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THE ACUTE EFFECT OF YO-YO INTERMITTENT ENDURANCE TEST LEVEL 1, ON VERTICAL JUMP HEIGHT OF VOLLEYBALL PLAYERS

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ABSTRACT. The purpose of this study was to compare volleyball block jump (VBJ) and volleyball attack jump (VAJ) height capacity after performing a conventional warm-up (CWU) and immediately after performing a Yo-Yo Intermittent Endurance Test-Level 1 (YYIE1). After two weeks of the preparation season, each one of thirty-experienced female and male volleyball players, ranged from regional to national level, performed eight VAJ and eight VBJ two minutes after CWU (pre-test), immediately continued with YYIE1, until reaching 80% of VO_2max, then after two minutes rest, they performed again eight VAJ and eight VBJ (post-test). Results show a significant positive difference in both VBJ and VAJ between post- and pre-test. Statistical significance is present when comparing average and highest measures. In addition, the first jumps at post-test, which were performed immediately after YYIE1, were significantly higher than the first jumps at pre-test, which were performed immediately after CWU. We conclude that vertical jump (VJ) of volleyball players at a regional and national level, is higher when carried-out immediately after performing YYIE1 until reaching 80% of VO_2max, than after CWU. Therefore, it should be considered as a warm-up for volleyball block and attack jump drills.

Key words: *vertical jump, volleyball block jump, volleyball attack jump, yo-yo intermittent endurance test-level 1, conventional warm-up.*

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Introduction

Volleyball is considered one of the most explosive and fast-paced sports (Stanganelli, Dourado, Oncken, Mançan & da Costa, 2008). For example, according to data examined among elite male players, found to have performed between 250 to 300 actions requiring explosive force production during a five-game match. The vertical jump (VJ) constitutes most of these actions (Hasegawa, Dziados, Newton, Fry, Kraemer & Häkkinen, 2002). Of these activities, the attack and block situations represent 45% of the total actions of the game and are also responsible for 80% of the points obtained within international matches (Voigt & Vetter, 2003). Setting for spike in high level volleyball, is also performed by VJ to shorten the flight time of the ball in the transition from passing to attack or from defense to offence (Borràs, Balius, Drobnic & Galilea, 2011). All of this implies that the ability to exhaust the highest VJ among volleyball players is of the utmost importance

The conventional warm-up (CWU) and preparation for optimal utilization of VJ capacity, including volleyball attack jumps (VAJ) and volleyball block jump (VBJ) mostly consists of few minutes of jogging, few minutes of stretching and few minutes of various types of running, skipping, hopping and vertical jumps on a 10-15 meter track (Mirzaei, Asghar, Norasteh, Saez de Villarreal & Asadi, 2014; Herrero, Izquierdo, Maffiuletti & Garcia-Lopez, 2006; Pearce, Kidgell, Zois & Carlson, 2009; Sheppard, Cronin, Gabbett, McGuigan, Etxebarria & Newton, 2008). However, some volleyball players have reported that after an exhaustive or near-exhaustive run of approximately 15 minutes, with almost no recovery gap, they can jump higher than after CWU.

In addition, researches have shown that immediately after an exhausting or near-exhausting 20-40 minute of intermittent, intervals or endurance run, athletes, most of them endurance runners, experienced an immediate and acute VJ enhancement, by comparison to results that achieved after CWU (Vuorimaa, Virlander, Kurkilahti, Vasankari & Häkkinen, 2006; Boullosa & Tuimil, 2009; Boullosa, Tuimil, Alegre, Iglesias & Lusquiños, 2011; Juarez, Lopez de Subijana, Mallo & Navarro, 2011; Cortis, Tessitore, Lupo, Pesce, Fossile, Figura & Capranica, 2011; García-Pinillos, Soto-Hermoso & Latorre-Román 2015; García-Pinillos, Soto-Hermoso & Latorre-Román, 2016). On the other hand, when measurements of VJs height performed immediately after longer than 40 minutes endurance run, there was reduction in VJ height by comparison to VJ pre-tests (Nicol, Komi & Marconnet, 1991; Elissavet, Ioannis, Gregory & Konstantinos, 2016). VJ post-test reduction was found also after 20-min exhausting cycling (McIntyre, Mawston & Cairns, 2012).

Among the researches that demonstrate an endurance run induces VJ enhancement, the larger difference between pre-test (30.9cm) to post-test (35.1cm) was achieved after 40 minutes of tempo run on treadmill, while running speed was adjusted to 80% VO_2max of the subject's capacity. The 40 minutes running protocol was performed by two minutes running and two minutes of walking rest, at total running time of 20 minutes (Vuorimaa et al., 2006). In addition, Juarez et al (2011) also found CMJ difference: between pre-test (41cm) to post-test (43cm) that was performed immediately after 20 minutes run at 80% of VO_2max capacity among young soccer players. As far as we know, this phenomenon has not been tested with volleyball players, when VJ is a major component of their physical capacity. Therefore, the purpose of this study is to validate the assumption that an endurance run at increasing speed until 80% of subjects' VO_2max, not exceeding 15 minutes for females and 20 minutes for males, leads to a higher immediate acute enhancement of VJ capacity by comparison to VJ capacity after CWU, among volleyball players.

Methods

In many of field tests that examine maximal voluntary contraction (MVC) of legs muscles, we measure and compare VJ as a simple and effective method. Most of the studies test MVC by three traditional types of VJ: Squat-Jump (SJ), usually performed from a knee bending angle of °90, without the eccentric phase of the jump; Counter movement jump (CMJ), which is an ordinary standing VJ, usually performed by hands kept on the waist; Drop jump (DJ), like CMJ but performed by jumping downward, mostly from a height of 40 cm, preceding to immediate VJ (Bosco, Viitasalo, Komi & Luhtanen, 1982; Bosco, Atteri, Fekete, Apor & Rusko, 1986). However, in researches that conducted on volleyball players, the specific volleyball VJ (i.e. VAJ, VBJ) were tested in addition or separately from the traditional VJ tests: CMJ, SJ, DJ (Newton, Kraemer & Haekkinen, 1999; Newton, Rogers, Volek, Häkkinen & Kraemer, 2006; Ziv & Lidor, 2010).

Stanganelli et al (2008), took it even farther and suggested that using VAJ and VBJ tests seem to be more sensitive to the training-induced adaptations and better reflect the specificity of volleyball game then the traditional VJ tests. In fact, VBJ is performed similarly to CMJ without arm swing and VAJ is a combination of DJ and CMJ. These VJ can be a valid measurement instrument, instead of the traditional VJ among volleyball players (Sattler, Sekulic, Hadzic, Uljevic & Dervisevic, 2012). Therefore, in this study VAJ and VBJ was chosen as the dependent variable.

Part of the researches of the phenomenon of endurance run induces VJ enhancement, performed Montréal University test (Berthoin, Baquet, Rabita & Blondel, 1999; Leger & Boucher 1980; Boullosa & Tuimil, 2009; Boullosa et al., 2011), which examine aerobic and anaerobic capacity in endurance run at an increasing speed. The Montréal University test used as the exhausting running before VJs post-test (independent variable). However, in this study it was necessary to find a measurable increasing speed endurance run test, which will fit into a volleyball gymnasium, in aim to reduce the transition time between the end of the run to the measurement of the first VJ. The Yo-Yo tests were found as a useful tool for evaluating aerobic capacity in intermittent sports like volleyball (Bangsbo, Iaia & Krustrup, 2008). In addition to the evaluation of aerobic capacity, for our purpose, the Yo-Yo Intermittent Endurance Test-Level 1 (YYIE1) was also found suitable as an indoor measurable exhausting endurance run before the VJ measurement. The YYIE1 has proven to be affected by submaximal cardiorespiratory fitness-related variables (Castagna, Impellizzeri, Belardinelli & Abt, 2006; Bradley, Bendiksen, Dellal, Mohr, Wilkie, Datson & Krustrup, 2014) and is also correlated with the Montréal University test (Dupont, Defontaine, Bosquet, Blondel, Moalla & Berthoin, 2010).

Subjects

Thirty experienced female and male volleyball players (12 female and 18 male), ranged from regional to national level, volunteered to participate in this study. The subjects' age ranged from 17 to 32 (mean 24.5 years of age). Their heights ranged from 165 to 178 cm (mean 171.5 cm) for women, and from 172 to 191 cm (mean 181.5) for men. Their body weights ranged from 45 to 75 kg (mean 60 kg) for women, and from 65 to 95 kg (mean 80 kg) for men. All of them underwent a medical examination required by the Sports Law in the State of Israel. All the subjects have been playing volleyball for at least six years and they are very well trained and skilled in VAJ and VBJ technique.

Table 1. Mean (range) of anthropometric values

Age (year) n=30	Women's age n=12	20.5 (16-25)
	Men's age n=18	24 (16-32)
Height (cm) n=30	Women's height (cm) n=12	171.5 (165-178)
	Men's height (cm) n=18	181 (172-191)
Mass (kg) n=30	Women's mass (kg) n=12	59.5 (46-73)
	Men's mass (kg) n=18	81(66-97)

Study design

The study included four parts as follows: 1) Nine minutes of CWU, similar to Pearce et al (2009), Start by three minutes running and then running drills on a 20 meters track, as shown in table 2; 2) Two minutes after CWU, performing VJ pre-test of eight VAJs and eight VBJs, half of the subjects in reverse order (Stanganelli et al., 2008), 15 seconds interval between jumps (Pereira, Almeida, Rodacki, Ugrinowitsch, Fowler & Kokubun, 2008); 3). Three minutes after the last jump, performing YYIE1, until reaching 80% of VO_2max, and 4). Two minutes after the end of YYIE1-80, performing VJ post-test of eight VAJ and eight VBJ (the subjects had to perform VAJ and VBJ in the same order as in pretest).

Procedures

The VJ test was conducted two weeks after the beginning of the preparation term for the game season. The subjects performed the test at the beginning of a practice unit and the data collected from all the subjects along a whole week. The test was performed at the evening and after a day of rest from exercise. Subjects were asked to sleep seven or eight hours at the night before the test and not eating during the three hours proceeding to the test. Other than that, other daily habits were not controlled. The test was performed on a parquet volleyball court.

Monitoring 80% of VO2max in YYIE1

80% of VO_2max was found in proximity to anaerobic threshold (Dwyer & Bybee, 1983). One of the simple and valid way to monitor anaerobic threshold in endurance running intensity is the talk test. The talk test performed when the examiner asks the subject to report verbally about her or his ability to talk comfortably couple of times when the intensity of the effort is increasing. When flow of the talk is interrupted by increasing of breathing, or when the subject reports speech discomfort, the level of effort is exciding anaerobic threshold and approximately 85% of VO_2max (Reed & Pipe, 2014; Reed & Pipe, 2016). The talk test is considered a useful tool to monitor ventilatory anaerobic threshold under field conditions (Rodríguez-Marroyo, Villa, García-López & Foster, 2013; Quinn & Coons, 2011). Therefore, in this study, the talk test was chosen to monitor the 80% of VO_2max as the intensity of YYIE1 is increasing.

Vertical Jump (VJ) measurement

The VJ height was measured using VERT Wearable Jump Monitor. The Vert (Mayfonk Athletic, Florida, USA) is a small inertial sensor measuring 6 × 3 × 0.5 cm. Inserted Into an elastic waistband, the sensor time stamps and calculates the vertical displacement of each jump. Data is subsequently streamed to a tablet via Bluetooth. (Charlton, Kenneally-Dabrowski & Spratford, 2017). VERT Wearable Jump Monitor was found to by a valid measurement instrument. (Charlton et al., 2017; Borges, Moreira, Bacchi, Finotti, Ramos, Lopes & Aoki, 2017; MacDonald, Bahr, Baltich, Whittaker & Meeuwisse, 2017). The VERT Wearable Jump Monitor can be connected to eight sensors and measures and counts the jump heights and number of jumps of each of eight volleyball players at the same time, ether during volleyball practice or during matches. All the data is recorded and saved by the VERT system.

Table 2. Exercise order of CWU

1. Three minutes light jogging	
2. running exercise on a 20 meters track:	Times of performances
• Skips with forward arm circles, easy jog return	2
• Skips with backward arm circles, easy jog return	2
• Run with high knees, easy skipping return	1
• Butt kicks run (hill to butt), easy skipping return	1
• Backwards run, easy skipping return	2
• Carioca drill, back and forth	2
• Power skips, walking return	1
• Bounding, walking return	1
• Sprint, walking return	2

Statistical analysis

To test our hypothesis, we conducted three types of statistical tests. First assuming that our sample is normally distributed, we conducted a paired t-test to test the difference between VBJ and VAJ pre-test to post-test. Next, assuming no inference can be made on the distribution of samples, we conducted the Wilcoxon signed rank test. Finally, when testing statistically the effect of the various tests on jumping improvement, traditional statistical tests that measure the effect on the average or median are improper, because the tests usually improve those parameters by a relatively small scale that a simple *t* test or Mann-Whitney U test cannot detect.

For example: In the case of jumping, improvement of volleyball player jumping at spike (attack) from 65 cm to 68 cm, would probably not be considered statistically significant, even if all subjects show such improvements. A simple *t* test would simply not recognize a significant difference between an average of 75 cm. and 80 cm. with a relatively small sample of subjects. In addition, the statistical test measures mathematical distances, and cannot realize that a 3 cm. difference may be considered significant in volleyball. For this reason, we apply the sign test that measures the number of improvements within the sampled group.

Under the null hypothesis, the intervention plan has no effect on the results. Therefore, we would expect the VBJ and VAJ pre-test results to be somewhat similar to those with higher post-test results (which reflects no significant differences overall). If, on the other hand, we find that the post-test results are significantly higher, we should – at least at some point – conclude that performing YYIE1 until reaching 80% of VO_2max has a significant positive effect on higher VBJ and VAJ capacity.

Results

The average result of the YYIE1 80% of VO2max was 1,400 m, with standard deviation of 635.56, stage 8.0.2 (females: 980m, with standard deviation of 362.75, stage 7.0.3; males: 1,680 m, with standard deviation of 623.6, stage 8.5.6). The YYIE1 test increased VJ in both VBJ and VAJ. Table 3 shows the values of pre-test and post-test VBJ and VAJ. The table also shows the difference between pre- and post-test values and the significance levels of three different statistical tests: the parametric t-test, and the non-parametric Wilcoxon signed rank and the sign tests. For the statistical tests, we measured VBJ and VAJ separately in two different ways. In the first, we measured the average of all jumps of each subject (A-VBJ and A-VAJ). In the second, we used the highest jump from each treatment (H-VBJ and H-VAJ). Table 3 provides the values of each measure. The table shows significant differences of both A- and H- measures across the entire subjects.

According to Table 3, the average of the first jumps performed immediately after the YYIE1 are significantly higher than the average of the first jumps after CWU, for both VBJ and VAJ. Table 4, shows the difference and the significant advantage of the average of the first VBJ (among17 subjects) and VAJ (among13 subjects), immediately after YYIE1 (post-test), compared to the first jumps before YYIE1 and after CWU.

Table 3. Average values and standard deviations of A- and H- VJs for pre-test and post-test separately immediately after YYIE1, and percentage change between them (Δ%).

Variables	Pre-test	Post-test	Δ %	p-value t-test	p-value Wilcoxon signed rank test	p-value sign test
VBJ (cm) Average	Ave. 46.67 SD. 9.18	Ave. 47.27 SD. 9.38	1.21	0.010	0.030	0.045
VAJ (cm) Average	Ave. 59.63 SD. 11.58	Ave. 60.49 SD. 11.27	2.16	0.001	0.004	0.100
VBJ (cm) Highest	Ave. 50.29 SD. 10.08	Ave. 50.55 SD. 10.2	0.71	0.278	0.320	0.137
VAJ (cm) Highest	Ave. 63.23 SD. 12.13	Ave. 64.33 SD. 11.88	1.83	0.046	0.082	0.201

Table 4. Average values and standard deviations of the subjects' first VJ height of pre-test compared to post-test immediately after YYIE1. Percentage of changes (Δ%) are also reported.

Variables	Pre-test	Post-test	Δ %	p-value t-test	p-value Wilcoxon signed rank test	p-value sign test
First VBJ (cm)	Ave. 46.32 SD. 9.4	Ave. 48.35 SD. 11.77	3.67			
First VAJ (cm)	Ave. 58.5 SD. 11.95	Ave. 60.13 SD. 10.64	3.38			
VBJ & VAJ (cm)	Ave. 51.61 SD. 12.06	Ave. 53.46 SD. 12.59	3.55	0.005	0.021	0.045

Discussion

In line with VJ height enhancement, achieved by Vuorimaa et al. (2006); Boullosa & Tuimil (2009); Boullosa et al., (2011); Juarez et al., (2011); Cortis et al., (2011); Garcia et al., (2015); Garcia et al, (2016), and as shown in table 3, our study found also a significant enhancement in VJ immediately after endurance run at increasing speed until reaching 80% of VO_2max, using YYIE1. As far as we know, this study examined, for the first time, population of volleyball players and tested them in VBJ and VAJ, that represent the natural VJ of this sport (Stanganelli et al., 2008; Sattler et al., 2012).

Although there is no clear explanation for the phenomenon of exhausting or near exhausting-run induces vertical jump enhancement, the researchers attempted to explain it. According to Vuorimaa et al (2006), the explanation for the phenomenon is that after an intensive run, a different coordination strategy counteracts strength loss and even improves power in extension movements, performed vertically with both legs, like VJ. They also suggested that the increase in VJ height could be the result of an increased utilization of muscle elastic energy during the stretch-shortening cycle (SSC),[2] which is better active immediately after prolonged exhausting or near exhausting run (Bosco et al., 1982). In addition, Komi (2000), indicates that moderate SSC fatigue may result in slight potentiation, which in our case, stimulates higher VJ.

Another explanation is provided by Boullosa & Tuimil, (2009) and Boullosa et al (2011): They attribute the phenomenon of exhausting-run induces vertical jump enhancement to post-activation potentiation (PAP),[3] when instead of reaching fatigue, an enhancement of power generation (potentiation), appears a few minutes after an exhausting or near exhausting effort. This phenomenon has generally attributed to the reinforcement of power generation in leg extensors, immediately after set of resistance exercise at intensity of approximately 3RM (Batista et al, 2007). Boullosa et al (2011), add and claim that the feasibility of PAP immediately after exhausting run,

[2] Stretch-Shortening Cycle (SSC) is a combination of two mechanisms. First, a mechanism like a spring in activities such as VJ. It includes the (1) eccentric phase of flexing the joints and in which the elastic energy is stored in the muscles and in the musculotendinous junction, which leads to (2) isometric transition phase, which leads to (3) the fast and explosive concentric phase. The elastic energy in the SSC joins the second mechanism: The stretching reflex, that begins in the eccentric phase while stretching muscle spindles and Golgi tendon organs, which provide the neural signal for operating a reflex arc which is increasing the recruitment and the contraction of fast twitch (FTb) motor units in the concentric phase. The SSC explains why VJ that preceded by a countermovement or a pre-stretch, increases vertical displacement above SJ in which the eccentric phase is eliminated (Turner & Jeffreys, 2010; Komi, 1984; Nicol, Avela & Komi, 2006).

[3] Post-activation potentiation (PAP) refers to the fact that instead of the appearance of fatigue after a concentric contraction in an exhausting resistance of RM3 or less, ror example, when performing squats in such resistance, power increasing (potentiation) appears a few minutes after the exhausting action (Wilson, Duncan, Marin, Brown, Loenneke, Wilson, & Ugrinowitsch, 2013; Bomfim Lima, Marin, Barquilha, Da Silva, Puggina, Pithon-Curi & Hirabara, 2011). The explanation for this is related to the following reasons: First, enhancement in the efficiency of ATP production in the phosphogenic energy pathway (ATP-CP) (Hodgson, Docherty & Robbins, 2005); Second, increasing the recruitment of fast twitch b (FTb) motor units and optimizing the electrochemical (neural) array involved in the recruitment (Enoka, 2002; Aagaard, Simonsen, Andersen, Magnusson & Dyhre-Poulsen, 2002; Aagaard, 2003).

does not contradict the reinforcement of stored elastic energy as part of SSC in fast twitch muscle fibers immediately after protocol of increased and prolonged exhausting or near exhausting run of 20-30 minutes.

However, a later study of Garcia et al (2016), suggest that as an effect of exhausting run, not the PAP is the reason for VJ enhancement, but another compensatory strategy may induce a re-organization of the movement structure and a new coordination pattern may appear, letting athletes maintain or even reinforce VJ performance, despite high levels of exhaustion. In addition, our study shows that the first and immediate VJ, that performed two minutes after the YYIE1 test, was significantly higher than their first jump performed immediately after the CWU (table 4). These results are supported by Boullosa & Tuimil, (2009), who found higher VJ, two minutes after the end of prolonged incremental run, than the height of VJ that performed seven minutes after the end of the same run. These findings also raise doubts about PAP as the reason for the increase in VJ height immediately after exhausting running, because according to Wilson et al (2013), and Bomfim Lima et al (2011), approximately five minutes are required for the beginning of the PAP effect.

Conclusions

This study was conducted among volleyball players, which are not well-trained for endurance run that is similar to the YYIE1. Nevertheless, the subjects experienced acute VJ enhancement in both VBJ and VAJ. Therefore, we conclude that VJ of volleyball players at a regional and national level, will be higher when carried-out immediately after performing YYIE1 until reaching 80% of VO2max, than after CWU. Therefore, it may be considered as a good warm-up for volleyball block and attack jump drills. In addition, it is hypothesized that performing multi-repetition of YYIE1 test immediately preceding VBJ and VAJ drills will create long term and chronic VBJ and VAJ enhancement among volleyball players.

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