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original article

Pre-competitive physical training and markers of performance, stress and recovery in young volleyball athletes

Treinamento físico pré-competitivo e marcadores de desempenho, estresse e recuperação em jovens atletas de voleibol

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Abstract – The aim of this study was to analyze the effect of physical training during a pre-competition period on power and explosive strength endurance of the lower limbs, stress and recovery in young volleyball athletes. Seven male athletes (15.8 ± 0.5 years, 186.1 ± 6.6 cm, 75.9 ± 1.8 kg) of an Under-16 volleyball team were trained during a pre-competition period of 4 weeks. The internal training load (ITL) was monitored by the session RPE method. The participants performed a countermovement jump test (CMJ) and an intermittent jump test of four sets of 15 seconds (IJT) on the first day of training (baseline) and on the last day of the 2nd (post-week 2) and 4th week (post-week 4). The RESTQ-Sport Questionnaire was applied at baseline and on the last day of the 2nd, 3rd and 4th week (post-weeks 2, 3 and 4). No difference was observed in ITL ($p>0.05$). CMJ performance increased gradually from baseline to post-week 2 and from post-week 2 to post-week 4 ($p<0.05$). The average power in the first 15 seconds and average power of the four sets of 15 seconds of the IJT were higher in post-week 4 compared to baseline ($p<0.01$). Scores on the Fatigue and Injury scales of the RESTQ-Sport changed during training ($p<0.05$). We conclude that training applied during the pre-competitive period provided increments in CMJ performance and explosive strength endurance, and the changes in the RESTQ-Sport suggest that the athletes had adequate levels of stress and recovery.

Key words: Muscle fatigue; Overtraining; Rating of perceived exertion, Sports, Strength training.

Resumo – *O objetivo deste estudo foi analisar o efeito do treinamento físico aplicado em um período pré-competitivo na potência e na resistência de força explosiva de membros inferiores, no estresse e na recuperação de jovens atletas de voleibol. Sete atletas (15,8 ± 0,5 anos, 186,1 ± 6,6cm, 75,9 ± 1,8kg) de uma equipe de voleibol sub-16, do sexo masculino, foram treinados durante um período pré-competitivo de quatro semanas. A carga interna de treinamento (CIT) foi monitorada pelo método PSE da sessão. Testes de salto vertical com contramovimento (CMJ) e de natureza intermitente, de quatro séries de 15 segundos (TSVI), foram avaliados no 1º dia de treinamento (linha de base), no último dia da 2ª (pós-semana 2) e da 4ª semana (pós-semana 4). O Questionário RESTQ-Sport foi aplicado na linha de base, no último dia da 2ª, 3ª e 4ª semanas (Pós-semana 2, 3 e 4). A CIT não foi diferente (p>0,05). O CMJ aumentou no pós-semana 2, comparado com a linha de base e no pós-semana 4, comparado com o pós-semana 2 (p<0,05). A média de potência nos 15 segundos iniciais e a média de potência das quatro séries de 15 segundos do TSVI foram maiores no pós-semana 4, comparado à linha de base (p<0,01). As escalas Fadiga e Lesões do RESTQ-Sport se alteraram ao longo do treinamento (p<0,05). Conclui-se que o treinamento aplicado durante o período pré-competitivo proporcionou incrementos no CMJ e no TSVI, e as alterações no RESTQ-Sport sugerem que os atletas apresentaram níveis adequados de estresse e recuperação.*

Palavras-chave: *Esportes; Fadiga muscular; Overtraining; Percepção subjetiva de esforço; Treinamento de força.*

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INTRODUCTION

Volleyball is an intermittent sports modality in which the main actions of the game are performed at high intensity, intercalated with periods of low intensity[1]. During games and training sessions, hundreds of jumps are performed, especially during attacking and blocking actions[1]. Furthermore, a greater jump height during serving and blocking actions is achieved by the most successful teams with victories of the same competitive level[2]. Thus, lower limb power associated with explosive strength endurance necessary for constant jumps is essential for success in this modality.

The improvement of lower limb power in volleyball athletes during the period before a competition is an important target of training programs[3,4]. Trajkovic et al.[3] found no differences in the vertical jump height or spike jump height of adult volleyball athletes submitted to a 6-week pre-season training program based on specific volleyball skills. This suggests that physical training is necessary to improve this ability[4,5]. In a meta-analysis, Markovic[6] defended the use of plyometric training to improve vertical jump height. In fact, the jumps performed in volleyball involve stretch-shortening cycle actions which comprise a rapid eccentric phase of movement, followed by an immediate concentric phase, with great use of elastic and neural components. The characteristics of these movements are similar to those seen in power and plyometric exercises[6,7]. Improvement of vertical jump ability has been demonstrated in previous studies on young and adult volleyball and soccer players using separate plyometric, strength or power training, or a combination of methods[4,5,8].

Monitoring training loads is necessary since the balance between training load and recovery is a determinant factor to obtain positive adaptations to training[9]. Studies have shown a decline in countermovement vertical jump (CMJ) performance after basketball training sessions[10], after cumulative sessions of overload rugby training with limited recovery[11], after a rugby game[12], and after a period of rugby competitions[13]. The loss of muscle function observed after these exhaustive exercises is related to metabolic fatigue and the magnitude of exercise-induced muscle injury[7,14]. On the other hand, studies indicate an increase in CMJ performance when the necessary recovery is applied[11,15]. Furthermore, the imbalance between training load and recovery may be associated with injuries, diseases and compromised quality of life of the athlete[16]. Therefore, the accurate quantification of training loads and the frequent monitoring of performance and of stress- and recovery-related variables are part of the appropriate monitoring of training loads[17].

The frequent jumps performed during volleyball training sessions and games require the ability to preserve power application for a prolonged period of time[1]. As a consequence, the evaluation of explosive strength endurance in volleyball athletes is as important as the evaluation of CMJ performance[18]. In this respect, endurance tests are indicated as the most appropriate methods to identify fatigue caused by training and insufficient recovery[19]. However, little is known about the effect of a physical training program on lower limb explosive strength endurance in volleyball athletes.

Although studies have demonstrated the importance of physical training to improve lower limb power[3,6], particularly during pre-competitive periods[3,4,8], there are few reports investigating the effect of this type of training on the explosive strength endurance of the lower limbs, as well as its impact on the recovery-stress state of young volleyball athletes. This knowledge should assist the decision of coaches and physical trainers regarding the organization of physical training designed to improve power during routine training of their athletes. Therefore, the objective of the present study was to analyze and describe the effect of physical training during a pre-competitive period on the power and explosive strength endurance of the lower limbs, stress and recovery in young volleyball athletes.

METHODOLOGICAL PROCEDURES

Sample

Ten male athletes of an Under-16 volleyball team were initially included in the study. However, three athletes were excluded from the sample since they missed more than three training sessions. Thus, the final sample consisted of seven athletes with a mean age of 15.8 ± 0.5 years, height of 186.1 ± 6.6 cm, weight of 75.9 ± 1.8 kg, and BMI of 22.1 ± 1.6 kg/cm^2. The inclusion criteria were training routinely for at least 4 months, age less than 16 years, and being related to participate in the reported championship. Criteria for exclusion were the presence of myoarticular injuries and not attending three or more training sessions. The study was approved by the Ethics Committee of the Federal University of Juiz de Fora (Universidade Federal de Juiz de Fora) (Permit No. 249.957/2013). All procedures were explained to the athletes and responsible persons who signed an informed consent form, and the study was conducted in accordance with Resolution 196/96 of the National Health Council.

Procedures

The young athletes were submitted to 25 days of training (pre-competitive period) divided into four weeks, the last week with four days. The number of weekly training sessions was four. The target competition, a state championship in which the team was among the four finalists, occurred in the 5th month of the annual training season. The week prior to the beginning of the study was regenerative. The training program was planned by the technical staff of the team. The main objective of this period was to intensify the training of technical and tactical volleyball skills, and the main objective of physical training was to improve lower limb power. The physical training sessions were held after the technical-tactical training.

The internal training load was monitored every day, 30 minutes after the sessions, by the session-rating of perceived exertion (session RPE) method[20,21]. The CMJ test[22] and the intermittent vertical jump test of four sets of 15 seconds (IJT)[18] were used as measures of performance and were conducted on the first day prior to the beginning of the training session (baseline) and on the last day of the second week of training (day 12, post-week 2) and of the fourth week of training (day 26, post-week 4). To evaluate the effect of training on the recovery-stress state of the athletes, the Recovery Stress Questionnaire for Athletes (RESTQ-Sport)[23] was applied at baseline and on the last day before the training sessions of the 2nd, 3rd and 4th week (post-weeks 2, 3 and 4).

Physical training

Physical training was applied on the training court. The following equipment was used: olympic bar, dumbbells, weights, chin-up bar, cones, plinth, and grandstand steps. The team was divided into groups of two and three athletes. Each group performed one exercise at a time in a rotating manner. The athletes were familiarized with the exercises and equipment for 3 days of the week prior to the pre-competitive period, with an interval of 48 hours between days. The physical training applied during the pre-competitive period is described in Table 1.

The first two weeks consisted of three days of training at intervals of 48 hours. The last two weeks consisted of four days of training at an interval of 48 hours between the first and second day and of 24 hours between the other days. During the pre-competitive period, the loads were applied in such a way that the athletes correctly performed all repetitions necessary. The athletes were asked to perform the repetitions at a fast speed (1 second of the eccentric phase and 1 second of the concentric phase). The exercise sequence described was followed and training was monitored to prevent inadequate execution and loads. The time interval between sets was 2 to 4 minutes. The exercise sequence and loads were adjusted after 2 weeks of training.

Quantification of training load

The training load was monitored using the session RPE method[20]. Thirty minutes after the end of each training session, the athletes answered the question "How was your training?" by indicating the response on a 10-point RPE scale[21] referring to the session as a whole. The product between the value observed on the RPE scale and the training time in minutes of each session was then calculated, corresponding to the training load of the session. The total weekly training load (TWTL) was calcualtes as the sum of training loads of each week. Monotony was calculated as the ratio between the mean and standard deviation of training loads of each week. Strain was calculated as the product between TWTL and monotony[20]. The athletes were previously familiarized with the method for one month. This method has been shown to be effective in monitoring training loads in team sports[24,25].

Countermovement vertical jump (CMJ) test

The CMJ test was used to evaluate the power of the lower limbs using a contact mat (Cefise®, Brazil) and the results were obtained with the Jump

System program (Cefise®, Brazil). Three jumps permitting movement of the arms[22] were performed by each athlete and the mean of the three measurements was used for analysis. A previous warm-up consisting of jogging and unilateral jumping was performed for 5 minutes. The intraclass correlation coefficient of this variable at the different time points was 0.91, 0.94 and 0.98, respectively.

Intermittent vertical jump test of four sets of 15 seconds (IJT)

The IJT was used to evaluate the explosive strength endurance of the lower limbs[18]. In this test, vertical jumps were performed in an intermittent manner with countermovement and without the help of the upper limbs[22], flexing the knee at an angle of approximately 110º. Four sets of 15-second vertical jumps were performed without interval, allowing an interval of 10 seconds between sets. The athletes were asked to perform a maximum effort on a contact mat (Cefise®, Brazil).

The following variables were evaluated: mean relative power ($W*kg^{-1}$) of the first 15 seconds (P15), mean relative power observed during the last set of 15 seconds (L15), mean relative power of the four sets of 15 seconds (P60), and the percent decrease in L15 compared to P15 (DP) (DP = {[(L15/P15)-1]*100}). The results were obtained with the Jump System program (Cefise®, Brazil).

Recovery Stress Questionnaire for Athletes (RESTQ-Sport)

The RESTQ-Sport was used to evaluate stress and recovery related to activities of the last three days and three nights. This questionnaire consists of 76 items answered on a Likert scale (0 = never; 6 = always). The questions are divided into 19 scales (seven referring to general stress, five to general recovery, three to stress in sports, and four to specific recovery in sports). The RESTQ-Sport developed by Kellmann and Kallus[23] was validated for the Portuguese language by Costa and Samulski[26].

Statistical analysis

The normality of the data was evaluated by the Shapiro-Wilk test. Analysis of variance (ANOVA) for repeated measures with the Tukey *post-hoc* test was used to determine differences between variables related to training load, between the CMJ and IJT tests and between the RESTQ-Sport scales at the different time points. The data were analyzed using the Statistica software (v.8.0, StatSoft®, Tulsa, OK), considering a probability of a type I error (α) of 5%.

RESULTS

The external training load is shown in Table 1. The variables related to internal training load (TWTL, monotony and strain) are shown in Table 2. No difference was observed between these variables ($p>0.05$).

Table 1. Description of the physical training applied.

	Weeks 1 and 2		Weeks 3 and 4	
Exercise	Sets	Repetitions	Sets	Repetitions
Back squat	4	8		
Back squat with jump			4	6
Bilateral consecutive jumps on 3 steps of the grandstand	4	5		
Unilateral consecutive jumps on 3 steps of the grandstand			4	5
Unilateral back squat	3	8	4	6
Lateral cone jump	4	10	4	10
Triple jump preparing to spike jump on steps (1 and 2 plinths)			4	6
Knee flexion	4	8	4	8
Push-up	3	8	3	8
Chin-up	3	10	3	10
Overhead press	3	8	3	6
Pull over			3	6
Dumbbell shoulder flexion			3	6
Sit-up	3	20	3	20
Diagonal sit-up	3	15	2	20

Table 2. Internal training load during the pre-competitive period.

	Week 1	Week 2	Week 3	Week 4
TWTL	1,922 ± 654	1,530 ± 691	1,874 ± 528	1,568 ± 312
Monotony	0.90 ± 0.12	0.83 ± 0.17	0.96 ± 0.17	0.90 ± 0.11
Strain	1,838 ± 780	1,348 ± 860	1,847 ± 707	1,413 ± 379

TWTL: total weekly training load.

The CMJ results are shown in Table 3. The athletes exhibited greater CMJ performance in post-week 4 compared to post-week 2 ($p<0.05$) and baseline ($p<0.01$). Higher values were also observed in post-week 2 compared to baseline ($p<0.05$).

Table 3 also shows the results of the IJT. Higher P15 and P60 values were observed in post-week 4 compared to baseline ($p<0.01$). There was no difference in DP or L15 ($p>0.05$).

Table 3. Countermovement vertical jump (CMJ) and intermittent vertical jump test of four sets of 15 seconds (IJT) at the three time points analyzed.

	Baseline	Post-week 2	Post-week 4
CMJ	40.51 ± 1.94	43.10 ± 2.48*	45.11 ± 3.29*+
P15	45.10 ± 1.61	46.71 ± 2.28	48.31 ± 2.01*
L15	37.04 ± 1.40	37.88 ± 2.43	38.98 ± 2.62
P60	40.92 ± 1.51	42.15 ± 1.73	43.69 ± 2.17*
DP (%)	-17.81 ± 3.49	-18.82 ± 5.41	-19.33 ± 4.14

Significant difference when compared to baseline (*p<0.01). Significant difference when compared to post-week 2 (+p<0.05).

As can be seen in Figure 1, a difference during training was only observed for the Fatigue and Injury scales of the RESTQ-Sport. Higher Fatigue scores were obtained in post-week 2 and post-week 4 when compared to baseline ($p<0.05$). Injury scores were higher in post-week 4 compared to baseline ($p<0.05$). No difference was observed for the other RESTQ-Sport scales ($p>0.05$).

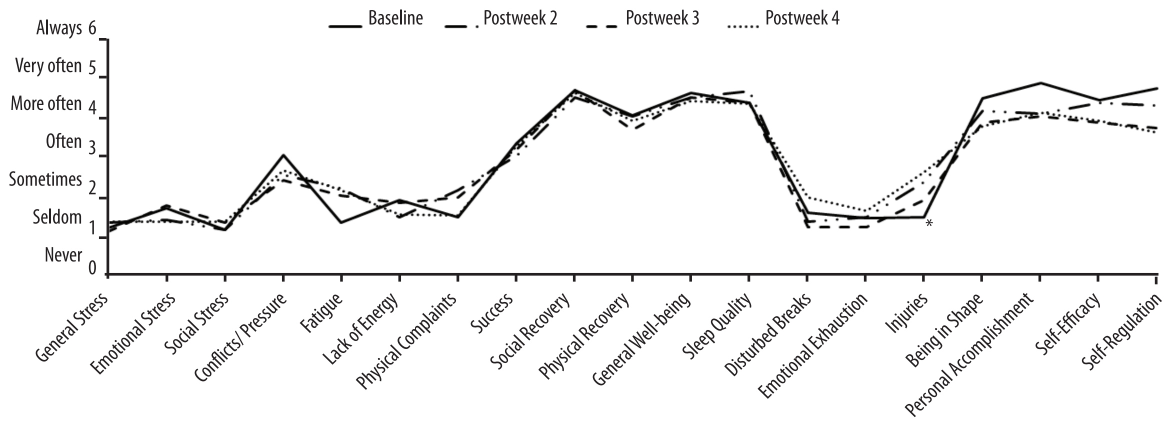

Figure 1. Comparison of the RESTQ-Sport scales between the different time points analyzed. *Significant difference between time points ($p<0.05$).

DISCUSSION

The main findings of the present study were that the physical training applied promoted an increase in CMJ performance and explosive strength endurance, demonstrated by the variables P15 and P60 in the IJT. A change in Fatigue and Injury scores of the RESTQ-Sport was observed during training. However, in general, this questionnaire revealed adequate levels of stress and recovery, resulting from the appropriate balance between training load and recovery.

Despite the increase in external training load (Table 1), no differences in internal training loads were observed. This fact might be explained by a possible adaptation effect to muscle damage as a result of repeated exercises during training[27], reflecting equivalent perceived exertion. According to Nakamura et al.[21], perceived exertion is a psychophysical response generated in the central nervous system to efferent neural impulses derived from the motor cortex. Thus, the adaptations resulting from training may lead to lower load perceptions[28]. This suggests that the adjustments made after the second week of physical training were important for the maintenance of adequate training stimuli.

The performance increases observed in the CMJ and IJT tests indicate that the training program promoted positive adaptations. The characteristic of the lower limb exercises applied during training at high speed, involving stretch-shortening cycle movements and loss of contact with the floor, probably provided neural, muscular and reflex adaptations that contributed to the increase in CMJ and IJT variables[6,7]. Improvement in this variable has also been demonstrated in young soccer players after 8 weeks of plyometric training[5], in volleyball players submitted to 4 weeks of combined electrostimulation and plyometric training[4], and in Under-14 soccer players after 12 weeks of strength and power training[8], in agreement with the results of the present study.

The results of the IJT test demonstrate an increase in explosive strength endurance. Curiously, studies investigating this variable in volleyball are sparse, although this ability is important for the modality due to the numerous jumps performed during games and training sessions[1,18]. Although no increase in L15 values was observed, the improvement in P15 and P60 and the lack of a difference in DP suggest that training promoted increases in explosive strength endurance of the lower limbs.

The results of the present study regarding performance and adequate scores on the RESTQ-Sport scales indicate positive effects of appropriate physical training consisting of a balance between training load and recovery, a fundamental factor to induce positive adaptations as suggested in the literature[17,21]. In contrast to the present study, the strategy of training load intensification, designed to promote functional overreaching during the periods that precede a competition, is frequently used to achieve good levels of performance in athletes[11,29]. However, this strategy can be associated with fatigue, accompanied by a temporary decline in performance[11,30]. In this respect, the present results agree with other studies[15,30] suggesting the application of adequate loads as the ideal training distribution strategy, resulting in minor negative impacts to athletes.

Despite the observation of an increase in the scores on the Fatigue and Injury scales of the RESTQ-Sport during training when compared to baseline, qualitative analysis showed that these scores remained low (less than 3 – often – on a scale from 0 to 6). These results, together with the lack of differences in the scores of the other RESTQ-Sport scales during training, suggest that the athletes were low on stress and high on recovery during the training period. The increase in the scores of these scales was expected since they are influenced directly by training. Other studies in which athletes were submitted to training loads considered to be adequate reported no differences in the scales of this questionnaire during training[29,30]. We found no studies investigating the impact of physical training on the RESTQ-Sport in young volleyball athletes, impairing comparison of the results.

The results of the IJT provide important information about the explosive strength endurance of volleyball athletes. However, tests reflecting the reality of the modality may provide more relevant and sensitive information and should be investigated in future studies. The instruments used in the IJT were not the same as those employed by Hespanhol et al.[18] and therefore did not produce the same results as those proposed these authors, such as peak power, average power and fatigue index. However, the P15, L15, P60 and DP results obtained in the present study are believed to be sufficient to interpret the changes in explosive strength endurance.

A major limitation of this study was the small size of the sample. In this respect, the difficulty in performing interventions in the training of volleyball teams during the period preceding a state championship should be highlighted. This difficulty becomes even greater since an Under-16 team was studied. Nevertheless, the results obtained in the performance tests after a period of physical training agree with the findings of other studies[4,5], thus supporting the results reported here.

The increase in explosive strength endurance after a period of physical training applied to young volleyball athletes during the period preceding a competition, as well as the performance increase in lower limb power tests using training loads that provided low levels of stress and adequate recovery, can be highlighted as original of the study, since reports on this topic that involve young volleyball players are sparse.

CONCLUSIONS

Physical training applied during a pre-competitive period promoted increases in CMJ performance and explosive strength endurance. The magnitude of the alterations in the Fatigue and Injury scores of the RESTQ-Sport, together with the lack of differences in the other scales, suggests that the athletes were low on stress and high on recovery during the training period analyzed. These results can encourage physical trainers to introduce a physical training program designed to increase muscle power associated with balanced levels of load and recovery in the periodization of young volleyball athletes. However, the small size of the sample (n=7) suggests caution in drawing conclusions and in generalizing them to other volleyball players of the Under-16 category. Further studies are therefore needed.

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