischiotibials, thus generating moments in other articulations. The isokinetic test performed in this study was made in open kinetic chain, thus, these compensations cannot occur. So, the deficit occurred in one test does not mean it will occur directly in other tests, and it does not allow to deduce any information from the hop test about unbalances on the muscular torque and work. Similarly, Petschnig *et al.* (1998)[11] and Noyes *et al.* (1991)[10] found a low association between the torque peak and the hop test in studies involving individuals in the post-surgical period of LCA reconstruction. Thus, the use of a test including eccentric and concentric contractions compared to another one performing only the concentric mode can be considered as a limitation of this study.

In the data analysis separating female from male individuals, it was tested the association between values of the isokinetic evaluation and the hopped distance with each LL solely. The relationship between variables depends on the LL tested and the gender of the individual. Among female individuals, the association was higher both in the torque peak analysis and the hopped distance,

TABLE 3
Values for the correlation (r) and significance level (p) to the right (D) and left (E) maximum torque (Tmax) at 60º/s (Tmax D and Tmax E 60º), at 300º/s (Tmax D and Tmax E 300º) and the right ad left work (W) at 60º/s (W D 60º and W E 60º,) and 300º/s (W D 300º and W D 300º) and maximum distance in the hop test (D hop) with the right (D hop LRL) LL and left (D hop LLL) LL. Significant values to * - p < 0.05 and non-significant values (ns) for p > 0.05

Men (n = 22)				Women (n = 8)			
Variables	r	p		Variables	R	p	
Tmax D 60º x D hop LRL	0.536	0.010	*	Tmax D 60º x D hop LRL	0.721	0.043	*
Tmax E 60º x D hop LLL	0.404	0.062	(ns)	Tmax E 60º x D hop LLL	0.200	0.634	(ns)
W D 60º x D hop LRL	0.562	0.007	*	W D 60º x D hop LRL	0.797	0.018	*
W E 60º x D hop LLL	0.358	0.101	(ns)	W E 60º x D hop LLL	0.222	0.597	(ns)
Tmax D 300º x D hop LRL	0.611	0.003	(ns)	Tmax D 300º x D hop LRL	0.547	0.161	(ns)
Tmax E 300º x D hop LLL	0.434	0.044	(ns)	Tmax E 300º x D hop LLL	0.039	0.927	(ns)
W D 300º x D hop LRL	0.469	0.028	(ns)	W D 300º x D hop LRL	0.568	0.142	(ns)
W E 300º x D hop LLL	0.187	0.404	(ns)	W E 300º x D hop LLL	0.276	0.508	(ns)

and to the work with hopped distance. It was found in these individuals a lower amount of variables with significant association.

This fact can be explained by the small number of female individuals in the sampling. With a higher number of individuals, further correlations observed could be significant.

However, probably in the absence of this limited participation of female individuals, the statistical analysis could sow a best association between variables.

Upon the comparison of the lower left limb (LLL) to the lower right limb (LRL), it was observed by us that every association presented a better result for the LRL. We believe that this can be related to the lower skill to the hop with the LLL of those athletes. As the population of this study was composed by non-sprained volleyball athletes experienced in hops, we consider to be small the influence of the trust factor in this study and the neuromuscular coordination factor added to the torque are the main responsible factors that explains the hop result. Among female individuals, we found a different correlation between LRL and LLL. Such finding suggests that female athletes may present a higher discrepancy between LL to develop functional activities. Ugrinowitsch (2000)[4] reports he do not use LRL to the statistical analysis, since in previous researches, he found a LLL bias to explain a major part of the total variance in the vertical hop. In the present study, the non-inclusion of the LRL in the analysis would be unviable, since this study seeks, among other things, to set an association between asymmetries among limbs detected by the hop test and the isokinetic dynamometer.

This study sought to evaluate associations between performance variables obtained with the hop test, and those obtained through the isokinetic dynamometer. Other types of hops, including vertical hops and other variations of the hop test and other isokinetic evaluation protocols (such as the eccentric mode and the closed kinetic chain) should be addressed in future studies. Other populations of athletes and non-athletes could also be tested.

In functional training, mainly in the clinical practice, professional physiotherapists start from the classical assumption that the aspects related to the body's structure and function (such as the muscular strength) are directly associated to the individual's performance in his activity (such as hops). The relationship between these factors is described in the International Ranking of Functionality (CIF)[20,21]. An example of this is the training of the muscular function of LL in volleyball athletes with the purpose to improve their hop performance. In this study, we observed the association between the body's structure and function (muscular performance), activity and participation (hop test). Results showed there is a low association between these variables in the major part of the situations evaluated. This suggests that it is impossible to deduce that only one aspect of the body's structure and function will influence the functional performance of the individual.

CONCLUSION

There is low association between the hop test and the muscular function data supplied by the evaluation of the knee's articulation at the isokinetic dynamometer in high level professional volleyball athletes. Such low association does not allow the use of the hop test as the method to classify the muscular function. It is necessary to develop further studies to assess the influence of each factor (strength, trust, and skill) in the hop test to test its utilization as method of classification.

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