Assessment of explosive strength-endurance in volleyball players through vertical jumping test

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ABSTRACT

The aim of this study was to verify the differences between the continuous jump test of 60 seconds (CJ60 sec) and the intermittent jump test of 4 sets of 15 seconds (IJ4x15 sec). The sample was composed of 10 male volleyball players with 19.01 ± 1.36 years, 191.5 ± 5.36 cm height and 81.74 ± 7.45 of body mass, who participated in this research as volunteers. The variables studied were estimated as the peak power (PP), mean power (MP) and fatigue index (FI). These performances were measured through tests of vertical jump with duration the 60 seconds and with the performance of 4 sets of 15 seconds with 10 seconds of recovery between the sets. The data were analyzed through descriptive statistics and the Wilcoxon test. The significance level was of $p < 0.05$. It was possible to analyze that the continuous and the intermittent jump test presented significant differences in MP ($p < 0.05$), FI ($p < 0.01$), and in the number of the vertical jump in 60 seconds ($p < 0.01$), and the height in 60 seconds exercise ($p < 0.05$). The MP found in IJ4x15sec was significantly higher than in the CJ60 sec in volleyball players. In conclusion, the results suggest the existence of significant differences between the CJ60sec and IJ4x15 sec.

Keywords: Assessment. Volleyball. Endurance. Jumping tests.

INTRODUCTION

Endurance assessment has been considered in volleyball due to the movements of explosive nature characteristics, which are associated with performance in actions of vertical jumps[1-4]. The tests with vertical jumps are suggested for the estimation of explosive strength endurance of volleyball players[1-3], who are submitted to repetitive movements. During a game, these movements[5-9] generate fatigue which effectively interferes in the performance of volleyball players. Concerning training, fatigue is understood as a transitory results decrease of the functional capacity of athletes, since it exposes the maintenance flaw in performance of certain variables, such as strength, velocity and power[10].

Strength endurance, generally expressed by the ability of the neuromuscular system to delay the appearance of the fatigue process[11], considered as the impossibility to carry on applying technique and tactics during the game to the strength and optimum velocity[12], has as specific characteristic to give straight support in the vertical jumps actions in attack and blocking. In this case, endurance which is considered a component which contributes to the maintenance of such performance, keeps the athlete as close as possible to maximal performance.

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According to the specialized literature[13-14], there are several types of tests with the purpose to measure the endurance capacity of explosive strength in volleyball players, such as the continuous vertical jump tests which have duration of fifteen seconds or sixty seconds. A particularity involving the methods with vertical jump tests is the repetitive use of a stretching and shortening cycle (SSC), derived from the lower limbs movements with actions of the vertical jump[3,15-17]. However, it is worth mentioning that continuous and intense exercises with SSC are means applied in this sports modality as training. Moreover, it is important to examine the fatigue manifestation, especially in this kind of exercise, and describe how it affects the production of strength and muscular power[15]. Nevertheless, in volleyball, a sport characterized by actions of short duration in a prolonged period of time[5-7], the manifestation of explosive strength endurance occurs under intermittent conditions[8-9]. In the case of the vertical jump tests of continuous nature with 60 seconds, the results may be underestimated, since the interval periods during work enable the recovery to another physical effort.

Nevertheless, a certain lack of studies with the aim to verify the manifestation of explosive strength endurance is observed in the intermittent context derived from vertical jumping tests[18-19]. Based on these premises, there is an issue to be solved about this aspect: is it possible to find differences in the estimation of explosive strength endurance between the continuous vertical jump tests and the intermittent test of four 15 second-sets? Therefore, the aim of the present study was to verify the differences between the vertical jump test of continuous nature of 60 seconds and the vertical jump test of intermittent nature of four sets of 10 seconds.

METHODS

Characteristics of the participants

Ten volleyball players (age range of 19.01 ± 1.36 years; height of 191.5 ± 5.36 cm; body mass of 81.74 ± 7.45 kg) participated in this group. The players had a mean of six years of experience with volleyball training and were registered in the Volleyball Federation of São Paulo. All players performed daily training sessions in a sports club which took part in the Volleyball Championship of the Federation of São Paulo in 2004, situated in the metropolitan area of Campinas – São Paulo.

All subjects signed a consent form of voluntary participation in the proposed study after it had been approved by the Ethics Committee of the Institution. The participants performed an adaptation process previous to the vertical jumping test so that error could be minimized, once this study was performed after the preparation competition season.

Equipment

Wooden stadiometers were used in order to measure height; a Plena Lithium Digital electronic scale was used for body mass. For the explosive strength endurance measurement, a Jump Test con-

tact mat connected to a digital timer, whose configuration implies the same principle of the Ergojump was used[20].

Anthropometric variables

The height (H), and body mass (BM), anthropometric measurements were used for characterization of the studied subjects, all according to standardization described by Alvarez, Pavan[21].

Explosive strength endurance variables

In this study, the explosive strength endurance variables in both tests were: power peak (PP), mean power (MP) and fatigue index (FI).

In the IVJT (intermittent vertical jump test), the PP was estimated according to the mean power produced in the first set and the MP estimated by the amount of work produced during a 60 second-effort, being performed in four sets of 15 seconds with 10 seconds intervals. The result was expressed in watts/kg ($W.kg^{-1}$), according to the equations for estimation of PP and MP in the vertical jumping test described by Bosco *et al.*[13]. The FI estimated from the ratio between the power peak (power of the first set), and the mean power generated in the last set (fourth set), was determined through the equation described by Bosco *et al.*[13], with the result being expressed in percentage (%).

Concerning the CVJT (continuous vertical jump test), the PP was estimated by the mechanical power produced in the first 15 seconds of a 60-second work. The MP was estimated by the amount of work during a 60-second continuous effort. For PP and MP, the results were expressed in watts/kg ($W.kg^{-1}$), according to the equation described by Bosco *et al.*[13]. The FI estimation was calculated between the power peak (work produced in the first 15 seconds), and the mean power generated in the last 15 seconds of a vertical jump work with 60 seconds of duration. The result was expressed in percentage (%).

The variables of the quality indicators of CVJT and IVJT were comprehended by the numbers of vertical jumps in 15-second (NVJ15sec), and 60 second work (NVJ60sec), in the vertical jump height in 15 (VJ15sec) and 60-second work (VJ60sec).

Vertical jumping tests

The explosive strength endurance was estimated through the vertical jumping tests in the continuous and intermittent contexts. For both tests, the vertical jumps of continuous (CVJT) and intermittent nature (IVJT), were applied to the vertical jump technique with counter-movement, with no aid of the upper limbs (CMJ), a procedure described by Komi, Bosco[16]. For that purpose, all participants performed knee flexion up to 110° angle, having it justified by an optimum angle for the application of strength[22].

The participants were told to perform the continuous vertical jumps during a work performed at maximal effort, with no pauses between jumps. The subjects were told to keep chest in vertical position, with no excessive advance to avoid influence in the results; as well as to keep knees in extension during the flight, remaining with hands around waist.

The IVJT had four sets of 15 seconds of continuous vertical jumps with a 10-second recovery interval between each set, following procedure described by Hespanhol *et al.*[23]. The CVJT had jumps during 60 seconds with procedures according to description by Bosco *et al.*[13].

The intraclass correlation coefficient was calculated for each variable of the tests (CMJ = 0.99; PP = 0.99; MP = 0.99; FI = 0.98). The results demonstrated high levels of reliability in the test-retest with vertical jumps.

Data collection

The data collections were performed in the sports gymnasium of the Volleyball Club, and the athletes were asked not to perform any extenuate activity 24 hs prior to the collections. The participants were evaluated in the jumping tests in the following order: firstly, the IVJT and seven days later, the CVJT. The anthropometric measurements were performed concomitantly to the IVJT.

The participants performed a 15-minute warm-up routine when performing the tests through stretching, running, coordination exercises and consecutive jumps (two sets of five vertical jumps).

Both tin the IVJT and CVJT the participants performed the jump action with the counter-movement technique with no aid of upper limbs (CMJ), 60 seconds after the warm-up end[14]. Although three trails have been performed, the highest jump within the results was chosen so that the maximal intensity of the effort to be applied in the tests was checked and, consequently the effort intensity could be controlled.

It was previously established that if the participant could not reach 95% of the maximal intensity during the three first vertical jumps, the test would be interrupted and would be resumed in a second trial, right after 60 seconds. The participants were given stimulus to jump the highest as possible during the time estimated in both tests.

Statistical analysis procedures

The results found were statistically treated by the Statistics software for Windows 6.0. Initially, descriptive statistical techniques were used. After this moment, K-S statistical technique was applied in order to verify the existence of normal data distribution, with the purpose to define the techniques to be applied in the comparative study. The Wilcoxon tests was applied to verify the existence of differences between the CVJT and IVJT, being the significance level used of $p < 0.05$.

RESULTS

In tables 1 and 2 the results found in the administration of the continuous and intermittent vertical jumping tests are presented. In the comparison done between tests, statistically significant differences were observed in the MP measurements ($p < 0.05$), FI ($p < 0.01$), NVJ60sec ($p < 0.01$) and VJ60sec ($p < 0.05$). Both in MP, NVJ60sec and VJ60sec, the IVJT presented values higher than the CVJT.

Concerning the mean values estimated for the FI of the continuous test, values of 48.6 ± 7.01% were found and for the intermit-

TABLE 1
Description of the PP, PM and IF for each test and the comparison between tests

Variables	Continuous test			Intermittent test			z	p
	n	Mean	SD	n	Mean	SD		
PP ($W.kg^{-1}$)	10	27.76	3.78	10	27.29	3.99	–1.260	0.208
FI (%)	10	48.60	7.01	10	59.33	4.92	–2.703**	0.007
MP ($W.kg^{-1}$)	10	19.56	2.59	10	21.12	3.43	–2.395*	0.017

* $p < 0.05$, ** $p < 0.01$; PP = Power Peak; MP = Mean Power; FI = Fatigue Index.

TABLE 2
Description of the quality indicators of the vertical jumping tests and comparison between tests

Variables	Continuous test			Intermittent test			z	p
	n	Mean	SD	n	Mean	SD		
CMJ (cm)	10	47.00	3.72	10	46.78	3.73	–1.826	0.068
NVJ60seg	10	50.80	2.66	10	54.80	3.12	–2.677**	0.007
NVJ15seg	10	13.60	0.52	10	13.90	0.74	–1.342	0.180
VJ15seg (cm)	10	39.59	3.98	10	38.50	4.16	–1.820	0.069
VJ60seg (cm)	10	29.03	4.05	10	31.10	4.27	–2.398*	0.016

* $p < 0.05$, ** $p < 0.01$; NVJ15sec = number of vertical jumps in 15; NVJ60sec = number of jumps in 60 seconds; VJ15sec = vertical jump height in a 15 sec work; VJ60sec = vertical jump height in 60 seconds.

tent jumping test, they were of 59.33 ± 4.92%, revealing greater fatigue produced for the CVJT than for the IVJT.

However, in the PP, CMJ, NVJ15sec, and VJ15sec variables, no statistically significant differences were found between tests; which denote in a similarity between the tests results considering these variables.

DISCUSSION

It is important to observe from the performance under fatigue viewpoint, that both continuous and intermittent tests produced decrease in PP performance. Such situation was also observed with college students, in which during the continuous and intermittent vertical jumping test, significant decrease occurred ($p < 0.001$) in strength production and height jumped with the CMJ technique[19]. This fact means that in both tests there is a certain degree of work under muscular fatigue conditions.

Based on the differences, it was observed that the intermittent tests tend to present lower fatigue conditions in relation to the ones presented in the continuous tests. Concerning the differences between mean power of the vertical and intermittent jumping tests, greater amount of work in the intermittent test was observed compared with the continuous one. Nonetheless, these differences between the jumping tests may be explained by the fatigue manifestations during the continuous and intermittent tests.

Evidence has shown that in the fatigue manifestations in the jumping tests, it is certified that the number of vertical jumps during 60 seconds in the intermittent test was higher than the number in the continuous one. In a certain extent, such fact is explained by the difficulty in the jumps coordination, since the subject when sustaining the power production in a maximal effort during 60 seconds of consecutive vertical jumps close to exhaustion, found greater difficulty than in 4 sets of 15 seconds. This fact was observed in continuous vertical jumps with volleyball and rugby players, in which there was significant increase in the muscles activation of the lower limbs ($p < 0.05$), in the vertical jumping action under muscular fatigue effect[24].

Several studies[25-27] suggest that the muscular fatigue effects in the stretching and shortening cycle (SSC) lead to different proportions to the contractible, recruiting, elastic and reflex components when the test requires continuous vertical jumps for a prolonged period. It is believed that the lower fatigue result of the intermittent test may be explained due to some lower changes in the contractible and elastic components which improve performance.

Although the effects for both tests are in neuromuscular performance terms similar to those which occur after continuous exercises with no recovery periods, the fatigue induced by the stretching cycle is much more problematic and complex due to the broader way it stimulates the neuromuscular system: mechanically and metabolically[15]. Remarkably, related with neuromuscular adjustments which occur in a trial to compensate for the incapacity of the lower limbs muscles induced by the continuous jumps and prolonged under fatigue conditions[15].

Concerning recovery capacity, it was seen that the superiority presented in the MP results estimated by the intermittent test, may be justified by the recovery capacity of the subjects during repeated work with intermittent nature. Nevertheless, such fact is due to different factors, such as the subjects' recovery in the four sets of 15 seconds test, and the contribution of the metabolism in order to keep the amount of repeated muscular work with intermittent nature[28].

In the studies by Bogdanis *et al.*[28] with college students, the results of the relationship between mean power performance in intermittent efforts of short duration with recovery of creatine phosphate concentration (CP), presented high correlations ($r = 0.91$). This information may show a trend that the vertical jumping test with four sets of 15 seconds produces higher mean power than the vertical jumping test with 60 seconds due to the relationship between CP concentration recovery and the mean power production.

In the comparative study by Essén[29] between continuous and intermittent efforts, it was observed that in the continuous effort the contribution of the muscular glycogen metabolism was used with greater emphasis than in the intermittent one. It is worth mentioning that other studies as the one by Balsom *et al.*[30], with Physical Education college students, demonstrated through intermittent efforts that subjects performed their repeated muscular work with low use of muscular glycogen. On the other hand, it is interesting to observe in some studies[31], with emphasis on efforts with intermittent nature, that the amount of muscular work was sustained by greater availability of the CP concentration in the muscles. Finally, as metabolic contribution is concerned, the existing differences between continuous and intermittent vertical jumps occurred due to the different use dynamics of energy provided for the amount of work produced.

Therefore, it is believed that there is a decrease of vertical jump height[32]; differences of the number of vertical jumps and consequently the power generated to keep the jump height in exhaustion process. Thus, continuously jumping close to exhaustion may indicate that the continuous vertical jump method is not the best test, once exhaustion may lead the athlete to compensate fatigue by other mechanisms.

The intermittent test partially avoids this exhaustion process, causing lower harm to the components of strength and use of metabolism components compatible to the movement, with no apparent need of neuromuscular adjustments and mechanical compensation, while vertical jumping exercises with high intensity are performed.

However, some considerations should be mentioned in this study with several limitations: a) small amount of investigations about the topic, making direct comparisons with similar studies difficult; b) small number of participants; c) a study applied only in one of the genders (male). Besides these limitations, several aspects should be explored in order to further comprehend the nature and mechanisms of tests with vertical continuous and intermittent jumps, such as: neural adaptation to fatigue as well as potential mechanisms for mechanical and metabolic responses.

CONCLUSION

Based on the results, the IVJT seems to be one of the most suitable tests for the estimation of explosive strength endurance in male volleyball players. This evidence can be observed in the different comparisons between vertical jumping tests which point out some important indicators:

a) The intermittent test presented greater amounts of work in a 60 second-effort in relation to the continuous test;

b) The FI of the IVJT was lower than of the CVJT, showing that the higher fatigue manifestations are generated by the CVJT indices.

Based on found results, it is suggested that the estimation of explosive strength endurance through the IVJT should be incorporated in sports training programs for volleyball, since in the analysis of the data generated by the test, the mean power (work amount), and the fatigue index (performance decline), the results are different from the CVJT, and consequently, by the specificity of a volleyball match, it is closer to the IVJT. The application of the IVJT is suggested for the evaluation of explosive strength endurance in volleyball players, since the use of CVJT results tend to underestimate performance.

All the authors declared there is not any potential conflict of interests regarding this article.

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