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Original Article

Effects of the improvement in vertical jump and repeated jumping ability on male volleyball athletes' internal load during a season

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Abstract
Changes in the level of physical conditioning, especially in the ability to perform repeated efforts, affect the perception of athletes' internal training load (ITL). However, little is known about the effectof improved vertical jumping and the ability to perform repeated jumps on the ITL ofvolleyball athletes. The aim of this study was to determine the relationship between ITL and the improvement in vertical jumping performance and repeated jumping abilityofmale volleyball athletes. The ITL of 15 volleyball athletes was analyzed for 6weeks during the season using the session rating perception effort method (session-RPE). Before and after this period, the athletes underwent the countermovement vertical jump test (CMJ) and intermittent vertical jump test performed in 60 s (IJT_{60}). The average power (AP) of $IJT_{60}$was used for the analysis. The paired t-test was used to compare the vertical jump and the repeat jumpingability before and after 6weeks. In addition, the Pearson correlation test was used to relate the average total weekly training load (A-TWTL) of each athlete with the change in vertical jump (Δ%) and with AP before and after the experiment. The athletes improved CMJ ($p \leq 0.001$) and AP ($p \leq 0.05$). A-TWTL showed a positive relationship withΔ% of CMJ ($r = 0.63$, $p \leq 0.001$) and a negative relationship with APpost-experiment ($r = -0.71$, $p < 0.05$). Based on the results, it is determinedthat the improvement in vertical jump can positively affectthe ITL of male volleyball athletes during the season, and the improvement in the repeated jumping ability may have contributed to the ability of athletes to supporthigher external loads during training and games.
Keywords: Team sport; Physical training, Performance; Rating of perceived exertion

Introduction

Volleyball is a sport that requires its practitioners to perform well in the vertical jump, which is an ability that directly interferes with attacking actions during a match (Martinez, 2017; Sattler, Hadzi, Dervisevi, &Markovic, 2015). During a game, an athlete can repeat the vertical jump action up to 32 times in a single set (Sheppard et al., 2007), while trying to maintain maximum performance from the beginning to the end of the game. Thus, strategies that optimize the ability to repeat vertical jumps should also be part of training programs for volleyball athletes (Hespanhol, Arruda, Neto, and Dini, 2007; Sheppard et al., 2007).Therefore, coaches and technical commissions emphasized the improvement of vertical jump by developing training programs that favor their potential (Stojanovic, Ristic, McMaster, &Milanovic, 2017; Slimani, Chamari, Miarka, Del Vecchio, &Chéour, 2016).

According to Slimani et al., plyometric training (PT) is aneffective method to improve the performance of vertical jump in athletes; PT can be applied duringannual training, including during the season (Freitas-Junior, Fortes, Santos, Batista, and Paes, 2018; Mroczek et al., 2018). PT promotes positive changes in neuromuscular structures, increase in the speed of the stretching–shortening cycle, neural drive, and myotactic reflex, which are responsible for jumping and depend on the duration of the program and number of jumps developed per session (Slimani et al., 2016). However, the eccentric actions imposed by PT can contribute to the appearance of muscle pain and injuries, which increases the need for extensive knowledge on the part of the technical committee about theneurophysiological responses of athletes to imposed exercises (Hody, Rogister, Leprince, Wang, &Croisier, 2013; Loturco et al., 2016). Therefore, it is necessary to monitor the internal training load (ITL), which allows the members of technical commissions to follow athletes' responses to the stressors imposed by the training; thus, the method of sessionrating of perceived exertion (session-RPE) is considered to be useful and has already proven its usefulness forvolleyball athletes (Debien et al., 2018; Mendes et al., 2018).

The ITL perceived by athletes can be influenced by factors that include the ability to perform repetitive high-intensity efforts (Manzi et al., 2010; Marcelino et al., 2013; Milanez et al., 2011). Manzi et al. (2010) have determined that basketball athletes with better results in the Yo-Yo intermittent recovery test level 1 (Yo-Yo

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IR1) had lower session-RPE scores when exposed to the same training situations. Marcelino et al. (2013) have observed in basketball athletes a negative relationship between ITL and the ability to perform repetitive high-intensity efforts. Milanez et al. (2011) have demonstrated that during the four-week training offutsal athletes, aerobic power, assessed through performance in Yo-Yo IR1, affectedthe accumulated ITL. During a competitive period, these resultsconfirm that the level of aerobic fitness or capacity for repeated efforts performed with high intensity can affect the perception of ITL. In volleyball, vertical jumping actions are frequently performed; thus, it is interesting to determine the extent to which the ability to repeatedly perform this action with high intensity can affect ITL in athletes during training sessions.

Becausevertical jump can be improved with systematic repetition through specific training (Slimani et al., 2016), verifying the relationship betweenITL and vertical jump improvement can provide information that indicates whether planned training meets the real needs of the athletes becauseadaptations that occur also depend on the magnitude of how external load is prescribed (Debien et al., 2018; Mendes et al., 2018).It has already been observed that ITL has a negative relationship with the delta of alteration in the performance of vertical jump with countermovement (CMJ) of dominant leg ofsoccer athletes (Los Arcos, Martinez-Santos, Yanci, Mendiguchia, & Mendez-Villanueva, 2015). On the other hand, no significant relationship was observedbetween ITL and alteration delta when CMJ is performed with both legs (Los Arcos et al., 2015; Nakamura, Pereira, Rabelo, Ramirez-Campillo, &Loturco, 2016). These findings reinforce the need for further research to elucidate this relationship, especially in volleyball, given the fundamental importance of making vertical jumps duringtraining and games.

The observation of how this relationship occurs can provide information regarding the athletes 'evolution regarding the necessary physical capacities for volleyball and if the training program's planning is consistent with the athletes' needs for improvement. Thus, this study aims to verify the relationship between ITL and changes in the performance of vertical jumping and verify the relationship between ITL and repeated jumping ability at high intensity in volleyball athletes during the season. The initial formulated hypothesis was that athletes with greater changes in CMJ performance and better performance inhigh intensity repeated jumping would have lower ITL values.

Materials and methods

Participants

A total of 15 athletes participated in the study. The athletes belonged to a volleyball team, III division of the Brazilian Superliga, (22.87 ± 3.04 years old, 83.22 ± 10.84 kg, 186.93 ± 6.91 cm), and had more than five years of experience with training and competitions in the modality. To be included in the study, athletes could not be during the period of recovery from muscle or ligament injuries, and athletes who missed 20% of the total training sessions were excluded from the study. All athletes were informed about the procedures used in this study and signed an informed consent form before beginning the study. The study followed the Declaration of Helsinki's recommendations and was approved by the Ethics Committee of the Federal University of Pernambuco.

Procedures

An experimental study of repeated measures was performed, which involved 6weeks of monitored training during the season. During this period, the athletes participated in a training program developed by the team's technical committee, aiming to improve the muscle power of the lower limbs. For this purpose, the athletes were submitted to PT. The athletes normally participated in resistance and technical–tactical training routines, which added up to a total of 7 weekly training sessions. The duration of training sessions varied between 60 and120 min. Duringthe morning shift, resistance training occurred three times a week; in the afternoon, technical–tactical and plyometric trainingwas performed. Three official matches (regional competitions) were played during this period (weeks 2, 4, and 6). The training schedule is described in Table 1.

Table I. Weekly team training program

Day	Training	
	Morning	Afternoon/night
Monday	Resistance	Technical–tactical + Plyometric
Thursday	Recovery	Technical–tactical
Wednesday	Resistance	Match*
Tuesday	Recovery	Technical–tactical + Plyometric
Friday	Resistance	Technical–tactical
Saturday	Recovery	Match**
Sunday	Off	Off

Note: *matches duringweeks 2 and 4; **match duringweek 6

Technical–tactical training occurred four times a week and aimed to improve the sport's technical gestures and the game system used by the team during the games. PT consisted of static jumping exercises, bilateral and unilateral countermovement jumps, frontal, lateral, and jumps starting from a superior plane. PT progressed from 160 to 240 hops during the first four weeks. The volume was reduced in the last two weeks, i.e., 210 and 200 jumps, respectively.

Before and after 6weeks, the athletes were submitted to CMJ and intermittent vertical jump test performed in 60 s (IJT_{60}). All athletes were already familiar with the procedures because the tests conducted were regularly used in the team's training program. The tests were performed 48 h before the training program started and 48 h after. Usingthe session-RPE method, ITL was obtained after all training sessions (plyometric and technical–tactical) and duringthe games played. The ITL of resistance training was not analyzed. The experimental design is shownin Figure 1.

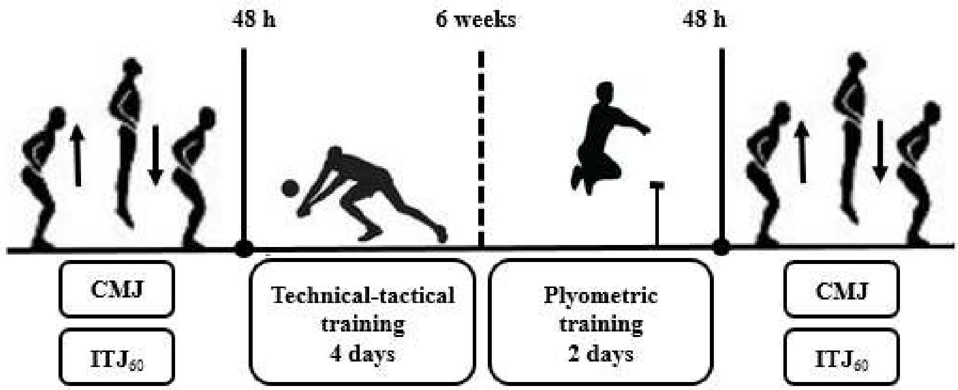

Figure I. Experimental design. CMJ: countermovement vertical jump; IJT_{60}: intermittent vertical jump test performed in 60 s(IJT60)

CMJtest

CMJ testwas used to assess the height of the athletes' vertical jump. It consisted of performing the vertical jump from the upright position, while keeping the knees in extension at 180° with the hands fixed close to the hips. After flexing the knee joint, the subject propelled the body upwards as high as possible, and at the time of the flight, the legs remained in extension (Balsalobre-Fernández, Tejero-Gonzalez, del Campo-Vecino, &Bavaresco, 2014). Each subject had three attempts with an interval of 30 s, and the best result wasconsidered for analysis. The data records of the CMJ test were evaluatedaccording to the procedures described by Balsalobre-Fernández et al. (2014). Jumps were measured by a Casio Exilim FH-25 camera (448 × 336 pixels) with a 240-fps resolution. The recorded videos were analyzed using the public domain software, Kinovea 0.8.15, which revealed flight times (FT). From FT, the height of each jump was obtained by adopting the formula h (m) = 1.32627 × FT (s). The intraclass correlation indexes (ICC) were 0.97 [95% confidence interval (CI) of 0.94–0.99] and 0.98 [95% CI of 0.96–0.99] for pre- and post-experiment tests, respectively.

IJT_{60}

$IJT_{60}$was performed to analyze the repeated jumping ability through the average power variable (AP). Each jump performed during IJT_{60} had the same characteristics as CMJ techniques, which areperformed in a successive sequence for 60 s and divided into four sets of 15 s with 10-sintervals (Hespanhol et al., 2007). The IJT_{60} data records were evaluatedusing the procedures described by Balsanobre-Fernandéz et al. (2014); the total number of jumps (n) and their respective FT areknown from the filming. Then, AP is calculated using the formula $AP\ (W \times kg^{-1}) = (g^2 \times FT \times 60) / (4\times n) \times (60 - FT)$, where g is the acceleration of gravity (Bosco, Luhtanen, &Komi, 1983). The reproducibility of IJT_{60} to thevalue of 0.99 in repeated evaluations on different days (Hespanhol et al., 2007.)

ITL

The quantification of ITL perceived by the athletes was performed using the session-RPEmethod (Jatene, Pereira, Chaperuto, Fukushima, & Doro, 2019). As proposed by Foster et al. (2001), the procedure consisted of asking athletes 30 minafter the end of the training "How was your training session?", which was answered according to the 10-point Likert scale (CR10). ITL was determined using the product between the duration of session (in minutes) and the session-RPE score. The sum of ITL was calculated to obtain the total weekly training load (TWTL) (Foster et al., 2001).

Statistical analysis

The data are reportedas themean and standard deviation, and normality was verified using the Shapiro–Wilk test. ANOVA with repeated measurementswas used to compare TWTL between the weeks. The t-test was used to compare the performance of CMJ and IJT_{60} between the pre- and post-experiment. The variation delta (Δ%) of CMJ and IJT_{60} was calculated using the equation: $\Delta\% = ([post - pre] / pre \times 100)$. In addition, effect sizes (ES), based on Cohen's d, were calculated. The ES values of 0.2, 0.5, and 0.8 were considered to be small, medium, and large (Cohen, 1988). Pearson's correlation was used to: a) verify the relationship between average TWTL (A-TWTL) of 6 weeks and Δ%of CMJ and IJT_{60}, b) verify the relationship between average A-TWTL and pre- and post-experiment performance of CMJ and IJT_{60}. For the analysis of correlations, the scale proposed by Hopkins (2002) was used, i.e.,: <0.1 trivial; 0.1–0.3 small; 0.3–0.5 moderate; 0.5–0.7 large; 0.7–0.9 very large, and >0.9 almost perfect. The level of significance used was p ≤0.05. For statistical analysis, the Statistical Package for the Social Sciences - SPSS version 21.0 (New York, USA) was used.

Results

The results of 15 athletes participating in the study were included in the analyses. The average TWTL of 6 weeks of training was 1404.20 ± 77.77 arbitrary units (AU), and its behavioris shown in Figure 2. Figure 1 shows that the TWTL of week 4 was higher than that of weeks 5 ($p \geq 0.05$) and 6 ($p< 0.01$).

According to the comparison analysis, it was observed that the training program improved the results of CMJ and IJT_{60} (Table II).

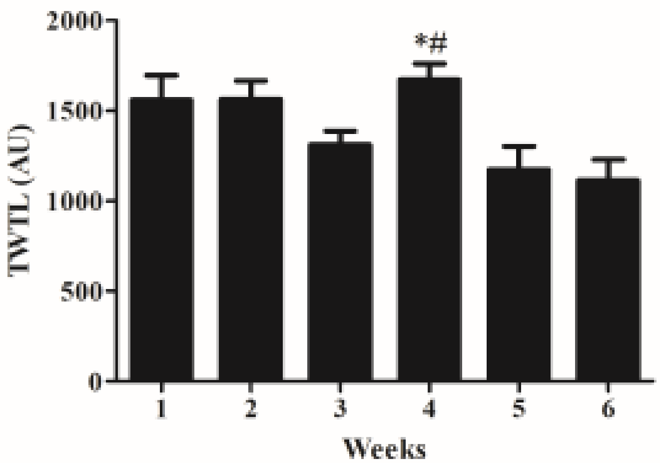

Figure II. ITL behavior during 6 weeks. *significantly different comparted toweek 5 (p <0.05). #significantly different compared toweek 6 (p <0.01).

Table II. Comparison of CMJ and IJT_{60} before and after 6 weeks of training

	Pre	Post	Δ%	ES	*p value*
CMJ (m)	00.44 ± 0.05	00.47 ± 0.06	05.89	0.60	0.001
IJT_{60} (Wkg^{-1})	26.95 ± 6.42	30.36 ± 8.30	12.66	0.63	0.05

Note: CMJ: countermovement vertical jump; IJT_{60}: intermittent vertical jump test performed in 60 s; Δ%: variation percentage; ES: effect size; CI: confidence interval

A-TWTL showed a positive correlation with Δ% of CMJ [r = 0.63 (large); p < 0.05] (Figure 3). Figure 4 showsthe correlations of A-TWTL of the 6 weeks of training with the AP values pre and post-experiments. It is observed that A-TWTL hada negative correlation [r = −0.71 (very large), p < 0.01] with the post-experiment AP. With the pre-experiment AP, the correlation, although also negative, was not significant (r = −0.31; p > 0.05). No significant correlations were observedbetween A-TWTL and CMJ results before and after the experiment (p > 0.05).

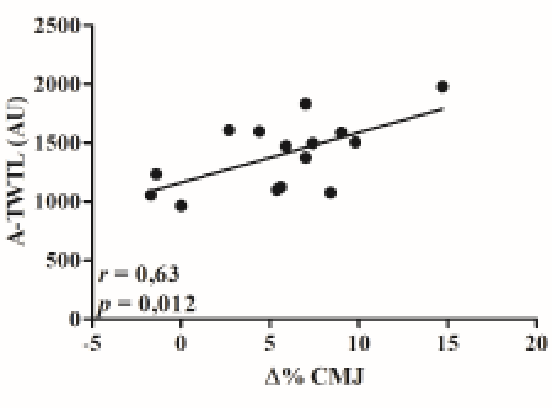

Figure III. Correlation between A-TWTL and Δ% of CMJ. A-TWTL: total week training load; CMJ: countermovement vertical jump

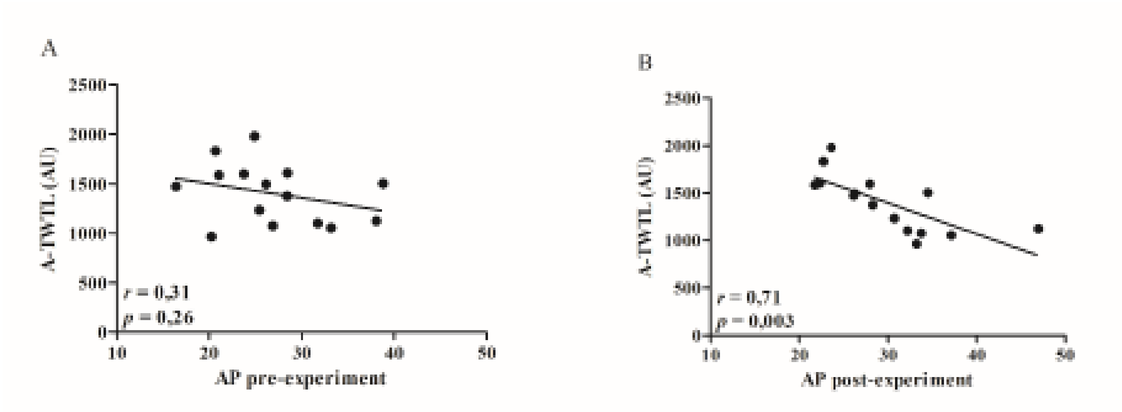

Figure IV. Correlations between A-TWTL and pre-experiment AP (A) and post-experiment AP (B)

Discussion

The purpose of this study was to verify whether ITL is related to the vertical jump and repeated jumping ability in volleyball athletes after 6 weeks of training during the season. Anincrease in performance observed in CMJ and AP after the experiment was significantly correlated, positively and negatively, with the A-TWTL of 6 weeks of training. These data partially confirm the initial hypothesis of the study.

During the 6 weeks of the season, the athletes reported A-TWTL of 1404 ± 77.77 AU, which was below the values obtained in other studies for athletes in volleyball (Freitas, Nakamura, Miloski, Samulski, & Bara-Filho, 2014; Freitas et al., 2015) and other sports (Delecroix, Mccall, Dawson, Berthoin, &Dupont, 2018; Nakamura et al., 2016). Compared to other studies in the literature, this is the first investigation that sought to verify the relationship between the improvement invertical jump in volleyball athletes and ITL. However, ITL and its relationship with changes in physical capacities have already been observed in soccer athletes, and the results revealed that the higher is cumulative ITL, the greater is the decline in vertical jump (Gil-Rey, Lezaun, & Los Arcos, 2015; Los Arcos et al., 2015).

Los Arcos et al. (2015), in a 9-week study onyoung elite soccer players, divided session-RPE into the subjective perception of the session effort into respiratory (RPEres) and muscle (RPEmus) components and asked the athletes 2 questions: “How difficult was your session onyour chest?”and “How difficult was your session on your legs?” The authors observed a negative relationship between RPEmus and alterations in CMJ fordominant and non-dominant legs (r = −0.61 and r = −0.53, respectively) after theaccumulation of 17086 + 2875 AU. In a study with a similar methodology,Gil-Rey et al. (2015) determined that for elite soccer players,there was "possibly a small" relationship between the sums of RPEres and RPEmus and the alterations in CMJ with arm balance (r = − 0.25 and r = − 0.17 respectively) after 9weeks of training during the competitive period with an accumulation of 13139 ± 1652 AU for the sum of RPEres and 13929 ± 1942 AU for the sum of RPEmus. These data differfrom our results, which showed that there was a large positive correlation coefficient between A-TWTL and Δ% of CMJ.

In this study, the PT performed by the athletes was possibly responsible for the difference between the results in this study and those in previously mentioned studies. This occurredbecause in the studies by Los Arcos et al. (2015) and Gil-Rey et al. (2015), muscle power was improved through resistance training. In addition, the methodology used in the studies by Los Arcos et al. (2015) and Gil-Rey et al. (2015) for the identification of ITL could have affected the divergence in the results of this study and thosein previous studies because the session-RPE scale was different compared tothe one adopted in this work. In both abovementioned studies, ITL was estimatedusingRPEres and RPEmus, which can provide a more detailed result for assessing ITL in team sports (Los Arcos et al., 2015). On the other hand, our study used a general assessment of session-RPE. Another factor that may resultin a positive coefficient in the relationship between A-TWTL and Δ% of CMJ observed in our study is associated with the neuromuscular and physiological characteristics of athletes in the modality in question because they perform this action several times during training, which can cause a protective effect on musculature joints (Horta et al., 2017). Therefore, to identifyimprovements in vertical jumping in volleyball athletes, it is normal for technical commissions to prescribe high loads related to jumping training, which may have affectedthe perception of ITL, especially in athletes with better performance.

Corroborating this hypothesis, Nakamura et al. (2016) demonstrated that athletes with better sprint performance perceived greater effort at a given external training load than slower athletes. In addition, according to Nakamura et al. (2016), this phenomenon can be explained by the fact that faster athletes need touse greater eccentric force for the phase of running deceleration and change indirection, which can lead to an increase in the magnitude of micromuscular injuries and muscle pain lateonset. Therefore, the high demand for the eccentric force generated in the vertical jump movement may cause greater muscle damage in athletes with higher performance in this type of action, which affects the athletes' higher ITL perception (Proske& Morgan, 2001). Specifically, in volleyball, Horta et al. (2017) determined that the athletes who performed the most jumping actions during training had a higher perception of ITL, including pointers and opposites.

The hypothesis of this study is that there is no significant correlation between athletes with pre-experiment AP. On the other hand, a negative correlation coefficient was observed with post-experiment AP. It is possible that the changes observed in IJT_{60} ($\Delta\% = 12.66$) during the training period partially explain this correlation coefficient. Based on the assumption that AP is an indicator related to the explosive strength endurance and consequently favors the maintenance of high intensity jumping efforts (Los Arcos et al., 2015), it is reasonable to suggest that such adaptations allowed athletes greater tolerance to dealwith the demands oftraining and games, given the frequent need for vertical jumping in volleyball to perform the movements of serving, setting, attacking, and blocking (Sheppard et al., 2007; Ziv and Lidor, 2010). This premise reinforces the negative coefficients reported between post-experiment AP and A-TWTL. Previous studies have also showedthat the ability to perform repeated sprints is related to the accumulated TWTL in athletes of intermittent collective modalities (Marcelino et al., 2013; Milanez et al., 2011).

From a practical point of view, the information obtained in thisstudy indicates that repeated jumping ability must be part of the planning of volleyball athletes, which may contribute to the improvement invertical jump, which is an important physical quality for this sport. Therefore, coaches are encouraged to identify the performance inCMJ and $IJT_{60}$to control and monitorITL during the season by considering the individual responses of athletes. In addition, the relationship between the performance of the jump and technical efficiency in volleyball is well-established; therefore, greater emphasis should be given to this ability in monitoring and planning the training load. However, further investigations are necessary to identify the relationship between vertical jump performance in a single effort and intermittent effort, when internal load is accumulated during different periods of preparation of the athletes, to obtainaccurate information that allows to detect levels of fatigue and symptoms related to overreaching/overtraining (e.g., upper respiratory tract infection).

It is worth highlighting some limitations of this study. First, the general assessment of session-RPE can hinder specific interpretations of ITL. The division of session-RPE into RPEres and RPEmusmayhave greater accuracy in the perception of athletes' effort, considering the demands from peripheral (neuromuscular) and central (aerobic fitness) points of view that are inherent in volleyball. Another limitation isthe number of participating athletes, whichcan be considered small. Furthermore, the analysis of creatine kinase and lactate dehydrogenase levels canbetter support this study to identify possible relationships between muscle fatigue and vertical jump performance. Despite these limitations, the importance of monitoring and quantifying ITL during the preparation of athletes is based on a consensus.

Conclusion

It is possible to conclude that ITL after6 weeks of training of volleyball athletes ispositively related to the changes in CMJ and negatively related to the changes in repeated jumping ability; athletes with better performances in CMJ hadhigher levels of effort perception. The improvement in repeated jumping ability, obtained through AP, seems to promote greater tolerance in athletesto supporting greater external loads. Thus, it is important that technical commissions and coaches prepare training programs aimed at improving the repeated jumping abilityofvolleyball athletes tooptimally develop the number of jumps that are required during training and games.

Conflicts of interest - none.

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