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Research article

Plyometric Training Improves Sprinting, Jumping and Throwing Capacities of High Level Female Volleyball Players Better Than Skill-Based Conditioning

Bahri Gjinovci [1] Kemal Idrizovic [2] Ognjen Uljevic [3] and Damir Sekulic [3]✉
[1] University of Prishtina, Faculty of Physical Education and Sports, Prishtina, Kosovo
[2] University of Montenegro, Faculty for Sport and Physical Education, Podgorica, Montenegro
[3] University of Split, Faculty of Kinesiology, Split, Croatia

Abstract
There is an evident lack of studies on the effectiveness of plyometric- and skill-based-conditioning in volleyball. This study aimed to evaluate effects of 12-week plyometric- and volleyball-skill-based training on specific conditioning abilities in female volleyball players. The sample included 41 high-level female volleyball players (21.8 ± 2.1 years of age; 1.76 ± 0.06 cm; 60.8 ± 7.0 kg), who participated in plyometric- (n = 21), or skill-based-conditioning-program (n = 20). Both programs were performed twice per week. Participants were tested on body-height, body-mass (BM), countermovement jump (CMJ), standing broad jump (SBJ), medicine ball throw, (MBT) and 20-m sprint (S20M). All tests were assessed at the study baseline (pre-) and at the end of the 12-week programs (post-testing). Two-way ANOVA for repeated measurements showed significant (p<0.05) "Group x Time" effects for all variables but body-height. Plyometric group significantly reduced body-mass (trivial effect size [ES] differences; 1% average pre- to post-measurement changes), and improved their performance in S20M (moderate ES; 8%), MBT (very large ES; 25%), CMJ (large ES; 27%), and SBJ (moderate ES; 8%). Players involved in skill-based-conditioning significantly improved CMJ (large ES; 18%), SBJ (small ES; 3%), and MBT (large ES; 9%). The changes which occurred between pre- and post-testing were more inter-correlated in plyometric-group. Although both training-modalities induced positive changes in jumping- and throwing-capacities, plyometric-training is found to be more effective than skill-based conditioning in improvement of conditioning capacities of female senior volleyball players. Future studies should evaluate differential program effects in less experienced and younger players.

Key words: Volleyball, plyometric exercise, small-sided games, conditioning.

Introduction

Volleyball places high requirements on a player's speed, agility, upper-body and lower-body muscular power, and maximal aerobic power (Gabbett, 2008; Sattler et al., 2015). Therefore, coaches and professionals involved in volleyball are interested in the potential effectiveness of different training regimes and improvement of those conditioning capacities are known to be important determinants of success (Pereira et al., 2015). One of such training regimes is plyometric training. Plyometric training uses the physiological phenomenon of a stretch-shortening cycle in order to enhance the ability of the neuromuscular system to produce maximal force in the shortest possible time (Markovic and Mikulic, 2010). Due to the characteristics of the game, which involve repeated jumping, frequent sprinting and changes in directions, this training regime is a particularly popular method for fitness development in volleyball players (Kim and Park, 2016; Pereira et al., 2015; Trajkovic et al., 2016).

Previous studies have investigated the effects of plyometric training on conditioning capacities in volleyball (Lehnert et al., 2017; Marques et al., 2008; Sheppard et al., 2008; Voelzke et al., 2012). Voelzke et al. (2012) evaluated the effectiveness of resistance training with additional plyometric exercises (n = 8) and electromyostimulation plus plyometric exercise (n = 9). In general, their results showed significant improvement in jumping performance as a result of both modalities (improvement of approximately 5%), whereas the latter additionally promoted speed and agility performance in male volleyball players (Voelzke et al., 2012). Sheppard et al. (2008) investigated the concurrent effects of training using accentuated eccentric load during jumping (n = 8) vs. non-loaded training (n = 8) in high-performance volleyball players (mixed gender groups). The results indicated that more intensive plyometric training (with additional loads) yielded superior jumping performance (improvement of 11% in displacement capacity) in comparison to regular jumping training with the player's own body mass. In a study on 10 elite female volleyball players, Marques et al, 2008 reported changes in strength and power performance as a result of a 12-week program performed during the in-season (10 regular plus 2 additional sessions consisting of combined resistance- and plyometric-exercises), and reported improvements in muscular strength (13% and 18% for squat and bench-press, respectively), ball-throwing- (13%), and countermovement jump (4%). In two studies done on female junior volleyball players, the authors reported significant improvements as a result of 5-week and 6-week plyometric training on generic- and specific-jumping performances (Kristicevic and Krakan, 2016; Trajkovic et al., 2016). Similarly, Pereira et al. (2015) confirmed significant improvements in jumping- and throwing-capacities (between 5.3% and 20.1%) among 14-year old female volleyball players after 8-week plyometric training. Very recently, Polish authors reported training-induced changes in different physical performances in 12 female junior volleyball players (<18 years) as a result of 8-week pre-season conditioning programs (including plyometric training), and they showed trivial to small changes in jumping performances (improvement of

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3.0% to 4.5%) (Lehnert et al., 2017).

Skill-based conditioning games (training-games or small-sided games) are a popular method for improving the skill and fitness levels of players from different team sports, including volleyball (Corvino et al., 2014; Gabbett and Mulvey, 2008; Schelling and Torres, 2016). The basic idea behind skill-based conditioning is the fact that the greatest improvements in fitness and performance occur when the training stimulus simulates the physiological and technical demands of competition (Gabbett, 2008). In volleyball, it is reasonable to expect that skill-based conditioning can improve those capacities that are regularly improved through plyometric training, such as jumping and throwing. Indeed, volleyball skill-based conditioning includes different plyometric exercises (jumping, spiking, etc.), which are also included in plyometric training in different forms. Therefore, skill-based conditioning games have already been studied as potentially effective not only for improving technical skills but also for increasing the conditioning capacities of volleyball players (Gabbett et al., 2006; Gabbett, 2008). In short, skill-based conditioning improved sprinting capacities over 5 and 10 meters but did not contribute to better results in vertical jump, spike jump, or overhead medicine ball throw in junior volleyball players (Gabbett et al., 2006). In additional investigation, it has been suggested that a combination of skill-based-conditioning (i.e. training oriented toward improvement of conditioning capacities), and skill-based-instructional training (oriented toward development of specific volleyball skills), is likely to confer the greatest improvements in conditioning parameters and skill in junior elite volleyball players (Gabbett, 2008). To the best of our knowledge, no study has simultaneously examined the effects of plyometric- and skill-based conditioning on possible improvements in volleyball player physical capacities.

From the previous literature overview, it is evident that there is a lack of studies on the effectiveness of plyometric training on fitness indices in high-level female volleyball players. Additionally, information on the differential effects between plyometric- and skill-based-conditioning in female volleyball players is particularly lacking. Therefore, the aim of this study was to evaluate the concurrent effects of plyometric- and volleyball-skill-based training on changes in sprinting-, jumping- and throwing-capacities in high-level female volleyball players. Increased knowledge about these training modalities will allow a better understanding of the concurrent effects of these two popular training methods in volleyball. The initial hypothesis of this study was that the plyometric-training will induce more positive changes than skill-based conditioning, in studied conditioning qualities.

Methods

Participants

In this randomized controlled study, the sample of participants originally consisted of 50 high-level female volleyball players from Kosovo, members of teams participating at the highest competitive level (i.e., first division players) (21.9 ± 2.0 years of age; 1.76 ± 0.06 m; 61.2 ± 7.1 kg). Total sample was divided into plyometric- (n = 25) and skill-based group (n = 25). All participants were older than 18 years, and had played volleyball for at least 8 years prior to the study. Plyometric- and skill-based conditioning were performed as an addition to the regular technical and tactical volleyball training (see later for training details). Prior to the study, the participants were informed about the possible risks and benefits of the study, and their participation in the study was voluntary. The study was approved by the corresponding author's Institutional Ethical Board, and all participating players provided written consent for the study participation. However, in this study we included only those participants who participated in at least 80% of training sessions. Therefore, a final sample included 41 participants (21.8 ± 2.1 years of age; 1.76 ± 0.06 m; 60.8 ± 7.0 kg; 21 and 20 participants in plyometric- and skill-based-group, respectively).

Training protocols

The plyometric- and skill-based conditioning protocols were performed twice per week during the 12-week period at the beginning of the season. A single session for both programs lasted up to 60 minutes (10-15 min of standardized warm-up, 25-40 min of skill-based or plyometric conditioning depending on program, and 10-15 min of cool-down and stretching).

Plyometric training in general included lower-body plyometric exercises (jumping exercises), and upper body plyometric exercises (throwing exercises). Lower body plyometrics included (from low- to high-demanding exercises): leg hops, vertical jumps, tuck jumps, lateral/diagonal jumps, broad jumps, obstacle jumps, different types of box jumps (step-ups, box shuffles, etc.), and drop-jumps. In general, jumps were performed as (i) two-leg jumps with two leg landings (low intensity), (ii) two leg jumps with one leg landings (medium and high intensity, depending on exercise), and (iii) one-leg jumps with alternate leg landings, or one-leg jumps with same leg lending (high intensity). High intensity jumps were introduced to training from 6th to 8th week, and regularly applied from 9th to 12th week. From 9th to 12th week of training, some players performed loaded (weighted) jumps, with loads of maximally 5% of player's body mass, depending on one's fitness level and motor proficiency. Upper body plyometric exercises included: explosive push-ups, jumping spider (combination of explosive push-ups and jump), clapping push-ups, and different forms of exercises with medicine ball (i.e. throws, passes). Throws were performed in different directions (upward, horizontal, downward, etc.) with 1-kg medicine ball (one-arm throws for medium intensity, and two-arm throws for low intensity), and 3-kg medicine ball (two-arm throws for medium and high intensity depending on exercises. When it was possible upper-body exercises were done in pairs, otherwise individually. Plyometric training is presented in Table 1.

Skill based conditioning is presented in Table 2 and generally consisted of: (i) volleyball drills, (ii) small-sided games, and (iii) real-game drills. First mode of skill-based conditioning (volleyball drills) included spiking-,

Table 1. Plyometric-training program.

Week	Body part	Exercises	Intensity	Reps (total)	Sets (total)	Rest between sets
1	**Lower body**	Leg hops, tuck jumps, vertical jumps	Low	40	12	2-3 min
	Upper body	Explosive push-ups, jumping spider	Low	40	12	2-3 min
2	**Lower body**	Lateral/diagonal and broad jumps	Low	40	12	2-3 min
	Upper body	Clapping push-ups, medicine ball presses, rotational throws	Low	40	12	2-3 min
3	**Lower body**	Vertical and obstacle jumps, box shuffles	Low	46	18	2-3 min
	Upper body	Clapping push ups, medicine ball presses, chest passes	Low	50	21	2-3 min
4	**Lower body**	Lateral/diagonal jumps, obstacle jumps, box shuffles	Medium	46	18	2-3 min
	Upper body	Clapping push-ups, rotational throws, chest passes	Medium	50	21	2-3 min
5	**Lower body**	Broad jumps, box jumps, box shuffles, drop jumps	Low	46	18	2-3 min
	Upper body	Medicine ball presses, rotational throws, overarm throws	Low	50	21	2-3 min
6	**Lower body**	Vertical jumps, obstacle jumps, box shuffles, drop jumps	Medium	48	18	2-3 min
	Upper body	Jumping spider, chest passes, overarm throws	Medium	52	21	2-3 min
7	**Lower body**	Lateral jumps, drop jumps (+ vertical jumps), box jumps	Medium	46	18	2-3 min
	Upper body	Explosive push-ups, clapping push-ups, rotational throws, overarm throws	Medium	52	21	2-3 min
8	**Lower body**	Tuck jumps, box jumps, drop jumps, box shuffles, obstacle jumps	High	46	18	3-4 min
	Upper body	Jumping spider, chest passes, overarm throw	High	52	21	3-4 min
9	**Lower body**	Obstacle jumps, box shuffles, drop jumps, broad jumps, box jumps	Medium	48	18	3-4 min
	Upper body	Jumping spider, rotational throws, overarm throws	Medium	52	21	3-4 min
10	**Lower body**	Drop jumps, drop jumps + vertical jump, lateral/diagonal jumps, obstacle jumps	High	46	18	3-4 min
	Upper body	Jumping spider, medicine ball throw, chest passes, overarm throws	High	56	24	3-4 min
11	**Lower body**	Tuck jumps, drop jumps, broad jumps, box jumps	High	48	20	3-4 min
	Upper body	Rotational throws, Chest passes, overarm throws	High	58	24	3-4 min
12	**Lower body**	Drop jumps, drop jumps + vertical jumps, lateral/diagonal jumps, obstacle jumps	High	48	20	3-4 min
	Upper body	Chest passes, overarm throws	High	58	24	3-4 min

blocking- , and digging-drills, performed as a single-element- (for low-intensity) or combined-element-tasks (for medium- and high-intensity). In small-sided games players participated in 3 vs. 3 (for medium- and high-intensity), and 4 vs. 4 games (for low- and medium-intensity drills). These conditioning games were performed on smaller court (9 x 4.5m). The third type of skill-based conditioning consisted of real-game volleyball drills. Throughout these exercises players were involved in standard 6 vs. 6 game, but majority of free balls were thrown by the coach. After each rotation, players took strict 1-2 min break, depending on necessary level of intensity (i.e. shorter breaks implied higher intensity of the training).

Both trainings were planned in advance. However, team coaches and main investigator (first author of this study) were in permanent contact, and single training sessions were frequently modified according to current needs (i.e. forthcoming game, health-related problems, recovery status). Therefore, the increase of the intensity for both training programs (see Tables 1 and 2 for details) is determined on a basis of the quality of performance evidenced throughout each week. Apart from specific conditioning program, all participants were involved in 7-8 regular volleyball training sessions per week (i.e. technical and tactical training), plus one game.

Variables and testing

The variables in this study included anthropometric indices (body height and body mass), and following conditioning qualities: sprinting performance over 20 meters (S20M), vertical countermovement jump – CMJ, standing broad jump – SBJ, and medicine ball toss (MBT).

All participants were assessed for all variables throughout pre-testing (4-5 days before the start of the training protocol) and post-testing (5-6 days after finalization of training). Pre-testing and post-testing were done over two days. The first day of testing included evaluation of anthropometrics, S20M, and MBT. The next day, the players were tested on CMJ and SBJ in a random order. All players were familiarized with testing procedures throughout several non-maximal attempts (not included in analyses).

The anthropometric variables were measured with stadiometer and scale (Seca, Birmingham, UK). Body height was measured to the nearest 0.5 cm, and body mass to the nearest 0.1 kg.

All conditioning capacities were measured over three trials with 30 seconds of rest between trials for MBT, 1-2 minutes of rest between trials for CMJ and SBJ, and 3-4 minutes of rest between trials for S20M. For all variables, the best achievement was retained as a final result after calculation of intra-session reliability for pre- and post-testing.

The SBJ was performed from a standing position using a standardized measuring mat (ELAN, Begunje, Slovenia). Standardized instructions were given to the participants to begin the jump with bent knees and to

Table 2. Skill-based conditioning program.

Week	Drills	Exercises	Intensity	Percentage of total for skill-based conditioning
1	Volleyball drills	Performed as a single-element	Low	50%
	Small sided games	4 vs. 4 games	Low	25%
	Game drills	6 vs. 6 games	Low	25%
2	Volleyball drills	Performed as a single-element	Low	50%
	Small sided games	4 vs. 4 games	Low	25%
	Game drills	6 vs. 6 games	Low	25%
3	Volleyball drills	Performed as a single-element	Medium	40%
	Small sided games	4 vs. 4 games	Medium	30%
	Game drills	6 vs. 6 games	Low	30%
4	Volleyball drills	Performed as a combined-element	Medium	40%
	Small sided games	4 vs. 4 games	Medium	30%
	Game drills	6 vs. 6 games	Low	30%
5	Volleyball drills	Performed as a combined-element	Medium	40%
	Small sided games	4 vs. 4 games; 3 vs. 3 games	Medium	30%
	Game drills	6 vs. 6 games	Medium	30%
6	Volleyball drills	Performed as a combined-element	Medium	30%
	Small sided games	3 vs. 3 games	Medium	40%
	Game drills	6 vs. 6 games	Medium	30%
7	Volleyball drills	Performed as a combined-element	Medium	30%
	Small sided games	3 vs. 3 games	High	40%
	Game drills	6 vs. 6 games	Medium	30%
8	Volleyball drills	Performed as a combined-element	Medium	30%
	Small sided games	3 vs. 3 games	Medium	40%
	Game drills	6 vs. 6 games	Medium	30%
9	Volleyball drills	Performed as a combined-element	Medium	25%
	Small sided games	3 vs. 3 games	High	50%
	Game drills	6 vs. 6 games	Medium	25%
10	Volleyball drills	Performed as a combined-element	Medium	20%
	Small sided games	3 vs. 3 games	High	40%
	Game drills	6 vs. 6 games	High	40%
11	Volleyball drills	Performed as a combined-element	Low	20%
	Small sided games	3 vs. 3 games	High	40%
	Game drills	6 vs. 6 games	High	40%
12	Volleyball drills	Performed as a combined-element	Medium	20%
	Small sided games	3 vs. 3 games	High	40%
	Game drills	6 vs. 6 games	High	40%

swing their arms to assist in the jump. The intra-class-coefficient (ICC) calculated for the three testing trials indicated high reliability of the test in the pre-test (ICC: 0.91) and post-test (ICC: 0.92)

For the 20-meter-sprint, two electronic timing gates (Speedtrap II, Brower Timing Systems, Draper, UT, USA) were positioned 1 m and 21 m from a pre-determined starting line. The participants were instructed to begin with their preferred foot forward placed on a line marked on the floor and to run as quickly as possible along the test distance. Times were recorded in hundredths of seconds. The reliability was appropriate (ICC: 0.73 and 0.75 for pre- and post-testing).

The CMJ test was measured by Optojump equipment (Microgate, Bolzano, Italy). Test began with the athlete standing in an upright position. A fast downward movement to an approximately 90° knee flexion was immediately followed by a quick upward vertical movement as high as possible, all in one sequence. The test was performed with an arm swing to mimic a real-game volleyball performance. The ICC showed good reliability of testing (ICC: 0.87 and 0.93 for pre- and post-test, respectively).

The MBT was used to assess throwing capacity, and standardized 2-kg medicine ball (ELAN, Begunje, Slovenia) was used for the measurement. The players stood still with the ball held at chest level with the arms extended horizontally so that the ball was located above the starting line. The players were asked to move the ball towards their chest and then to throw the medicine ball in a horizontal direction as far as possible using a 2-handed chest pass. During the throw, they were not allowed to step forward. The reliability of the testing was high (ICC: 0.90 and 0.85 for pre- and post-test, respectively).

Statistical analyses

The normality of the distribution was confirmed by Kolmogorov-Smirnov test for all variables. Therefore, descriptive statistics included calculations of means and standard deviations. The homoscedasticity of all variables was proven by Levene's test.

A two-way analysis of variance (ANOVA) with repeated measures (group [plyometric- and skill-based-conditioning] × time [Pre- and Post-training]), with Scheffe post-hoc analysis was used to determine the effects of training on the studied variables. The differences between pre- and post-testing for each group were evaluated by magnitude-based Cohen's effect size (ES) statistics with modified qualitative descriptors. The effect size was assessed using the following criteria: <0.02 =

Table 3. Descriptive statistics (Mean ± Standard Deviation) for pre- and post-training results in each group; results of two-way analysis of the variance for main effects (Group and Time) and Interaction (Group x Time), and pre- to post-training differences in percentages (%).

	Plyometric-group (n = 21)			Skill-based-group (n = 20)			Analysis of variance (F test)		
	Pre-	Post-	%	Pre-	Post-	%	Group	Time	Interaction
BH (cm)	177.9 ± 5.5	177.2 ± 5.1	<0.1	175.4±7.0	176.0±7.1	<0.1	2.9	0.1	0.1
BM (kg)	61.9 ± 5.2	61.2 ± 5.4 *	1.1	58.5±7.5	58.5±7.9	<0.1	2.2	4.0	4.3 #
S20m (s)	3.80 ± 0.32	3.53 ± 0.22 *	7.6	4.15±0.27	4.10±0.30	1.2	34.7 #	15.5 #	7.3 #
SBJ (cm)	190.7 ± 22.9	205.3 ± 17.3 *	7.6	167.3±18.5	172.4±18.7 *	3.1	21.8 #	96.8 #	22.4 #
CMJ (cm)	38.0 ± 6.5	48.5 ± 5.2 *	27.6	28.9±7.2	34.1±7.1*	18.0	34.3 #	275.1 #	31.5 #
MBT (m)	6.1 ± 0.6	7.6 ± 0.7 *	24.5	5.3±0.8	5.8±0.8 *	9.4	34.5 #	166.1 #	40.2 #

BH – body height, BM – body mass, S20m – sprint over 20 meters distance, SBJ – standing broad jump, CMJ – countermovement jump, MBT – medicine ball throw, # denotes F-test significance of $p < 0.05$, * denotes pre- to post-measurement post-hoc significance of $p < 0.05$.

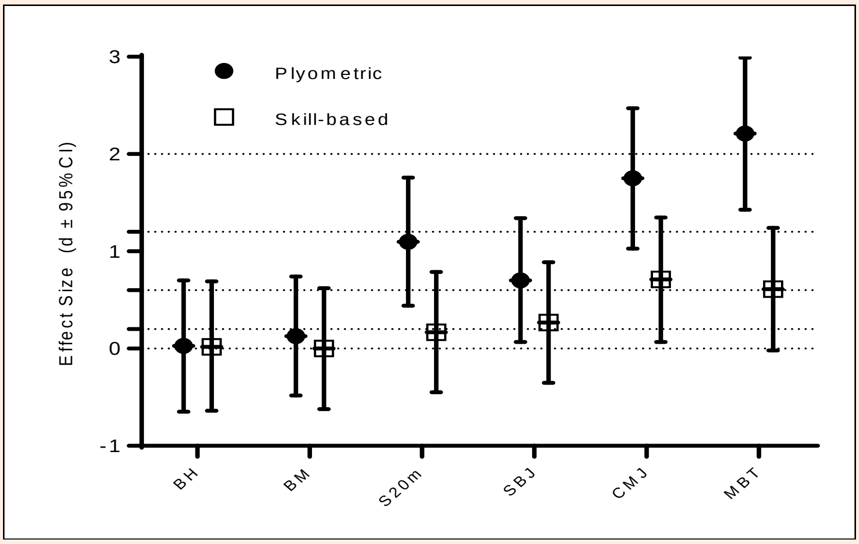

Figure 1. Effect Size (ES) differences between pre- and post-testing results for plyometric- and skill-based-conditioning group with 95% confidence interval (95%CI). BH – body height, BM – body mass, S20m – sprint over 20 meters distance, SBJ – standing broad jump, CMJ – countermovement jump, MBT – medicine ball throw, dashed lines present ES ranges (<0.02 = trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large; and >2.0 very large differences).

trivial; 0.2–0.6 = small; >0.6–1.2 = moderate; >1.2–2.0 = large; and >2.0 very large differences. Also, pre- to post-testing differences were presented as average percentage of changes.

To identify possible associations between changes that occurred as a result of both applied conditioning programs, we calculated the differences between pre- and post-testing for each variable. The associations between variables of differences for all outcome measures were assessed by Pearson's product moment correlation coefficients.

A significance level of $p < 0.05$ was applied, and Statistica 13.0 (Dell Inc., Tulsa, OK) was used for all statistical analyses.

Results

The results of factorial ANOVA (Group x Time) are presented in Table 3. Significant main effects for "Group" were evident for S20M (F = 34.74, p = 0.01), SBJ (F = 21.83, p = 0.01), CMJ (F = 34.3, p = 0.01), and MBT (F = 34.5, 0 = 0.01). Significant effects for "Time" were evidenced for body mass (F = 4.3, p = 0.04), S20M (F = 15.5, p = 0.01), SBJ (F = 96.8, p = 0.01), CMJ (F = 275.1, p = 0.01), and MBT (F = 166.1, p = 0.01). Significant "Group x Time" interactions were found for S20M (F = 7.34, p = 0.02), SBJ (F = 22.4, p = 0.01), CMJ (F = 31.5, p = 0.01), and MBT (F = 40.2, p = 0.01) (Table 3).

Over the course of the study, the plyometric group significantly ($p < 0.05$) reduced body-mass (trivial ES differences; 1% pre- to post-measurement changes), improved their performance in Sprint-20m (moderate ES differences; 7.6% changes), MBT (very large ES differences; 24.5% changes), CMJ (large ES differences; 27.6% changes), and SBJ (moderate ES differences; 7.6% changes). Players involved in skill-based-conditioning improved their capacities in CMJ (large ES differences; 18% changes), SBJ (small ES differences; 3.1% changes), and MBT (large ES differences; 9.4% changes) (Table 3 and Figure 1)

Table 4 presents the correlations between variables of difference (i.e. differences between pre- and post-testing) in each group. In the plyometric group, pre- and post-differences in S20M values correlated significantly with the changes evidenced for CMJ (r = 0.62, $p < 0.05$) and SBJ (r = 0.53, $p < 0.05$).

Table 4. Product moment correlation coefficients for variables of differences (changes) calculated on a basis of pre- and post-testing for plyometric-conditioning and skill-based-conditioning.

		BH_{diff}	BM_{diff}	$S20m_{diff}$	SBJ_{diff}	CMJ_{diff}	MBT_{diff}
BM_{diff}	Plyometric-	0.12	-				
	Skill-based-	0.20	-				
$S20m_{diff}$	Plyometric-	0.02	-0.26	-			
	Skill-based-	0.09	0.18	-			
SBJ_{diff}	Plyometric-	0.11	-0.32	0.62*	-		
	Skill-based-	-0.01	-0.33	-0.07	-		
CMJ_{diff}	Plyometric-	0.05	0.01	0.53*	0.38	-	
	Skill-based-	0.13	-0.36	0.18	0.42	-	
MBT_{diff}	Plyometric-	0.21	-0.03	-0.24	0.00	0.05	-
	Skill-based-	0.24	-0.21	0.36	0.29	0.43	-

BH_{diff} – variable of difference in body height between pre- and post-testing, BM_{diff} – variable of difference in body mass between pre- and post-testing, $S20m_{diff}$ – variable of difference in sprint over 20 meters distance between pre- and post-testing, SBJ_{diff} – variable of difference in standing broad jump between pre- and post-testing, CMJ_{diff} – variable of difference in countermovement jump between pre- and post-testing, MBT_{diff} – variable of difference in medicine ball throw between pre- and post-testing, * denotes coefficients significant at $p < 0.05$

Discussion

There are several important findings of this study. First, the plyometric-conditioning resulted in significant decrease in body mass (0.3% changes between pre- and post-measurement), and improvement in sprinting capacity (8% changes). Both training programs resulted in improvements in jumping and throwing capacities, but the changes induced by plyometric training were larger than those achieved by skill-based conditioning (8-22% and 3-15% changes, respectively). Therefore, initial hypothesis of the study is confirmed. Finally, the changes in fitness parameters that occurred as a result of plyometric conditioning were more inter-correlated than those induced by skill-based conditioning.

Our results showed significant decreases in body mass for plyometric-group. In one of the rare studies that reported the effects of plyometric exercise training on anthropometric indices in female volleyball players of advanced level, authors noted no significant influence on participants' body mass (Lehnert et al., 2017). However, our respected colleagues investigated junior players (<18 years of age) who were still experiencing maturational changes, irrespective of training (Malina et al., 2004). Therefore, it is likely that growth and developmental changes could override the training stimuli and consequently diminish the possible influence of plyometric exercises on changes in anthropometric indices (Lehnert et al., 2017).

Skill-based conditioning did not result in significant changes in body mass. Probably, the overall training workload (i.e., energetic demands) of the skill-based conditioning program was insufficient to result in changes in this measure. Most likely, this was due to the high level of the players involved and their familiarity with exercise programs, which consisted mostly of volleyball-specific skills. This could potentially cause low metabolic costs related to skill-based conditioning and low energy expenditure, which altogether resulted in retention of body mass at pre-training values in skill-based group (Beneke et al., 2001). However, since this investigation did not include any measurement of caloric expenditure and/or energetic demands of the training, for a more profound interpretation of this issue additional studies are needed.

Plyometric training induced significant improvement in sprinting capacity (improvement of 7.6 %), whereas skill-based conditioning did not contribute to changes in this conditioning ability. Although we were not able to find any study that directly compared effects of skill-based and plyometric training in volleyball players, our results are comparable to the results of studies from other sports. For example, 20-m sprint improved significantly in collegiate rugby players following a plyometric-based (3.34±0.25 and 3.25±0.16 s) versus standard rugby conditioning-program (3.22±0.24 and 3.26±0.19 s, for pre- and post-test results, respectively). Additionally, the 8-week plyometric training course resulted in significant improvement of sprint performances over 5, 10 and 20 meters in young tennis players, whereas no improvement in sprinting capacities was found for those participants who were involved in tennis-specific conditioning (Fernandez-Fernandez et al., 2016a; 2016b).

We must note that not all studies confirmed the differential effects of plyometric and sport-specific conditioning on sprinting performance. For example, combined plyometric-plus-soccer conditioning did not result in improved 40 m sprint performances relative to soccer conditioning alone (Ronnestad et al., 2008). Such inconsistency in findings could be possibly attributed to differences in sprinting tests (40 m in a soccer study vs. up to 20 m in tennis, rugby and our investigation) (Fernandez-Fernandez et al., 2016a; 2016b; Pienaar and Coetzee, 2013; Ronnestad et al., 2008). Finally, and contrary to our results, Australian study reported a positive influence for skill-based conditioning on 5- and 10-meter sprints in junior male volleyball players (Gabbett et al., 2006). However, a differences in gander and subject age (15.5 and 22 years in Australian and our study, respectively) partially explains the different findings.

Jumping and throwing capacities improved significantly in both training-groups. Considering the results of previous studies that repeatedly confirmed positive changes in jumping capacities in athletes from different sports, the positive effects of plyometric training are expected (Bogdanis et al., 2017; Impellizzeri et al., 2008; Kim and Park, 2016; Kristicevic and Krakan, 2016; Trajkovic et al., 2016). What is also important, when previous studies reported effects of plyometric training in females, authors noted ES differences in CMJ between 1.00 (for untrained physically active females), up to 3.36 (for female soccer players) (Makaruk et al., 2011; Ozbar, 2015). Therefore, magnitude of changes in CMJ for plyometric group in our study (ES: 1.75) is within expected values.

It seems that even skill-based conditioning provided a solid base for the development of jumping and throwing capacities in female volleyball players. Indeed, the main advantage of skill-based conditioning is the hypothetical applicability of characteristic volleyball elements and movements (i.e., blocking, spiking, sprinting, and changes-in-direction) in conditioning of volleyball players. However, the effects of skill-based conditioning are rarely investigated in experimental settings. Specifically, in a previously discussed 8-week study done on junior volleyball players, the authors reported no significant changes in vertical jump (45.7 ± 2.3 and 45.7 ± 2.4 cm), spike jump (50.0 ± 2.5 and 51.2 ± 2.9 cm), and overhead medicine ball throw (6.7 ± 0.3 and 6.8 ± 0.3 m, for pre- and post-test respectively) (Gabbett et al., 2006). However, our skill-based conditioning program lasted considerably longer (12-weeks vs. 8-weeks), which probably explains the positive effects observed in jumping and throwing capacities of female volleyball players included in our study.

Irrespective of the positive effects of skill-based training on jumping and throwing variables, the plyometric-training is evidently more effective conditioning method than skill-based conditioning. Several physiological factors explain these findings. First, plyometric exercises result in: (i) stimulation and activation not of an increased number of motor unit, and (ii) in higher neural firing frequency, which both lead to higher generation of force (McLaughlin, 2001; Pienaar and Coetzee, 2013). While all conditioning capacities studied herein are directly dependent on rate of force generation, the improvements in sprinting, jumping and throwing capacities are logical consequence of such adaptation. Next, previous studies showed increased the maximal Achilles tendon elongation, which resulted in an increased amount of stored elastic energy as a result of plyometric training (Kubo et al., 2007). This adaptation could also have directly contributed to better jumping performance, as evidenced in our study. Moreover, it has been suggested that plyometric training increases the sensitivity of the muscle spindle system and improves joint proprioception (Swanik et al., 2002; 2016). Although this adaptation may not seem directly related to jumping and throwing capacities in our study (i.e. we have evidenced single- and not repeated-performances), it could positively contribute to sprinting performance, which was also evidenced as a differential effect between the plyometric- and skill-based conditioning programs in our study.

One can argue that most of previously specified adaptations to plyometric training could occur as a result of skill-based conditioning or simply by the fact that volleyball movement templates that are consisting part of skill based conditioning involve similar muscular actions. However, it is beyond a doubt that plyometric exercise has higher intensity and therefore challenges mentioned capacities to a greater extent than skill-based training. Additionally, the overall training-volume and training-intensity are more controllable in plyometric- (i.e., number of sets, periods of rest, depth of the jump, etc.), than in skill-based settings. While adjustment of training loads is important parameter of training efficacy, it probably resulted in superior training-induced changes for plyometric-group (Makaruk et al., 2011; Ozbar, 2015; Stojanovic et al., 2017)

Although not being the primary aim of this study, the correlations between the changes that occurred as a result of plyometric- and skill-based-training are important findings of this research. The correlations between variables of pre-to-post differences in jumping were significant only in plyometric-group (i.e. significant correlation between changes which occurred in sprinting-, and changes which occurred in jumping-capacities). This leads us to conclude that the plyometric training-induced changes in sprint and jumping performance were caused by a general underlying mechanism. Therefore, and considering the proposed adaptations for plyometric training, (i) increased maximal Achilles tendon elongation (and increased amount of stored elastic energy) together with (ii) better joint proprioception because of the increased sensitivity of the muscle spindle are probably the most important mechanisms for the improvement of jumping and sprinting capacities of players involved in plyometric training (Kubo et al., 2007; Swanik et al., 2002; Swanik et al., 2016). Meanwhile, based on low correlations between MBT_{diff} with other variables of differences, improvement in MBT is probably related to some other adaptation, such as an increased number of activated motor units, higher neural firing frequency, or simply by cognitive – motor learning effects (McLaughlin, 2001; Pienaar and Coetzee, 2013).

Limitations and strengths of the study

In this study we observed female senior athletes, and therefore generalization of results is limited to similar samples of athletes. Next, we did not collect data on physiological and psychological responses to each of the applied training programs, which would almost certainly allowed insight into overall training volume and the personal motivations to train of the players included in the study. Finally, this study lacked information on the eventual influence of studied training modalities on players' technical skills (i.e., accuracy, technique assessment), which are probably the most important determinants of success in volleyball. Previous studies which investigated effects of plyometric- and skill-based conditioning in volleyball observed systematically smaller number of participants (Stojanovic et al., 2017). Therefore, relatively large sample, together with high-competitive level of studied players are probably most important strengths of this study.

Conclusions

Although results obtained should be partially attributed to the fact that training programs were applied at the beginning of the season, and therefore pre- to post- differences for both groups are relatively large in magnitude, following conclusions can be made.

The observed 12-week plyometric training performed twice a week induced stronger positive changes in the studied conditioning capacities than did the corresponding skill-based conditioning program. The higher intensity together with possibility of more accurate adjustment of training load in plyometric training are probably the most important determinant of such differential influence. Therefore, we may suggest application of the similar plyometric-training program in order to improve sprinting-, jumping- and throwing-performances in advanced level senior (+18 years of age) female volleyball players.

It is likely that the skill-based conditioning program did not result in changes of higher magnitude because of the players' familiarity with volleyball-related skills. Namely, in this study we included experienced senior players (+18 years of age), which could have resulted in a low impact of this skill-based conditioning and consequently did not result in adequate training stress. Therefore, in future studies, the influence of plyometric- and skill-based conditioning should be evaluated in younger and less experienced volleyball players.

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Key points

- Plyometric- and skill-based-conditioning resulted in improvements in jumping and throwing capacities, but plyometric training additionally induced positive changes in anthropometrics and sprint-capacity
- The changes induced by plyometric training were larger in magnitude than those achieved by skill-based conditioning.
- The higher intensity together with possibility of more accurate adjustment of training load in plyometric training are probably the most important determinant of such differential influence.
- It is likely that the skill-based conditioning program did not result in changes of higher magnitude because of the players' familiarity with volleyball-related skills.

AUTHOR BIOGRAPHY

Bahri GJINOVCI
Employment
University of Prishtina, Faculty of Physical Education and Sports, Prishtina, Kosovo
Degree
Doctoral student
Research interests
Athletics, Strentgth and Conditioning, Volleyball
E-mail: bahri.gjinovci@uni-pr.edu

Kemal IDRIZOVIC
Employment
Professor. University of Montenegro, Faculty for Sport and Physical Education, Podgorica, Montenegro
Degree
PhD
Research interests
Athletics, Strength and Conditioning
E-mail: kemo@t-com.me

Ognjen ULJEVIC
Employment
Assistant Professor. Faculty of Kinesiology, University of Split, Croatia.
Degree
PhD
Research interests
Strength and conditioning, water polo, sailing, nutrition and doping in sport
E-mail: ognjen.uljevic@kifst.hr

Damir SEKULIC
Employment
Professor. Faculty of Kinesiology, University of Split, Croatia.
Degree
PhD
Research interests
Test construction and validation, Strength and Conditioning Substance use and misuse in sport and exercise
E-mail: damir.sekulic@kifst.hr

✉ **Professor Damir Sekulic**
University of Split Faculty of Kinesiology, Teslina 6, 21000, Split, Croatia