Sports Science

Effect of land- and aquatic-based plyometrics on spike and block reaches in young volleyball players: a pilot study

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Abstract - Aim: The purpose of this pilot study was to analyze the feasibility of the intervention and measures of a six-week land- and aquatic-based plyometric training on spike and block reaches in young volleyball athletes. **Methods:** Twelve female players were divided into a land group (LG) (n = 6, 12.4 ± 0.3 years, 1.61 ± 0.04 m, 57.0 ± 9.3 kg) and a water group (WG) (n = 6, 12.5 ± 0.5 years, 1.57 ± 0.06 m, 48.9 ± 8.5 kg). The spike and block (without step, with slide step, and with crossover step) reach and countermovement jump height were evaluated before and after a 6-week plyometric training protocol. Duration (total and of each session), adhesion and adherence, and safeness of the intervention; completion of assessments, within-trial reliability, and variability of the outcome measures and preliminary results were the variables of interest. To analyze the effect of the training on jump performance, the Wilcoxon test was used ($p < 0.05$), and effect sizes (r) were calculated. **Results:** All participants concluded the intervention and the assessments as planned. No dropouts or adverse events were registered during the study. The within-trial reliability for all assessment tests was considered excellent (ICC ≥ 0.9). Preliminary results indicate that LG improved the reach of the spike and block with the slide step; and that WG improved the spike, block with the slide step to the left, and block without movement reaches ($p < 0.05$; large effect size). **Conclusion:** An intervention of six weeks of plyometric training on land and in water is feasible, and preliminary results indicate that both training protocols may benefit the performance of spike and block in young volleyball athletes.

Keywords: plyometric training, vertical jump, aquatic exercises.

Introduction

Plyometrics is a traditional training method composed of exercises that use the elastic potential of the muscle stretched by an eccentric action followed immediately by a concentric action[1]. Widely used in sports training, it causes positive effects on strength, speed, agility, and vertical jump performance, among others[2-5].

In volleyball, considering that many specific technical actions require performing vertical jumps (e.g., serving, attacking, blocking), the use of plyometrics is recommended for developing the capacities related to jumping performance[6]. A recent systematic review[5] that included twenty-one studies showed that plyometric training improves vertical and horizontal jump performance, flexibility, and agility/speed in volleyball athletes. In a systematic review with the metanalysis of fourteen studies, Ramirez-Campillo et al.[7] concluded that different plyometric training protocols caused improvement in vertical jump height (with large effect sizes) of volleyball players of different ages and genders.

Under the prerogative of reducing the considerable mechanical overload that occurs while performing plyometric jumps[8], training in an aquatic environment has been proposed as an alternative[9-11]. In water, this load reduction occurs due to buoyancy, which attenuates the ground reaction force (i.e. the impact) during the execution of different types of jumps in comparison to land[12-14]. Held et al.[15] compared the effects of plyometrics on land and water in a systematic review that included eight studies. The participants in these studies were healthy men and women (physically active and inactive) and athlete men (basketball and wrestling), and the results showed that the effect of plyometric training in water on the force of lower limbs, running speed, and the vertical jump performance on land is like that observed when the training is carried out on the land.

In volleyball athletes specifically, the plyometric training programs in water caused improvement in agility[16], muscle strength[16,17], and vertical jump height[16-18]. In these studies, although the vertical jump height was the most analysed variable, it draws attention that none of them evaluated specific jumps of the modality. The spike and block reach differentiate the levels of the athletes[19,20] and the performance of such fundamentals is directly related to the performance of the team in a match[21]. For professional male players, squat (SJ) and countermovement jump (CMJ) performance are highly correlated ($r > 0.8$) with block and attack height, respectively[22]. Thus, volleyball players may benefit from training programs capable to improve SJ and CMJ performance, such as those previously described[5,7]. Further investigation is needed to analyze if this improvement in "general" jump capacity will reflect attack and block-specific gains, whether in magnitude or time of training to reach them. Considering that attack and block performance is a key factor for success in a game[19-21], it is important to develop and investigate training methods capable of promoting task-specific gains in volleyball players. The purpose of this pilot study was to analyze the feasibility of the intervention and measures of a six-week land- and aquatic-based plyometric training protocol on spike and block reaches and countermovement jump height in volleyball athletes.

Methods

Participants

Twelve young female volleyball athletes participated in this study and were divided into land and water groups. The participants were paired according to the countermovement jump height during the pretest and allocated randomly to the study groups. The inclusion criteria for participation in the study were the following: (a) not reporting during the first contact/interview any complaints of musculoskeletal compromise; (b) having at least two years of experience in the training of the modality aimed toward participation in competitions of at least the state level, and (c) being adapted to the aquatic environment. All procedures were approved by the Human Research Ethics Committee (CAAE 54343216.3.0000.0118). The athletes signed the consent form, and their legal guardians agreed with their participation upon the signature of the specific form.

Experimental design

This pilot study was performed to analyze the following aspects of feasibility: (i) intervention (total intervention time, duration of individual sessions, adhesion and adherence to the intervention, number of sessions performed by each participant, and safeness); and (ii) measures (completion of assessments, within-trial reliability and variability of the outcome measures and preliminary results).

An experimental design with paired groups (land group and water group) was used. The assessments were performed before and after a six-week plyometric training protocol on land and in water (two sessions per week). This period was part of the pre-season of the team, and the technical-tactical training sessions were maintained normally during the entire intervention.

The land group performed the plyometric training on the team court, and the water group used a swimming pool with a depth of 1.2 m (74 ± 2% of the body immersed). The jump training sessions were performed on non-consecutive days after the technical-tactical training. Both groups performed the same training. Table 1 presents the exercises and volume of each training session. Each session lasted on average 25 min.

Assessments

The following tests were performed before and after the intervention period: (1) static block reach (SBR) - positioned in front of the net, the athlete makes a countermovement, jumps, and performs the complete blocking movement; (2) block reach with a slide step to the right (BSR) and the left (BSL) - positioned in front of the net, the athlete takes a side step and performs the complete blocking movement; (3) block reach with a crossover step to the right (BCR) and the left (BCL) - positioned in front of the net, the athlete takes a crossover step (using three steps and the movement of the arms, starting from the middle to the ends of the net) and performs the complete blocking movement; (4) spike reach (SPR) - a complete spike jump was performed involving the approximation steps toward the net, the jump, and the spike movement; and (5) countermovement jump (CMJ) - starting from the standing position with the hands at the waist, a countermovement was performed followed by a maximum vertical step. The specific jumps were performed on the training court of the team following the description by

Table 1 - Plyometric training protocol.

Week	Exercise	Series	Repetitions	Contacts per session
1	DJ40	3	8	60
	SJ4	3	3	
2	DJ40	3	10	90
	SJ4	5	3	
3	DJ40+1	4	8	124
	SJ4	5	3	
4	DJ40+1	4	10	140
	SJ4	5	3	
5 and 6	DJ40+1	4	12	156
	SJ4	5	3	

DJ40 is the drop jump with a drop height of 40 cm. DJ40+1 is the drop jump followed by a maximum vertical jump. SJ4 are four sequential maximum jumps.

Martinez[23] and Lobietti[24], and the volleyball net was used as a reference.

To obtain the reach of the specific jumps of the modality, a piece of equipment similar to commercial equipment *Vertec Jump Test* (Jump USA, Sunnyvale, USA) was built and used. The equipment has eighty sticks and a telescopic rod that allows fine-tuning the base height. The jump reach in meters was calculated by adding the base height (stick 1) and the height of the last dislocated stick, measured from the base position. For the spike reach, the measuring equipment was placed at position 4, at approximately 0.5 m of the net. For the block reaches, the equipment was placed on the opposite side of the court at around 0.1 m from the net (enabling the entrance of hands).

The CMJ height in meters was calculated from the flight time using the following equation: height = (flight time in seconds^2*9.81)/8). The flight time was measured using a force plate with dimensions of 500 mm x 500 mm, built based on the study by Roesler and Tamagna[25]. The force plate was connected to the ADS2002-IP signal acquisition and conditioning system (AC2122, Lynx Tecnologia Eletrônica LTDA, São Paulo, Brazil). The sample rate was set at 1500 Hz. The data obtained using the force plate was exported through software AqDAnalysis 7.02 (Lynk Technologia Eletrônica LTDA, Brazil) and analyzed through a processing routine created with Scilab 4.1.2 software (INRIA, France). The force plate signal was low pass filtered using a third-order recursive Butterworth filter with a cut-off frequency of 100 Hz.

After a period of familiarization with the analyzed jumps, the participants executed two valid attempts in each test. The best attempt (higher reach/height) in each test was considered for the statistical analysis.

Data analysis and statistics

Data on the total intervention time, duration of individual sessions, adhesion and adherence to the intervention, and the number of sessions performed by each participant were registered for each group from the start to the end of the plyometric training program. The occurrence of adverse events (injuries or accidents), used as the indicator of intervention safeness, was monitored, and registered from the preparation to the end of each intervention session. The frequency of completion of the tests was analyzed during the assessment sessions. All this information was registered by the main investigator using electronic sheets in Microsoft Excel 365 software (Microsoft Inc., USA). An exploratory analysis was performed for all variables measured before and after the intervention. The within-trial reliability for each test was assessed by the intraclass correlation coefficient [two-way mixed model, absolute agreement, ICC (3,1)]. We considered ICC values ≥ 0.9 as excellent, between 0.7 and < 0.9 as good, between 0.6 and < 0.7 as acceptable, between 0.5 and < 0.6 as poor, and < 0.5 as unacceptable. Considering the small sample size, we used the Wilcoxon test to compare the variables obtained before and after the plyometric training protocol and analyze the preliminary results on the effect of the intervention. Effect sizes (r) were estimated as follows[26]: $r = Z/\sqrt{n}$, where Z corresponds to the z-score from the Wilcoxon test and n corresponds to the total number of observations. Values of r between 0.1 and 0.3 were considered as a small effect, r values between 0.3 and 0.5 as a moderate effect, and values greater than 0.5 as a large effect[27]. All procedures were performed using the statistical program SPSS version 20.0 for Windows (IBM, USA), and the 5 % significance level was adopted for all tests.

Results

Participants' characteristics of both groups are presented in Table 2. There was no difference between groups for age, body mass, height, and CMJ height on baseline ($p > 0.05$).

In both the land and water groups, all the recruited players engaged the intervention and there were no dropouts during the period of the study. Each training session, in both environments, lasted approximately 25 minutes as planned. All participants concluded the twelve training sessions in non-consecutive days in a six-week interval. No adverse event was registered during the period of the study. The duration of assessments was considered adequate, and all participants completed all tests planned for each session (before and after the plyometric training protocol).

The within-trial ICC values obtained for all tests (block, spike, and CMJ) in both assessments (before and after the intervention) ranged from 0.92 to 0.99. The preliminary results of the intervention are presented in Table 3.

Discussion

The main findings of this pilot study point that the purposed intervention and measures are feasible, and that preliminary results indicate similar benefits on jump performance for both land and water plyometric training protocols. The good results obtained regarding the feasibility

Table 2 - Mean ± standard deviation of participants' characteristics included in land and water groups.

	Land group (n = 6)	Water group (n = 6)	p
Age (years)	12.4 ± 0.3	12.5 ± 0.5	0.676
Body mass (kg)	57.0 ± 9.3	48.9 ± 8.5	0.155
Height (m)	1.61 ± 0.04	1.57 ± 0.06	0.144
Baseline CMJ height (m)	0.25 ± 0.02	0.24 ± 0.02	0.221

CMJ: countermovement jump.

Table 3 - Median, lower (LQ), and upper (UQ) interquartile range and Wilcoxon results and effect sizes (r) for the variables analyzed before and after intervention for both water and land groups.

Variables	Group	Before			After			Wilcoxon test	
		Median	LQ	UQ	Median	LQ	UQ	p	r
SPR (m)	Land	2.44	2.41	2.48	2.53	2.44	2.56	0.028	0.635
	Water	2.46	2.41	2.49	2.55	2.44	2.60	0.028	0.635
SBR (m)	Land	2.32	2.29	2.36	2.35	2.32	2.43	0.075	0.514
	Water	2.37	2.33	2.43	2.40	2.36	2.47	0.046	0.576
BSR (m)	Land	2.31	2.29	2.38	2.35	2.32	2.43	0.027	0.639
	Water	2.36	2.34	2.44	2.39	2.35	2.47	0.075	0.514
BSL (m)	Land	2.33	2.29	2.38	2.35	2.32	2.40	0.028	0.635
	Water	2.36	2.32	2.41	2.40	2.34	2.46	0.028	0.635
BCR (m)	Land	2.32	2.30	2.41	2.36	2.34	2.43	0.113	0.453
	Water	2.38	2.35	2.46	2.43	2.37	2.47	0.116	0.453
BCL (m)	Land	2.37	2.31	2.44	2.38	2.35	2.43	0.345	0.272
	Water	2.39	2.34	2.49	2.43	2.39	2.47	0.173	0.393
CMJ (m)	Land	0.25	0.24	0.27	0.25	0.21	0.27	0.345	0.272
	Water	0.24	0.22	0.26	0.23	0.20	0.27	0.916	0.030

SPR: spike reach; SBJ: static block reach; BSR: block reach with a slide step to the right; BSL: block reach with a side step to the left; BCR: block reach with a crossover step to the right; BCL: block reach with a crossover step to the left; CMJ: height of the countermovement jump.

of the intervention are certainly associated with the fact that all the steps were planned and organized together with the technical staff of the involved team. This allowed us to determine the best period (within the preparation season) and the appropriate logistics to carry out the intervention. In addition, the fact that the intervention consisted of relatively short sessions (~25 min) and lasted just over a month (6 weeks), probably contributed to the greater engagement of the participants, resulting in the excellent adhesion and adherence rates. Although it would be better to include the plyometric training before the technical-tactical training (TT), the intervention was performed after the TT routine due to operational issues, aiming to minimize the transition time between activities. The total duration and logistics of the intervention are determinants for its applicability throughout the preparation program of a sports team.

Concerning the intervention safety (no adverse events were recorded), it should be noted that plyometric jumps are commonly applied to the training routine of volleyball teams. Although we cannot affirm that this eliminates the chance of injuries or accidents during the intervention, being familiar with the exercises used during the sessions possibly contributes to minimizing the risks. Moreover, the participants of our study were considered familiar with the aquatic environment (capable of balancing, floating, diving, and performing movements with a combination of movements in the water). This is an important issue to consider when planning exercise interventions in this environment.

The within-trial reliability for all measures obtained during the assessments is considered excellent (ICC $\geq$ 0.9). The preliminary results on the effect of the intervention corroborate findings of previous studies that have demonstrated that the effect of plyometrics (six- or eight-week protocols totalizing twelve to twenty-four sessions) on physical performance, both in healthy individuals and in athletes, is similar when the environments are compared[10,11,15]. This matter becomes particularly interesting because it seems possible to promote performance gains through aquatic plyometrics, in parallel to the reduction of the impact promoted by water.

Although little explored in scientific studies[5,7], the specific volleyball jumps are highly relevant to athletic performance and professional practice[28]. The spike is one of the main victory predictors for young volleyball players[29]. Hale et al.[30] reported that, among volleyball players with an average age of 15 years, an eight-week plyometric training protocol on land caused a moderate increase in spike jump height, with a mean difference of 5.4 cm. In our study, both groups increased the spike reach by approximately 7 cm after the training (large effect size, Table 3), indicating the effectiveness of plyometrics in improving the performance of this skill. This improvement is important since greater spike reaches favor the performance of this action and, consequently, the gaining of point[31].

In turn, blocking is an important fundamental of the defense complex and also a game action related to the victory of a team[24]. Among all evaluated variations, only block reach with a crossover step performance did not change from pre- to post-intervention assessment ($p > 0.05$, small to moderate effect size). One of the reasons for this may be the high technical complexity of executing this movement[24], especially for the age range in question. Depending on the environment and the variation, on average, an increase of 2 cm to 3.5 cm for the block reach was observed (most of them reaching the statistical significance and large effect size). After eight weeks of plyometric training on land, Hale et al.[30] reported a mean increase of 3.8 cm in the static block. The improvements in the block and spike jump heights reported by the authors and corroborated by our results may be attributed to the neural adaptations caused by the training[32,33].

The effect of training on land and in water was small and not significant for the CMJ height. In a recent systematic review, Stojanović et al.[4] found a small increase in the height of this type of jump after interventions lasting less than ten weeks were performed on the ground. For junior volleyball players (under 19), an eighteen-week macrocycle (with technical-tactical training sessions, resisted training, physical conditioning training, and matches - there is no report on the use or not of plyometrics) did not cause alterations to the CMJ height but generated positive effects on the attack and block jumps and reaches[28]. Although we understand the operational difficulty of assessing different types of jumps in studies involving many participants and recognize the utility of the CMJ as an assessment tool, we consider the inclusion of specific jumps in the analysis of the performance of volleyball players important and necessary.

In water, the contact time in plyometric jumps (e.g., drop jumps) is greater than on the land[12,13], and the eccentric-concentric transition phase is likely slower. This may limit and even mischaracterize the plyometric training[34]. Exercises in which the stretch-shortening cycle is performed slowly may not be so beneficial for athletes who primarily need fast actions in sports practice[35,36], however, if the main objective is to increase the jump height, longer contact times allow a more considerable generation of force and a greater maximum jump height[36]. It is worth stressing that it is possible to achieve different goals by manipulating variables such as the type of jump, the countermovement type (short, normal, large), the movement amplitude (that reflects the contact time), and the drop height, among others[37]. Although plyometric training in water likely does not cause the same neuromuscular adaptations as training on the ground, it seems to be an effective tool for developing jump capacity in volleyball. These specific adaptations will possibly be developed in parallel with the technical-tactical training routine of the modality, which involves various jumps and movements (accelerations and decelerations).

The main limitations of the present study are the absence of a sample calculation and the small number of participants in each group, which are characteristics of a pilot study. However, it is the first to assess the feasibility and the preliminary effects of plyometric training in water on the performance of specific jumps among young volleyball athletes. Even with the reduced sample size, our preliminary results indicate a significant and large effect for most of the specific jumps in a relatively short intervention period (which is relevant from the viewpoint of feasibility and applicability over the team preparation season). These results should be interpreted with caution since they are preliminary, and their generalization is dependent upon many observations.

Conclusions

The results of this pilot study indicate that an intervention of six weeks of plyometric training on land and in water is feasible considering aspects such as the duration (total and of individual sessions), adhesion and adherence to the program, safeness, duration, and completion of assessments and within-trial reliability of the outcome measures. Additionally, our preliminary results indicate that the designed intervention, both on land and in water, may benefit the performance of specific jumps (block and spike reach) of young volleyball athletes. Although there are difficulties in operationalizing plyometric training in water as part of the athlete preparation routine, this alternative seems promising given that it promotes gains similar to those that occur in response to training on land, with reduced overload. A further investigation, involving a larger sample, is needed to confirm these results.

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