Original article (short paper)

Specific warm-up exercise is the best for vertical countermovement jump in young volleyball players

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Abstract — We evaluated the effect of performing various distinct warm-up exercises on vertical countermovement jump (VCMJ) performance. Eight volleyball players (age 15.4 ± 0.5 yrs) performed five different warm-up activities (in a counterbalanced, randomized crossover study) over five days, at 24-h intervals: stretching (4 × 30 s, 30 s between sets), cycloergometer (5 min at 50 W + 5 min at 100 W), resistance exercise (leg press 45°, 3 × 5 repetitions maximum, 3-min pause between sets), specific vertical jumping (4 × 10 VCMJ, 2-min pause between sets), and no warm-up at all (control condition). Beginning 3 min after their warm-up, the players performed 3 attempts (at intervals of 3 min) of VCMJ (on a contact carpet), and each player's best jump was considered in the analysis. All warm-up activities presented higher VCMJ performance ($p < 0.05$) than the control condition, with the exception of stretching. Vertical jumping revealed a large effect size (0.8) than other interventions. We conclude that in practical terms, vertical jumps are the best warm-up exercise (when applied by itself) to acutely improve VCMJ performance in volleyball players, but that other exercises can make a complementary contribution.

Keywords: performance, jumping technique, team sport, potentiation, athletes

Introduction

Vertical countermovement jumps (VCMJs) are considered essential to success in volleyball, as they are used in both defensive (blocking) and offensive (attacking, passing, and serving) motions[1,2] VCMJs are performed frequently by volleyball players during training and competitions, and several studies have focused on how athletes can enable themselves to jump most effectively[3,4] Volleyball players must jump frequently in matches, making good jumping technique crucial. An analysis of two matches showed that the average player executed about 45 jumps and subsequent landings, and that the players' overall performance depended heavily on these actions[5].

The importance of VCMJs in volleyball makes understanding the factors that influence jumping ability essential. Limiting factors such as flexibility in the joints involved in jumping movements, the strength and muscle power of athletes (e.g., maximal force, maximal velocity, and stretch-shortening cycle utilization), and specific techniques seem to be reasonable variables to consider.

Sports scientists and coaches are constantly seeking the best ways to maximize players' performance. Examining the phenomenon known as post-activation potentiation is one pathway associated with this purpose, at least acutely[6]. Most studies about post-activation potentiation have used VCMJs because studying this movement can detect variations in lower limb performance (i.e., muscle power, strength) and because these jumps are important in several sports such as volleyball[7].

Although particular exercises are commonly performed during warm-up before practices and matches, aiming at a better transition from a resting state to high-intensity activity, little is known about the effect of this activities (e.g., stretching, resistance exercise, jumps, jogging) on VCMJ performance by volleyball players. Thus, the aim of this study was to evaluate the acute effect of each of four distinct warm-up activities (performed as the subjects normally completed them, not influenced by researchers) on VCMJ performance in young volleyball players. We hypothesized that a more specific warm-up (e.g. jumps) would induce greater improvement than other activities.

Methods

Subjects and ethical concerns

Eight female volleyball players who participated in a Brazilian state championship competition (age 15.4 ± 0.5 years; 4.3 ± 1.2 years of training; 5 training sessions/week; 90 min/session) participated voluntarily, having been recruited through by convenience sampling. They had experience in strength training (1 repetition maximum [RM] for leg press 45° = about 335.8 ± 16.5 kg). This study was conducted according to the Declaration of Helsinki, and the protocol was fully approved by the ethics committee of the local university before we began conducting our assessments. All participants were informed that they could withdraw from the study at any time without penalty, and their parents (or guardians) signed an informed consent form.

Inclusion and exclusion criteria

We sought participants with no history of lower limb musculoskeletal injury diseases that could affect the results. All participants had to meet the following inclusion criteria: (1) having at least two years of experience playing volleyball; (2) having participated in the state championship competition; (3) not consuming nutritional supplements or potential ergogenic aids of any kind (exogenous anabolic androgenic steroids); (4) non-smoker; (5) normal blood pressure; (6) not diabetic; and (7) familiar with the exercises used in the evaluation.

General design of the experiment

To address the question of whether any exercises usually used in warm-ups could influence VCMJ performance by themselves (i.e., if performed alone without any other exercise), we performed a counterbalanced, randomized crossover study. In the course of five days (at 24-h intervals), participants performed the control activity (no warm-up) and four distinct warm-up protocols, following the same general procedures carried out in training or before matches, and then had their VCMJ performance measured. We did not influence the content (i.e., type, duration, and intensity) of each warm-up and simply asked the players to perform each warm-up activity by itself. The four warm-ups selected were as follows.

Resistance exercise: This exercise (leg press 45°) consisted of 3 sets of 5 repetitions maximum (RM) with a 3-min pause between sets. The intensity (5 RM) was determined by the team's fitness coach, because he already had information on the players' abilities. The velocity of the movement was observed (without influence) by a pacer alarm (SEIKO DM50, Tokyo, Japan), and the average for all players was about 4 s for each repetition (2-s concentric and 2-s eccentric phases).

Static stretching: Four sets (30 s stretching and 20 s pause) for the following muscles: lateral/medial and adductors/abductors of hip, flexor/extensor of hip, and knee and ankle plantar flexors. The players' fitness controlled the intensity of the stretching by using the visual analog pain scale, from 0 ("no pain") to 10 ("maximum pain"). Players were instructed to keep their intensity level between 3 and 4 ("annoying, uncomfortable, troublesome pain")(8), as they normally did during daily warm-up activities.

Stationary cycloergometer (bicycle): The players spent 10 min riding a cycloergometer (Maxx-Pro standard Monark®, Varberg, Sweden). The initial load was 5 min at 50 W (1 kp, 50 RPM), followed by an additional 5 min at 100 W (2 kp, 50 RPM).

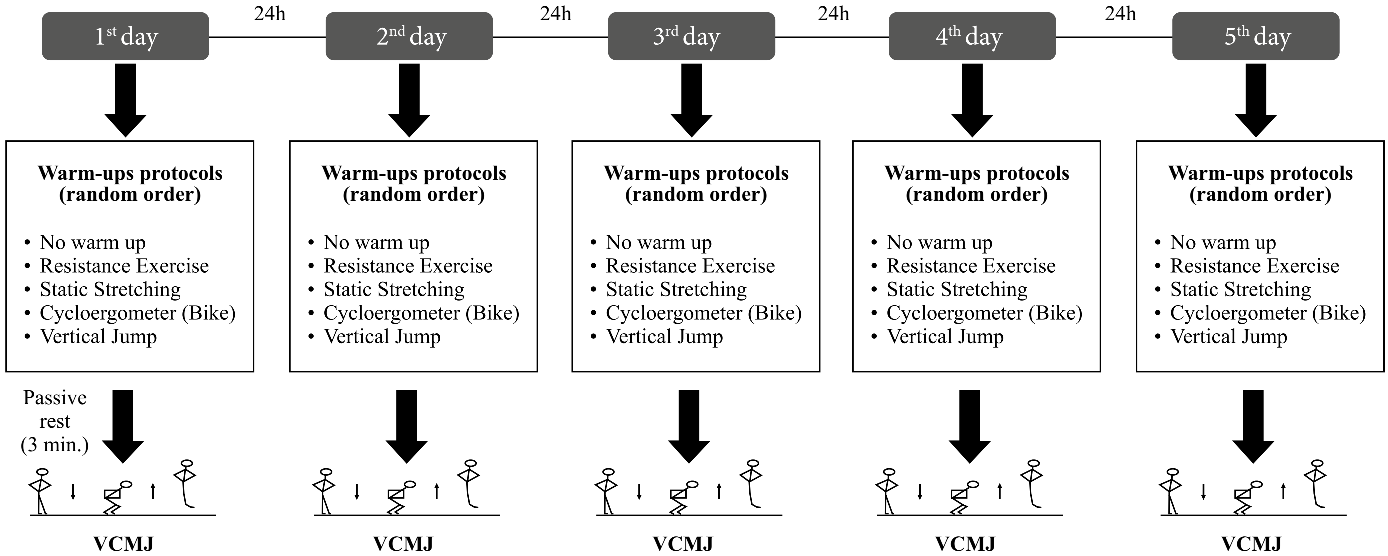
Vertical jump: This warm-up consisted of 4 sets of 10 jumps, simulating VCMJs, with a 2-min pause between sets. The fitness coach asked the players to jump vertically as high as they were capable of doing during the sets.

The order of the warm-up protocols was counterbalanced to avoid potential bias associated with the warm-up protocol sequence. The sequence of the warm-up protocols for each participant was determined by lot. The only changes was that players performed each warm-up exercise by itself, whereas they would usually combine two or more exercises (e.g., stretching, bicycling, and vertical jumps) in their typical warm-up rather than performing only one. Since the warm-up exercises used in this study were already part of the players' daily routine, they were fully familiar with how to execute each activity.

The study was carried out at the beginning of the volleyball season, and the players were instructed to arrive at the gym in a rested and fully hydrated state, at least 2 h postprandial, and to avoid strenuous exercise in the previous 24 h. Each subject was tested at the same time of day (10:00–12:00 h), at a temperature of 25 ± 2° C, and strong verbal encouragement was given to all players to motivate them to perform each test action. Additionally, the players wore exactly the same uniforms for all protocols. The experimental protocol design is displayed in Figure 1, and the sequence in which each participant performed the warm-ups is shown in Table 1.

VCMJ test

To measure the jumping height, a contact platform measuring 100 x 60 x 8 cm, sensitive to small changes in pressure and coupled with Jump Test® software (CEFISE, Jump System Pro, Nova Odessa, Brazil; interface connection cable, 25-pin, parallel USB port; sampling frequency 1Mhz, mean error ± 3 ms) was used. The VCMJ performance test consisted of a bilateral



Notes: No warm up (control) / Resistance Exercise (Leg Press 45°, 3x5 repetitions, 3 min. pause between sets) Static Stretching (4x30s, 30s between sets) / Cycloergometer = Bike: (5 min. 50W + 5 min. 100W) Vertical Jump (4x10 VCMJ, 2 min. pause between sets)

Figure 1. Experimental design of the study (n = 8)

Table 1. Sequence in which each participant performed the warm-up protocols. The interventions are coded as follows: 1 = control; 2 = resistance exercise; 3 = bicycling; 4 = vertical jumps; 5 = stretching.

Participants	1st day	2nd day	3rd day	4th day	5th day
1	3	5	2	4	1
2	1	2	4	5	3
3	2	1	3	4	5
4	5	2	3	1	4
5	4	3	1	2	5
6	1	5	3	2	4
7	4	1	2	3	5
8	5	3	2	1	4

vertical jump from an orthostatic position with hands on the hip (no arm swing allowed), in the suprailiac region. Leg-thigh flexion relation occurred until about 90°. The participants then did a fast leg and hip extension, trying to push the body upward and vertically without previous movement of any other body part. The trunk was held upright vertically without excessive advance. Another important technical detail is that the knees remained extended during the flight. All technical evaluations were performed beginning 3 min after the warm-up. Each participant performed three trials with 3 min of recovery between trials, and we used only the best performance in our analysis. The test was invalidated if the players violated any of these conditions: (1) did not start or complete the jump with both feet inside the platform; (2) used upper body movement during the jump; or (3) adopted a sort of "group" (i.e. flexion of the hip, approaching the thighs of the trunk) at the time of landing (which increases the time of flight).

Statistical Analysis

All data were checked for normality using the Shapiro-Wilk test. Data were presented as means ± standard deviations, delta (Δ%) compared to the control group, and effect sizes. The effect sizes were interpreted using the scale of magnitudes proposed by Cohen(9). Repeated measures ANOVAs were used to examine the main effects between the warm-up protocols. Mauchly´s Test of Sphericity was conducted initially, followed by ANOVAs, with Greenhouse-Geisser correction where appropriate. Alpha was set at $p < 0.05$.

Results

All warm-up protocols presented higher VCMJ performance ($F_{(3,20)} = 14,8$; $p < 0.01$; $\eta^2 = 0.679$) than the control condition, except for static stretching (Table 2). Vertical jump warm-up led to the highest VCMJ performance (12% greater than control, $p < 0.01$, effect size 0.8), followed by bicycling (7% greater, $p = 0.049$, effect size 0.5) and resistance exercise (6% greater, $p = 0.031$, effect size 0.4).

Discussion

The main finding of this study was that a skill-specific warm-up (vertical jumping) was the best exercise (largest effect size) to improve VCMJ performance when applied by itself. Thus, the use of jumping exercises in warm-up appears to be effective prior to training and matches, but other methods can also be applied as complementary warm-up activities.

The exact mechanisms supporting the potentiation effect elicited by plyometric exercise (vertical jump) as preload are still unclear[2]. Although electromyography was not performed in the present study,

Table 2. VCMJ performance changes following warm-up protocols (n = 8)

Warm-up protocols	Mean ± SD	CI 95%	In relation control condition	
Control	28.2±3.5	25.2 - 31.1	Δ%	Effect size
Stretching	28.4±3.4	25.5 - 31.3	1%	0,06
Bicycling	30.1±4.0*[a]	26.7 - 33.4	7%	0,5
Resistance exercise	29.8±3.7*	26.7 - 32.9	6%	0,4
Vertical jumps	31.5±4.4*[a]	27.9 - 35.2	12%	0,8

CI: confidence interval; *significant differences ($p < 0.05$) between warm-ups protocol and control; [a]significant differences from stretching. Effect sizes of < 0.09, 0.10–0.49, 0.50–0.79, and > 0.80 were considered trivial, small, moderate, and large, respectively (Cohen, 1988). Data represent mean ± standard deviation.

we can suggest that post-activation potentiation effects could be attributed to such neural mechanisms as increased motor neuron excitability, enhanced motor unit recruitment patterns, or increased activation of synergists (or all of these)[2,10].

Bicycling showed better results than control and stretching, but not better than resistance exercises and vertical jumping. This result relative to the latter two exercises is not surprising, because to obtain the benefits from post-activation potentiation, type II (fast twitch) fibers must be recruited during conditioning activities (size principle). Because the bicycling warm-up was performed at a low intensity, it was probably unable to activate type II muscle fiber and generate post-activation potentiation. Nevertheless, it has been found that exercise with low loads also can create an optimal environment for power production[11]. This improvement in neuromuscular function can occur through the increase of body temperature and the acceleration of metabolism[12]. In this way, although through different mechanisms, the bicycle warm-up at low intensity was also somewhat effective in improving VCMJ.

In the present study, VCMJ performance increased after resistance exercise, similar to the results of other investigations that demonstrated a positive change in jumping performance after high-intensity squat exercises[13,15]. Although the leg press is a multi-joint exercise (similar to jumping), biomechanically the two have some differences (e.g., the ballistic nature of jumping, and the different body positions) that could influence the post-activation potentiation response[16]. Despite this, warming up with high-intensity leg presses improved VCMJ performance, probably due to the increase of phosphorylation of myosin regulatory light chains and the recruitment of higher-order motor units[17]. There is also evidence to suggest that acute changes in the pennation angle may contribute to post-activation potentiation. All these mechanisms result in greater cross-bridge attachments and higher muscle power[17].

The stretching protocol was the only exercise that did not improve VCMJ relative to the control condition (i.e., no warm-up at all) in the present study. Also, we did not observe a negative influence of the stretching protocol on VCMJ, in agreement with some previous studies[18,19]. However, other studies have shown negative effects on vertical jump performance after static stretching[20,23]. The differences among studies could be due to the volume and/or intensity level of the stretching protocol. The fact that our protocol applied a relatively high volume (4 sets of 30 s) but low intensity of exercise could be related to the lack of negative impact on jumping performance. In addition, the participants performed a similar stretching protocol to their normal training routine, and this fact could also help to explain the maintenance of VCMJ capacity.

Another interesting finding in our study was that resting for 3 min was sufficient to avoid negative impact on VCMJ performance in all protocols. Generally, the rest interval needed to obtain post-activation potentiation effects has ranged between 5 and 18.5 min. [24]. Although several factors can interfere with post-activation potentiation, including the rest interval[17,24-26], our data showed that the interval used (3 min) did not decrease VCMJ performance.

Once we carried out a crossover randomized assignment to avoid any influence of treatments, our findings were robust, reinforcing our initial hypothesis that a more specific warm-up (i.e., vertical jumping) would be better than others when applied in an isolated way to acutely improve VCMJ.

Finally, the current data should be interpreted with caution, because we analyzed isolated warm-up protocols. This method was suited to our purpose, as it enabled us to compare the impact of four distinct warm-up exercises, but single-exercise warm-ups rarely if ever happen in the real world of high-level sports. Thus, future research could elucidate the impact of combined warm-up protocols and other possibilities.

Conclusion

In practical terms, vertical jumping is the best warm-up exercise to acutely improve VCMJ performance in volleyball players, when compared to other exercises and when each one is applied by itself. The results suggest that acute-response, high-intensity resistance exercises and low-intensity bicycling on an ergometer can improve VCMJ performance to a lesser degree, whereas static stretching exercises do not.

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Acknowledgments

The authors would like to thank the players and coaches that contributed in this study.

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Manuscript received on April 23, 2016
Manuscript accepted on May 17, 2016