BABEŞ-BOLYAI UNIVERSITY OF CLUJ-NAPOCA

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SUMMARY OF DOCTORAL THESIS

CONDUCĂTOR DE DOCTORAT

DOCTORAL COORDINATOR

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Student-doctorand

Doctoral student

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IMPROVING VOLLEYBALL PLAYERS' PERFORMANCE BY AN ORIGINAL PHYSICAL PREPARATION PROGRAM

ABSTRACT/SUMMARY
(English)

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Key Concepts

Conventional warm up (CWU), Vertical jump (VJ), Range of motion (ROM), Maximal voluntary contraction (MVC), Delayed Onset Muscle Soreness (DOMS), Countermovement jumps (CMJ), Drop jump (DJ), Squat jump (SJ), Plyometric training/jumps (PT), Resistance training (RT), Weight lifting (WL), Electromyostimulation (EMS), Yo-Yo intermittent endurance run/test level 1 (YYIE1), YYIE1 until reaching 80% of VO2max (YYIE1 80%), YYIE1 until reaching 95-100% of VO2max (YYIE1 95-100%), Stretch-shortening cycle (SSC), Post-activation potentiation (PAP), Volleyball attack jump (VAJ), Volleyball block jump (VBJ), Volleyball attack jump without the attention to the ball (VAJF), Volleyball block jump without the attention to the ball (VBJF), Volleyball attack jump with an attention to the ball (VAJW), Volleyball block jump with an attention to the ball (VBJW).

INTRODUCTION

The demand for high level of explosive force in the volleyball, is one of the highest in sports (Stanganelli, Dourado, Oncken, Mançan & Costa, 2008). For example, among elite male volleyball players, during a five-sets game, the players have performed between 250 to 300 actions that required explosive force production. These actions require high level of agility and mostly, high vertical jump (VJ) (Hasegawa, Dziados, Newton, Fry, Kraemer & Häkkinen, 2002). Therefore, enhancing VJ is one of the most important objectives when enhancing overall physical capacity of volleyball players. A main part of their training program is supposed to be designed for enhancing this capacity. However, due to the many tasks that are required from a volleyball player, from a personal and a group perspective, the training for enhancing the capacity VJ becomes secondary and less important, especially during the games term (Stanganelli et al., 2008).

the phenomenon of endurance exhausting or near exhausting run induces acute vertical jump enhancement

Most volleyball players use conventional warm up (CWU) (sub-chapter 2.2.) in aim to reach their full potential of VJ capacity. However, athletes have reported that after an exhausting or near exhausting run of 15-20 minutes, with almost no recovery gap, they can jump higher than after a CWU. Moreover, they also claim that the jump is carried out as without effort with a floating feeling. This phenomenon which appeared in occasional reports, was already investigated among different athletes, most of them are endurance athletes (chapter 1.4.), none of them were volleyball players.

Gap of knowledge, the originality and the aim of the thesis

If the phenomenon of endurance exhausting or near exhausting run brings about an acute VJ enhancement, it may be possible that multi repetition of training units, which will be consisted of an exhausting or near exhausting endurance run, immediately preceded by VJ training, will bring about a chronic VJ enhancement? This question was never examined. Therefore, the originality and the aim of this thesis was examining the effect of an intervention program of repeated performances of an endurance run at increasing speed until reaching exhaustion or near-exhaustion, preceding to an immediate VJ training, on the chronic enhancement of VJ among volleyball players. The originality of the thesis was also reflected by examining the phenomenon of endurance exhausting or near exhausting run and its acute effect on the immediate enhancement of VJ and agility of volleyball players.

Development of the research studies

The studies were developed from the phenomenon of the endurance exhausting or near exhausting run, which induces an acute vertical jump enhancement and represented by four studies:

- First study: in aim to examine whether this phenomenon also occurs among volleyball players, a pilot study was conducted: "The acute effect of endurance run at increasing speed, which was performed by Yo-Yo Intermittent Endurance 1 (YYIE1) test (Bangsbo, Iaia & Krustrup, 2008), on VJ height of volleyball players". The data collection of the study began at the middle of May 2017 and was lasted a month (table 1).

Three more research studies were conducted

- Second study: in aim to examine whether the endurance run at increasing speed also affects the agility of volleyball players, we examined the acute effect of endurance run at increasing speed, which was performed by YYIE1, on the agility of volleyball players. The data collection of this study began at the middle of August 2017 and was lasted a month (table 1).
- Third study: an intervention program was conducted, in aim to investigate whether performing multi repetitions of endurance run at increasing speed until reaching exhaustion or near exhaustion (YYIE1), accompanied by an immediate jump training, can lead to a chronic enhancement of VJ height.
- Forth study: conducted in aim to examine whether there is an effect of the intervention program, on the volleyball VJ with the attention to the ball (volleyball attack and volleyball block).

The intervention program

The intervention program was conducted in two terms, began at the middle of September, in total time of six and a half months and performed with addition to the regular volleyball program of all the research participants (table 1). Three groups of volleyball players among different volleyball teams, were participated in the program. The distribution of the examinees to research groups was not based on belonging to a specific volleyball team and the examinees from each team were divided into each of the research groups.

The intervention program compared between two experimental groups and compared each one of these groups, to a control group. The intervention program was performed in two training terms. At the first term one experimental group performed a jump training of approximately 80 VJs to maximum height (divided into four jumping styles), immediately after YYIE1 until exhausting or near exhausting, and the other experimental group performed the same jump training immediately after CWU. At the second term the groups were switched. Both groups were VJ tested at the beginning of the program, between the training terms and at the end of the program. The results of both research groups were compared with the tests results of the control group, which VJ tested only, without any specific VJ training.

No study has been found to examine the effect of an intervention program involving multi series of VJs to maximum height, as an independent training program to increase VJ height. All the program methods which are detailed in the literature review (sub-chapter 1.3.4), are engaged with resistance training (RT), plyometric training (PT) and recently Electromyostimulation (EMS) training (de Villarreal, Kellis, Kraemer & Izquierdo, 2009; Markovic, 2007; Tricoli, Lamas, Carnevale & Ugrinowitsch, 2005). However, there was a chance that the multi repetition trainings of VJs to maximum height for itself, no matter what preparation preceded it (YYIE1 or CWU), may also has a VJ enhancement potential. Therefore, it was important to compare, the same multi repetition trainings of 80 VJs to maximum height, ether immediately after exhausting or near-exhausting YYIE1 or immediately after CWU, and switch between the groups at the second training term, in aim to strengthen the investigation of the effect of the intervention program.

In addition (forth study), it is been assumed that within volleyball drills in regular volleyball training and during volleyball block jumps (VBJ) and volleyball attack jumps (VAJ) with attention to the ball, there is no maximization of jump height. Thanks to the sophisticated measuring instrument (VERT – Mayfonk Athletic, Florida, USA, chapter 2.2.), it became possible to measure the height of VBJs and VAJs while referring to the ball inside volleyball drills. The forth study compares between VJs with an attention to the ball to VJs without the attention to the ball. This comparison was made after the end of the second VJ training term of the intervention program and was lasted month and a half (table 1), in aim to find differences between volleyball players that went through a complete intervention program, and the control group of volleyball players, with similar characteristics, that did not participate in the intervention program.

The importance and the originality of this comparison is that if this hypothesis is correct, then a volleyball player maybe not perform, during regular volleyball trainings, any maximal stimulation for VJ enhancement, unless she or he perform a training of VJs to maximum height without a ball. This insight is not obvious due to the world-wide conventional approach, in which a volleyball player should practice as close as possible to the conditions of the game, which means as much as possible, attention to the ball.

The research was conducted with regional and national level volleyball players (females and males). All of them have other necessary occupations (jobs, students), unlike international level volleyball players, which mostly have optimal training conditions. Therefore, on the one hand, the findings of the intervention program that will be presented later in the thesis, should be qualified only for this population of volleyball players, but, on the other hand, most of the volleyball players in the world belong to a population like these research participants. It is likely that this population is also looking for methods to improve its physical capacity under the conditions and the constraints in which it acts.

Table 1. The calendar of the collection of the data of the thesis's studies

May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
End of 2016-2017 indoor volleyball season and preparatory term of 2017 beach-volleyball season				Preparatory term of 2017-2018 indoor volleyball season		2017-2018 indoor volleyball games season						End of 2017-2018 indoor volleyball season and preparatory term of 2017 beach-volleyball season	
Data collection of the first study: "The acute effect of endurance run at increasing speed on vertical jump height of volleyball players"				Data collection of the second study: "The acute effect of yo-yo intermittent endurance run level 1 run on the agility of volleyball players"	Data collection of the third study: "The effect of repeated performances of yo-yo intermittent endurance run level 1 preceding to an immediate vertical jump training, on the chronic enhancement of vertical jump among volleyball players" (intervention program)						Data collection of the forth study: "The effect of the attention to the ball on volleyball block jump height and volleyball attack jump height, among volleyball players"		
					Data collection of first training term of the intervention program		Interval between terms and mid-term tests	Data collection of second training term of the intervention program		End of program tests			

FIRST PART. LITERATURE REVIEW

1. THEORETICAL BACKGROUND

The literature review discusses the familiar ways to perform a higher VJ. The review engages with two general approaches for maximizing VJ. First, the acute maximization, which is reflected by more efficient warm-up or preparation process, immediately prior to VJ and second, the chronic VJ enhancement as affected by continuous training process.

First, reviewing the findings that are related to efficient warm-up or conditioning activity, which is usually related to an intense warm-up (Batista, Ugrinowitsch, Roschel, Lotufo, Ricard & Tricoli, Lamas, Carnevale, 2007), leading to an acute change in maximal voluntary contraction (MVC) in leg muscles, which in many studies is tested by VJ. This part engages with conditioning activity which induces post-activation potentiation (PAP) (as explained in sub-chapter 1.1.1.) or fatigue in leg muscles' force production.

Second, reviewing the findings that are related to stretching as part of warm-up: The way in which static stretching impairs muscle force production, which mostly examined by VJ; The mechanical and neural factors for MVC impairment after long static stretching. This part is important in order to explain the absence of stretching as part of the two pre-VJ activities: CWU and YYIE1

Third, reviewing the ongoing training process and the methods to achieve chronic VJ enhancement: the effect of plyometric training (PT); the effect of electromyostimulation (EMS) training; and the effect of the resistance training (RT). This review also emphasizes the integration of these methods, how they complement one another and therefore present higher VJ enhancement when integrated, either in general or with specific attention to volleyball players.

Forth, reviewing a unique phenomenon of the acute effect of exhausting or near-exhausting endurance run, on the immediate performance of maximal VJ height- the phenomenon of exhausting or near-exhausting run, induces vertical jump enhancement. This review discusses also the possible reasons for the presence of the phenomenon, including stretch shortening cycle (SSC) (as explained in sub-chapter 1.1.2.) and PAP. This part leads to a pilot study which applies this phenomenon also among volleyball players.

SECOND PART. PILOT STUDY

2. THE ACUTE EFFECT OF ENDURANCE RUN AT INCREASING SPEED ON VERTICAL JUMP HEIGHT OF VOLLEYBALL PLAYERS (PILOT STUDY)

Introduction

The conventional warm-up (CWU) and preparation for optimal utilization of vertical jump (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 exhausting or near-exhausting 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 was 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, Molina-Molina & 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; Rousanoglou, Noutsos, Pappas, Bogdanis, Vagenas, Bayios & Boudolos 2016). VJ post-test reduction was found also after 20-min exhausting cycling (McIntyre, Mawston & Cairns, 2012). There findings (see table 3, chapter 1.4.) indicate that this phenomenon occurs after running for approximately 20 minutes in total, whether as continuous running or as an intermittent running.

Among the studies 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% VO2 max of the subject's capacity. The 40 minutes tempo 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 difference in counter-movement jump (CMJ) between pre-test (41cm) to post-test

(43cm) that was performed immediately after 20 minutes run at 80% of VO2max capacity among young soccer players. 80% of VO2max is approximately the anaerobic threshold (Dwyer & Bybee, 1983).

The originality and the purpose of the study

This phenomenon has not been tested with volleyball players, which 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, performed by yo-yo intermittent endurance test/run level 1 (YYIE1) until reaching 80% of each subject's VO2max (YYIE1 80%), which continues until approximately 20 minutes, leads to a higher and immediate acute enhancement of VJ capacity by comparison to VJ capacity after CWU, among volleyball players. In addition, it was also important to examine how immediate is the effect of the endurance run on VJ. Therefore, a comparison was also made between the first jump after CWU and the first jump after the run.

Methods

This pilot study and the next research studies are relied on the comparison between the YYIE1 effect (post-test) to the CWU effect (pre-test) on explosive force production and VJ height. Therefore, it was essential to create a unified pattern of tests as described in table 6. The study was methodology conducted by comparing between pre-test to post-test of one group of volleyball players, similarly to Vuorimaa et al (2006); Boullosa & Tuimil (2009); Boullosa et al (2011); Juarez et al (2011); Cortis et al (2011); García-Pinillos et al (2015); García-Pinillos et al (2016). Thirty experienced female and male volleyball players ranged from regional to national level, volunteered to participate in this study. Each one of the subjects was tested according to the next test structure (table 6) and comparisons between pre-test results to post-test results were made:

Table 6. The structure of the vertical jump test, using yo-yo intermittent endurance run/test level 1, until reaching 80% of VO2max.

Activity	Conventional warm-up				
Interval time	Two/three minutes				
Activity	Pre-test	Eight volleyball block jumps	and	Eight volleyball attack jumps	20 second interval between each jump
Interval time	Two/three minutes				
Activity	*YYIE1 until reaching 80% of VO2max				
Interval time	Two/three minutes				
Activity	Post-test	Eight volleyball block jumps	and	Eight volleyball attack jumps	20 second interval between each jump

*YYIE1 = Yo-yo intermittent endurance run/test level 1

The conventional warm-up

According to Pearce et al (2009), and in aim to create optimal conditions for the designated activity of explosive force and VJ, we created we created a conventional warm-up (CWU) (table 7), that is going to be used throughout the entire thesis. This optimal warm-up was necessary in purpose of reducing the doubts regarding to possible assumption that non-optimal warm-up resulting in non-optimal findings, which will bias the findings to lower and slower ones, compared to the those who achieved after YYIE1. In all the following studies of this thesis, there will be only two preparatory activities for the designated activities: YYIE1 and this unified CWU.

Table 7. Conventional warm-up. Order of exercises.

1. Three minutes light jogging	
2. running exercise on a 20 meters track:	Number 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

The yo-yo intermittent endurance test

In this present research it was necessary to find a measurable test for endurance run at increasing speed, 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 have rapidly become some of the most extensively studied fitness tests in sports science. Due to their specificity and practicality, the tests have also been widely applied in many team sports to assess athletes' ability to repeatedly perform high-intensity exercise. The participants in the Yo-Yo Intermittent Endurance Run-Level 1 (YYIE1) test are running 20m shuttles, with a recovery period of five seconds. For a trained athlete, the YYIE1 test lasts 10–20 minutes and is mainly focusing on the ability to perform increasing intensity of aerobic work, continuing to additional lactic-anaerobic work (Bangsbo et al., 2008).

In addition, in this study the YYIE1 was utilized not only for tests, but as a warm-up of the endurance running at increasing speed for the jump training program, in half of the training units of each training term in the intervention program, which in the third part of the thesis.

Practically (figure 1), in the YYIE1 the examinee runs 20 meters back and forth, walks 5 meters back and forth for 5 seconds and repeats this track until reaching exhaustion. The walking time remains 5 seconds even when the running time is becoming shorter every 8-6 repetition. The shorter the running time, the faster the running speed. The running speed is timed by an audio system which makes a beep (signal) to start 20 meters, a beep to change direction on the 20-meter cone and a beep to return to baseline. After the 5-seconds walk, a starting beep is played again. In this study the YYIE1 was performed almost until reaching anaerobic threshold in approximately 80% of VO2max (YYIE1 80%) as will be explained below.

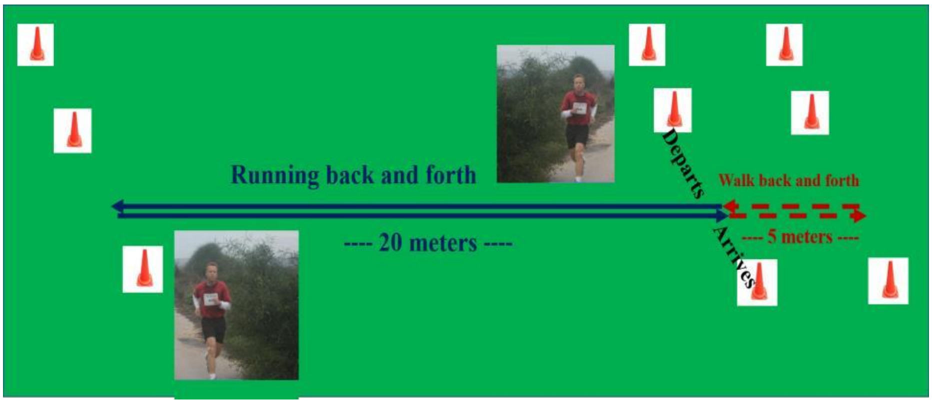

Figure 1. Yo-Yo Intermittent Endurance Test. Level 1 (YYIE1).

Monitoring 80% of VO2max in yo-yo intermittent endurance run level 1

80% of VO2max 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 80% of VO2max (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 VO2max as the intensity of YYIE1 is increasing.

Vertical jump measurement

The VJ height was measured using VERT Wearable Jump Monitor. The VERT system was found to by a valid measurement instrument. (Charlton, Kenneally-Dabrowski, Sheppard & Spratford, 2017; Borges, Moreira, Bacchi, Finotti, Ramos, Lopes & Aoki, 2017; MacDonald, Bahr, Baltich, Whittaker & Meeuwisse, 2017). The Vert system (Mayfonk Athletic, Florida, USA) has a small inertial sensor measuring 6 × 3 × 0.5 cm (figure 2). The sensor is inserted into an elastic waistband or attached to pants or tights by a clip (figure 3). The sensor calculates the vertical displacement of each jump. Data is subsequently streamed to a tablet via Bluetooth. (Charlton et al., 2017) (figure 4).

Figure 2. Vert VJ sensor

Figure 3. Attaching Vert sensor to pants or tights

Figure 4. vertical jump graph as it appears on the monitor

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.

Statistical analysis

To test this study hypotheses (No. 1 and 2), 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 mean or median may be improper if the amplitude of the difference is less important than the effect itself. 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 a mean 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 difference of 3 Cm. 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 conclude that performing YYIE1 80% has a significant positive effect on higher VBJ and VAJ capacity.

Results

Although the first part of the test, after CWU, has a potential of creating fatigue, both VBJs and VAJs after YYIE1 80%, were found higher than those performed in the first part after CWU. Table 8 shows the values of pre-test and post-test VBJ and VAJ, before and immediately after YYIE1 80%. The table shows also the difference between pre-test 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 VBJs and VAJs separately in two different way. In the first, we measured the mean of all jumps of each subject (M-VBJ and M-VAJ). In the second, we used the highest jump from each treatment (H-VBJ and H-VAJ). Table 5 provides the values of each measure. Table 8 shows significant differences of both M- and H- measures across the entire subjects in *t*-test at VAJ ($P < 0.05$) and in M- measures across the entire subjects in *t*-test at VBJ ($P < 0.05$).

Table 8. Mean values and standard deviations for pre-test and post-test, percentage changes and significance values.

Variables	Pre-test	Post-test	Δ %	p-value *t*-test	p-value Wilcoxon signed rank test	p-value sign test
VBJ (cm) Mean	Mean. 46.67 SD. 9.18	Mean. 47.27 SD. 9.38	1.21	0.010	0.03	0.045
VAJ (cm) Mean	Mean. 59.63 SD. 11.58	Mean. 60.49 SD. 11.27	2.16	0.001	0.004	0.100
VBJ (cm) Highest	Mean. 50.29 SD. 10.08	Mean. 50.55 SD. 10.2	0.71	0.278	0.32	0.137
VAJ (cm) Highest	Mean. 63.23 SD. 12.13	Mean. 64.33 SD. 11.88	1.83	0.046	0.082	0.201

VBJ = Volleyball block jump, VAJ = Volleyball block jump

As illustrated in table 9 and according to table 10, among the total first VJs (VBJ and VAJ), out of sixteen jumps per each subject, which performed in the pre-test (after CWU) and the total first VJs, out of sixteen performed in post-test (after YYIE1), the mean of the first jumps performed immediately after the YYIE1, was significantly higher ($P < 0.05$) than the mean of the first VJs after CWU, for both VBJ and VAJ (figures 6, 7).

Table 9. Illustration of the comparison between first vertical jumps.

Conventional warm-up
First vertical jump among 16 jumps, two/three minutes after the end of the conventional warm-up
Yo-yo intermittent endurance run, level 1 until reaching 80% of VO2max
First vertical jump among 16 jumps, two/three minutes after the end of the yo-yo intermittent endurance run

Table 10 shows the difference and the significant advantage ($P < 0.01$) of the mean of the first VJ (VBJ among17 subjects and VAJ among13 subjects), immediately after YYIE1 (post-test), compared to the first VJs before YYIE1 and after CWU (pre-test).

Table 10. Mean values, SD, percentage changes and significance values of the subjects' first VJ height, for pre-test and post-test before and immediately after YYIE1.

Variables	Pre-test	Post-test	Δ %	p-value *t*-test	p-value Wilcoxon signed rank test	p-value sign test
First VJ (VBJ & VAJ)	Mean. 51.61 cm. SD. 12.06	Mean. 53.46 cm. SD. 12.59	3.55	0.005	0.021	0.045

VJ = Vertical jump, VBJ = Volleyball block jump, VAJ = Volleyball block jump

Discussion and conclusions

Hypothesis 1: "The Yo-Yo Intermittent Endurance Test/run level 1 until reaching 80% of VO2 max will immediately affect explosive force production of volleyball players, which will be reflected by acute enhancement of vertical jump height". This hypothesis was found correct. Significant acute VJ enhancement was found in the mean of total VJ values after YYIE1 (post-tests) by comparison to mean of total VJ values after CWU (pre-test). Although the results were significant, they were rather small by comparison to the reviewed studies' results. Those who mostly conducted with endurance athletes (Vuorimaa et al., 2006; Boullosa & Tuimil, 2009; Garcia et al., 2015). This implies that as much higher the aerobic capacity, the higher the VJ in post-tests. Due to the nature of volleyball, the volleyball players in this study, are less likely to train their aerobic capacity. The findings of this study support more frequent integration of aerobic and anaerobic-lactic activity with explosive force actions, in the volleyball training system.

Hypothesis 2: "A comparison of the height of the first VJ (volleyball block jump or volleyball attack jump) immediately after conventional warm-up and the first VJ immediately after the YYIE1 until reaching 80% of VO2 max, will show better results after the conventional warm-up". This hypothesis was found incorrect. The average of the first and immediate VJ, of all thirty subjects, that performed two/three minutes after the YYIE1 run, was found significantly higher than the first VJ that was performed immediately after the CWU. These findings raise doubts about PAP as the reason for the phenomenon, because according to Wilson, Duncan, Marin, Brown, Loenneke, Wilson, & Ugrinowitsch, (2013), Lima, Marin, Barquilha, Puggina, Pithon-Curi, & Hirabara, (2011), approximately five minutes after the exhausting effort, are required for the beginning of the PAP effect.

The contribution of this study to the theoretical knowledge

The existence of the phenomenon raises questions regarding to the reasons for its occurrence. According to the literature, the SSC mechanism may be positively affected by the YYIE1 80% and therefore there is an acute enhancement in VJ height. The literature also raises the possibility that after the YYIE1 (80% or 95-100%), a PAP effect is occurred. However, the literature also doubts the occurrence of PAP effect as a result of the YYIE1 and therefore, it will also be right to examine the following assumption, which, if will be proven, it would make a significant contribution to the knowledge, regarding to how muscle's motor units are being recruited after exhausting efforts:

Exhausting run at increasing speed is exhausting legs' Slow-Twitch (ST) motor units and even Fast Twitch a (FTa) motor units. FTa are the slower muscle's fibers among the FT motor units, which are also activated when the running speed is increased. This leaves the fastest motor units (FTb) to act with no inhibition, until a recovery of ST and FTa motor units.

Practical implications and recommendations

According to the findings, that show an acute VJ height enhancement after YYIE1 80%, it can be assumed that using this method as a warm-up for training and even for volleyball game, can enhance performance. However, because we do not know yet, how long the body is positively affected by the YYIE1, this assumption deserves further examination.

If the YYIE1 is replaced by another activity that is similar in its effect on the aerobic and lactic-anaerobic systems and which integrates activity with a ball and volleyball skills, then it can be performed several times during volleyball training, provided that immediately afterwards a drill of an explosive force activity, will be performed. Because of the positive effect on VJ height by the immediately YYIE1 80%, it would be right not to rest for more than two minutes after the aerobic and lactic-anaerobic volleyball exercise, and immediately start the drill of explosive force such as VJ.

In addition, many times volleyball training tends to be performed in a slow pace, with little intense movement. This practice pattern usually characterizes training during the games season. In such a situation, in which body temperature and blood flow declines, it is difficult to continue with a practice that requires a high level of explosive force. In this kind of situation, performing YYIE1 or other volleyball exercise at a similar intensity level, in the middle of a workout, as well as at the end of the training, as illustrated in figure 8, it can help to continue an effective exercise, even for enhancing VJ or any other explosive force capacity.

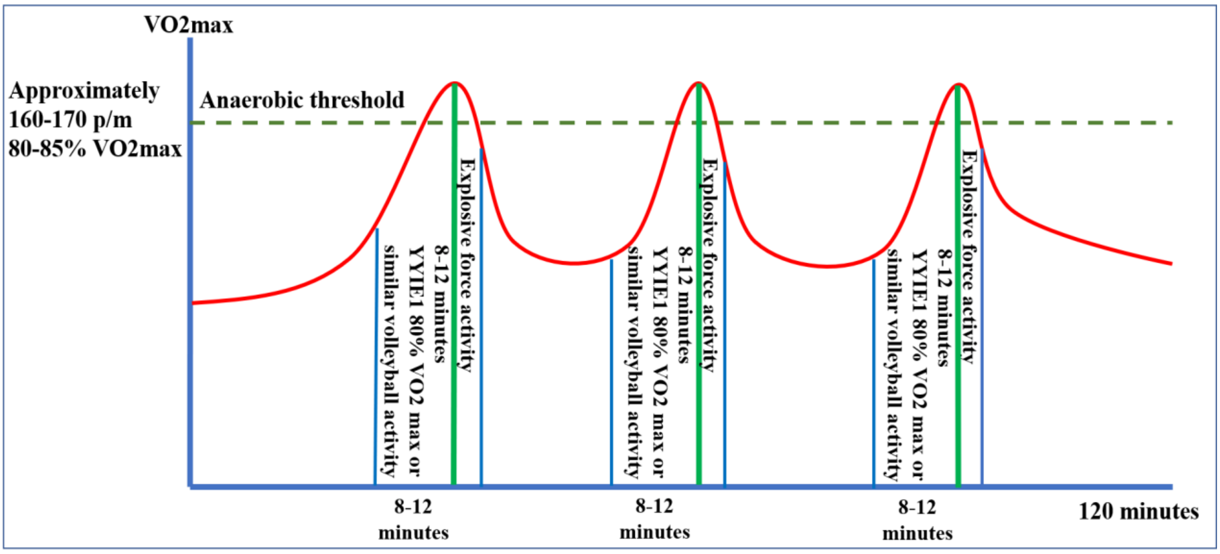

Figure 8. A volleyball training structure that integrates three peaks of eight-twelve intense activity and an immediate explosive force activity like vertical jumps to maximum height.

THIRD PART. RESEARCH STUDIES

3. THE ACUTE EFFECT OF YO-YO INTERMITTENT ENDURANCE RUN LEVEL 1, ON THE AGILITY OF VOLLEYBALL PLAYERS

Introduction

The previous study "The acute effect of endurance run at increasing speed on vertical jump (VJ) height of volleyball players" found significant acute enhancement in VJ ($P < 0.05$) among volleyball players immediately after YYIE1 80%. However, in addition to higher VJ, volleyball players are also required for quick movement on the court. A movement that requires high level of VJ is associated with high level of agility. Miller, Herniman, Ricard, Cheatham & Michael (2006), found that plyometric jumps (PT), which is one of the most influencing method on VJ enhancement (Bauer, Thayer, & Baras, 1990), improved also the agility of the subjects due to the enhancement of muscles' motor units' recruitment and neural adaptations, as a result of six weeks of PT, twice a week. The enhancement was due to the reason that these physiological functions are also responsible for better agility performance (Šimek, Milanović, & Jukić, 2008; Heang, Hoe, Quin, & Yin, 2012). Sahin (2014), suggests that coaches can utilize agility training for VJ enhancement.

Because of the similarities in the characteristics required to induce a high VJ and good agility, and as a result of the significant acute effect of endurance run at increasing speed on VJ height, from the previous study, we can expect for an acute agility enhancement immediately after approximately 15-20 minutes of endurance run at 80% of VO_2 max capacity. A study that strengthens this expectation is the one of Meckel, Gottlieb & Eliakim (2009), that found significant time reduction in repeated sprint test among young basketball players at half-time break of a basketball game, after playing twenty minutes, by comparison to baseline.

The originality and the purpose of the study

As far as we know, the effect of endurance running at increasing speed, performed by yo-yo intermittent endurance run level 1 (YYIE1), on the agility enhancement, has not been tested yet with volleyball players, which agility is one of the major components of their physical capacity. Therefore, the purpose of this study is to validate the hypothesis that an endurance run at increasing speed until reaching 80% of the subjects' VO2max, which continues until approximately 20 minutes, leads to an immediate faster acute enhancement of agility speed by comparison to agility speed after conventional warm-up (CWU), among volleyball players.

In addition, the previous study found that the first VJ immediately after the YYIE1 was significantly higher ($P < 0.05$) than the first VJ immediately after CWU. Therefore, because each volleyball player performed two trials of the same agility test after CWU and two trials after YYIE1, it was also important to compare the first trials after CWU and after YYIE1.

Methods

This study examines the difference between the agility of volleyball players which is measured by modified agility T-test (MAT) after CWU (see sub-chapter 2.2.) and their agility, which is measured by the same MAT, two/three minutes after YYIE1 until reaching 80% of VO2max. The study compares between the MAT results immediately after YYIE1 (post-test) to MAT results after CWU (pre-test), of one group of volleyball players. The study was methodology conducted by comparing between pre-test to post-test of one group of volleyball players, similarly to Vuorimaa et al (2006); Boullosa & Tuimil (2009); Boullosa et al (2011); Juarez et al (2011); Cortis et al (2011); García-Pinillos et al (2015); García-Pinillos et al (2016). Forty-one experienced female and male volleyball players, from regional and national levels, volunteered to participate in this study. Thirty of them participated also in the previous study. Each one of the subjects was tested according to the next test pattern, presented in table 14:

The pattern of the comparison between the agility tests

The comparison was included four parts as it appears in table 14. The CWU is detailed in chapter 2 (table 7), the YYIE1 is detailed in chapter 2. Two/three minutes after the CWU, the subject performs pre-test of two trials of MAT, five minutes rest between the trials; Two/three minutes after the second MAT trial, the subject performs YYIE1 80%. Two/three minutes after the end of YYIE1-80%, the subject performs post-test of two trials of MAT, five minutes rest between the trials. The pattern of the comparison between the agility tests is detailed in table 14:

Table 14. The structure of the comparison between the agility tests, using yo-yo intermittent endurance run/test level 1, until reaching 80% of VO2max.

Activity		Conventional warm-up	
Interval time		Two/three minutes	
Activity	Pre-test	Two trials of modified agility T-test	Five minutes rest between trials
Interval time		Two/three minutes	
Activity		*YYIE1 until reaching 80% of VO2max	
Interval time		Two/three minutes	
Activity	Post-test	Two trials of modified agility T-test	Five minutes rest between trials

*YYIE1 = Yo-yo intermittent endurance run/test level 1

Agility test

The most used test to assess agility is the T-test. It is well accepted as a standard test for measuring agility (Gabbett & Georgieff, 2007; Melrose, Spaniol, Bohling & Bonnette, 2007; Peterson, Alvar & Rhea, 2006). It is simple to perform and control and requires only minimal equipment. The T-test involves fast running speed with four directional changes. However, because the original T-test is long and wide and designed to assess football players' agility, which should run across a much larger field than a small volleyball court, the T-test was modified and was reduced in its size. Instead of 40 meters, the total distance of the MAT is 20 meters was validated as a useful instrument to evaluate volleyball players' agility (Sassi, Dardouri, Yahmed, Gmada, Mahfoudhi & Gharbi., 2009). In this study the time of each MAT was measured by stop watch and mean time between the two trials was calculated. The same person measured the time of all subjects.

The test is performed as follows (figure 9): A subject starts the MAT by running as fast as he can, 5 meters from cone A to cone B, then turns left, runs 2.5 meters to cone C, turns right, runs 5 meters to cone D, turns left, runs 2.5 meters back to cone B and finally runs back to cone A.

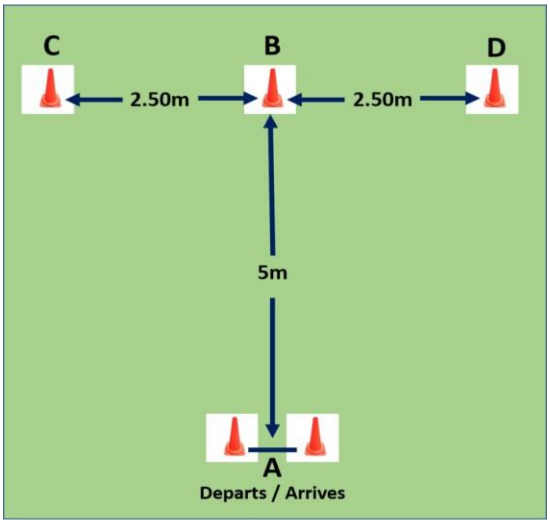

Figure 9. Modified agility T-test (MAT).

Statistical analysis

To test this study's hypothesis (No. 3), three types of statistical tests were conducted. First, assuming that our sample is normally distributed, a paired *t*-test was conducted in order to test the difference between MAT pre-test to MAT post-test. Next, assuming no inference can be made on the distribution of samples, the Wilcoxon signed rank test was conducted.

Finally, when testing statistically the effect of the various tests on agility enhancement, traditional statistical tests that measure the effect on the mean or median may be improper if the amplitude of the difference is less important than the effect itself. In this test case, the tests meant to enhance those parameters by a relatively small scale that a simple *t*-test or Wilcoxon signed test cannot detect. For example: In the case of agility, enhancement of volleyball player agility speed from 7.10 sec. to 6.90 sec. 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 a mean of 6.50 sec. and 6.30 sec. with a relatively small sample of subjects. In summary, the statistical test measures mathematical distances, and cannot realize that a difference of 2 tenth of a second may be considered significant in volleyball court movement.

For this reason, we apply the sign test that measures the number of enhancements within the sampled group. Under the null hypothesis, the intervention plan has no effect on the results. Therefore, we would expect the MAT pre-test results to be somewhat similar to those with faster post-test results (which reflects no significant differences overall). If, on the other hand, we find that the post-test results are significantly faster, we should conclude that performing YYIE1 80% has an acute significant positive effect on better volleyball agility capacity.

Results

Although the first part of the test, after CWU, has the potential of creating fatigue, MAT results after YYIE1 80% of VO2max, were higher than those performed in the first part after CWU. Table 15 shows the mean values of pre-test MAT before YYIE1 and post-test MAT two/three minutes after YYIE1. The table also shows the percentage change between pre-test and post-test results and the significance levels of three different statistical tests: the parametric t-test, and the non-parametric Wilcoxon signed rank and the sign tests.

Table 15. Mean and SD results for pre-test and post-test of modified agility T-test, before and after yo-yo intermittent endurance run until reaching 80% of VO2max.

Variables	**Pre-test (seconds)**	**Post-test (seconds)**	**Δ %**	**p-value *t*-test**	**p-value Wilcoxon signed rank test**	**p-value sign test**
MAT (females)	Mean. 7.24 SD. 0.27	Mean. 7.14 SD. 0.28	-1.41	0.008	0.014	0.052
MAT (males)	Mean. 6.06 SD. 0.25	Mean. 5.96 SD. 0.17	-1.54	0.002	0.002	0.001
MAT (females & males)	Mean. 6.72 SD. 0.64	Mean. 6.62 SD. 0.62	-1.47	0.000	0.000	0.000

MAT = Modified agility T-test

When examining the differences between the first trial of pre-test to first trial of post-test, it shows significant MAT time reduction in females ($P < 0.001$), in males ($P < 0.05$) and in total ($P < 0.001$) (table 16).

Table 16. The difference between first trial of pre-test modified agility T-test, after conventional warm-up, to first trial of post-test modified agility T-test, immediately after yo-yo intermittent endurance run until reaching 80% of VO2max.

Variables	**Pre-test 1**	**Post-test 1**	**Δ % Pre-test 1 to Post-test 1**	**p-value *t*-test**
MAT time females	Mean 7.29 sec. SD. 0.29	Mean 7.13 sec. SD. 0.29	-2.12	0.000
MAT time males	Mean 6.18 sec. SD. 0.31	Mean 6.04 sec. SD. 0.28	-2.22	0.048
Total MAT time	Mean 6.8 sec. SD. 0.63	Mean 6.65 sec. SD. 0.62	-2.17	0.000

MAT = Modified agility T-test

Discussion and conclusions

Hypothesis 3: "Yo-Yo Intermittent Endurance Test/run level 1 until reaching 80% of VO2 max, will immediately affect explosive force production of volleyball players, which will be reflected by acute enhancement of volleyball players' agility". This hypothesis was found correct. The study found a significant enhancement and mean MAT time reduction of 1.47 second in MAT time. Because of the similar characteristics of high VJ and good agility, a possible explanation for the phenomenon of exhausting or near exhausting run, induces VJ and agility enhancement might be an increasing in muscle's elastic energy during the SSC, which occurs immediately after an exhausting or near exhausting endurance run (Bosco, Viitasalo, Komi & Luhtanen, 1982). Komi (2000), indicates that moderate SSC fatigue mayresult in slight strengthening, which stimulates faster explosive force production.

Practical implications and recommendations

According to the results of this and the previous studies it implies that activity, which is similar in its nature to YYIE1 80%, can be the proper warm-up for tasks required by volleyball players and even as general warm-up at the beginning of volleyball training or before specific warm-up for volleyball game. In addition, if the YYIE1 80% will be replaced by other activities that are similar in their effect on the aerobic and lactic-anaerobic systems and may integrate volleyball drills, then a volleyball coach can integrate these drills several times in a training unit, provided that immediately then, an exercise of maximum height VJ and/or fast run like MAT, will be performed.

During the games term, volleyball trainings tend to be performed in a slow pace. When body temperature declines, explosive force activities are not performed optimally. Performing a YYIE1 80% or any similar intensity volleyball drill, twice or even three times in a training unit (figure 8), may create an effective training, as far as VJ and agility enhancement is concerned. In addition, due to the positive effect on the VJ height immediately after the YYIE1 80%, it would be right to rest no longer than two minutes after the YYIE1 80% or similar intensity volleyball drill and immediately start the agility or other explosive force drill.

4. THE EFFECT OF REPEATED PERFORMANCES OF YO-YO INTERMITTANT ENDURANCE RUN LEVEL 1, PRECEDING TO AN IMMEDIATE VERTICAL JUMP TRAINING, ON CHRONIC ENHANCEMENT OF VERTICAL JUMP, AMONG VOLLEYBALL PLAYERS

Introduction

This intervention program was developed as an original program to enhance VJ height among volleyball players at regional and national level. No study has been found to examine the effect of an intervention program involving training units of twenty minutes of multiple series of VJs to maximum height, with intervals of twenty seconds between each jump, as an independent training program for enhancing VJ height. This method is different than the methods that are detailed in the literature review (sub-chapter 1.3.4.), that are engaged with resistance training (RT), plyometric training (PT) and electromyostimulation training (EMS) methods, most of them are integration of one and the other (de Villarreal, Kellis, Kraemer, & Izquierdo, 2009; Markovic, 2007; Tricoli et al., 2005).

The originality and the purpose of the study

If a single performance of exhausting or near exhausting endurance run at increasing speed, which performed by YYIE1, creates conditions for more efficient acute performances of higher VJ and faster agility tasks, as had been shown in chapter 2 and 3, then what could be the chronic results of ongoing repetition of VJ training sessions (the intervention program), which are performed immediately after YYIE1, approximately twice a week, over a term of approximately six months for a single volleyball player?

The originality and the purpose of this study is to examine the chronic effect of multiple training units of multiple series of VJs to maximum height, on the VJ height of volleyball players, and at the same time, examining the effect of YYIE1 immediately before this method of VJ training, as a reinforcing factor, which increases the training effect of the chronic enhancement of this VJ training method.

Methods

Apart from a control group that did not perform the VJ training program, but only the periodic tests, there were two other experimental groups: Experimental groups – Y-group and R-group and control group. The dividing into two research groups, was done in aim to determine how effective and may stands by itself, is the jump training that is consisted of eighty VJs to maximum height (detailed in table 24) and to determine how effective is the performance of YYIE1 immediately before this jump training (effective means the contribution to VJ enhancement).

In addition, the training program was conducted twice, in two terms of activity, each one of them was lasted approximately two months and over total time of approximately six months. At the first training term Y-group began every training unit with YYIE1 and R-group began every training unit with CWU and at the second term they were switched (table 23). This method was conducted in aim to examine which order would present better results. Fifty-two experienced female and male volleyball players, from regional and national levels, volunteered to participate in this study. Forty-one of them participated also in the previous (agility) study.

Table 23. The structure of the intervention program for each participant

	Y-group		**R-group**		**Control group**
Four weeks	Baseline tests				
First term: **Two months**	First training term. Twelve-fourteen VJ training units per each subject. Each training unit begins with **YYIE1**.	Two VJ training units per week in addition to routine volleyball trainings	First training term. Twelve-fourteen VJ training units per each subject. Each training unit begins with **CWU**.	Two VJ training units per week in addition to routine volleyball trainings	Routine volleyball trainings. No VJ trainings.
Four weeks	Mid-program test				
Second term: **Two months**	Second training term. Twelve-fourteen VJ training units per each subject. Each training unit begins with **CWU**.	Two VJ training units per week in addition to routine volleyball trainings and games	Second training term. Twelve-fourteen VJ training units per each subject. Each training unit begins with **YYIE1**.	Two VJ training units per week in addition to routine volleyball trainings and games	Routine volleyball trainings. No VJ trainings.
Three weeks	End-program test				

VJ = vertical jump, YYIE1 = yo-yo intermittent endurance test/run level 1, CWU = conventional warm-up

Mid-program tests and End-program tests

Although these tests were performed according to the test pattern, presented in table 6, for the purpose of measuring the chronic enhancement, only the VJ results after CWU were taken into account in Mid-program and End-program test.

The vertical jump training unit

The trainings were performed twice a week with a difference of at least two days between training sessions. Occasionally, for technical reasons, there were intervals of five/six days between one VJ training session to the other. Rarely, training sessions were also performed with a gap of one day from the other. The trainings were conducted according to a weekly arrangement, which was coordinated personally, between the volleyball player and the researcher. Trainings and measurements were performed on a daily basis, seven days a week, throughout the overall data collection term. The VERT system (chapter 2) enabled training and measurements, simultaneously for up to eight volleyball players. However, for many technical reasons, training was often performed only for one, two or three subjects at the most. This is in order to meet the training program of each one of the subjects, throughout of the entire intervention program.

No jump training was performed after a volleyball training and the players were asked not to train at least six hours before the jump training. During the entire duration of the intervention program, the players were asked not to perform an Olympic lift (snatch, clean and jerk) or any other style of squats, using weights. It was not possible to ask them to refrain from any other physical activity in the morning before the exercise, because some were high-school students and attended physical education classes, from time to time, and some were physical education students who had to participate in physical activity within the college.

The trainings were usually carried out in the volleyball court where the volleyball trainings were conducted, on a parquet floor and if it was not possible, they were carried out in another gymnasium with a parquet floor. The players were not limited for jumping to a specific goal (basketball board or ring, for example). The VERT system enabled them to measure the VJ height for any goal they chose and everywhere on the court but without an attention to the ball (free VJ). After each jump, each player was encouraged to watch the result of the jump on the monitor (iPad). At the end of the training day the researcher recorded and summarized the results of the jumps and delivered the information personally to each player. Outstanding achievements were published among the two experimental groups in a specific WhatsApp group. This personal and general information was important in aim to further increase the players' motivation for progress throughout the long training program.

The structure of a single vertical jump training unit of eighty jumps to maximum height

The intervention program was constructed of training units of 35-50 minutes each. The difference in the time length of the training unit was depended on the duration of the YYIE1 which has been extended if there was an enhancement in the aerobic capacity of the subjects. The Jump training began two/three minutes after the end of the YYIE1 or the CWU, depend to which experimental group the subject belongs and was it limited to approximately 80 VJs, each one of them to maximum height, in total time of 20 minutes: set of 8 VBJ – set of 8 VAJ – set of 8 Squat jumps (SJ) – set of 8 plyometric jumps (PT) × 2. and then repeat the same sets again: 8 VBJ – 8 VAJ – 8 SJ

– 8 PT × 2. The combination of the volleyball VJ, SJ and PT was due to the conclusion of De Villarreal et al (2009). The interval time between the jumps within each one of the VBJ, VAJ and SJ sets, was approximately 20 seconds. The interval time between the sets, was one minute. The order between VBJ and VAJ sets and the order between SJ and PT sets, was switched every other training session. The structure of the training unit is detailed in table 24.

Table 24. The order of a single training unit of eighty vertical jumps to maximum height

Pre-activity	*YYIE1 or **CWU, depends to which experimental group the subject belongs.	Switching roles in the second term
Interval time to the beginning of the VJ training	Two/three minutes	
First set	Eight volleyball block jumps	20 second interval between jumps
Interval time between sets	One minute	
Second set	Eight volleyball attack jumps	20 second interval between jumps
Interval time between sets	One minute	
Third set	Eight squat jumps	20 second interval between jumps
Interval time between sets	One minute	
Forth set	Two sets of eight plyometric jumps. One-minute interval between sets	
Interval time between sets	One minute	
Fifth set	Eight volleyball block jumps	20 second interval between jumps
Interval time between sets	One minute	
Sixth set	Eight volleyball attack jumps	20 second interval between jumps
Interval time between sets	One minute	
Seventh set	Eight squat jumps	20 second interval between jumps
Interval time between sets	One minute	
Eighth set	Two sets of eight plyometric jumps. One-minute interval between sets	

*YYIE1 = Yo-yo intermittent endurance test/run level 1, CWU = conventional warm-up

**CWU = Conventional warm-up

The reason for twenty minutes vertical jump training unit

The 20 minutes per each VJ training unit was determined because some of these VJ training units were scheduled before and near general volleyball trainings and more importantly, this 20 minutes limitation was based on the assumption that this endurance run creates post-activation potentiation (PAP) effect that enhances legs force output (Boullosa et al., 2011), when the "window of opportunity" for achieving PAP effect is up to 20 minutes from the end of the conditioning activity (Bishop, 2003).

The jump styles for measurements and for practice

In aim to enhance jump capacity of volleyball players, it became essential to train them in the jump styles that they use (Stanganelli et al., 2008). Therefore, for measurement and practice purposes, VBJ and VAJ were chosen for the intervention program:

- **Volleyball block jump** (VBJ) – performed by standing jump or by limited movement to the side (left or right). In both jump pattern, hands movement is limited. Because there are different styles of VBJ approach that may affect VBJ height and in aim to create unified movement pattern among all subjects, we choose to use standing VBJ for all the research tasks. VBJ was chosen also because of its multiple frequency in volleyball games (Voigt & Vetter, 2003) and its similarity to CMJ (Stanganelli et al., 2008; Sattler, Sekulic, Hadzic, Uljevic & Dervisevic, 2012).

Figure 15. Volleyball block jump (VBJ)

- **Volleyball attack jump** (VAJ) - in contrast to VBJ, are performed within running steps and jumping approach through optimal utilization of hands swinging movement. Experienced and skilled volleyball players can fully utilize their VAJ capacity when jumping with both legs at once, in full jumping approach. Unlike VBJ side movement pattern, which turned to be different from one volleyball player to another, the VAJ movement pattern is unified among experienced and skilled volleyball players. VAJ is also performed very frequently in a volleyball game (Voigt & Vetter, 2003), VAJ is also similar to drop jump (DJ) (mostly carried out while dropping/jumping from 40cm height), and therefore, valid among volleyball players for measuring VJ height (Stanganelli et al., 2008; Sattler et al., 2012).

Figure 16. Volleyball attack jump (VAJ)

Two additional jump styles, only for the for practice in the intervention program

- **Squat jump** (SJ) – which is based more on the ability to produce muscle power, almost eliminates the stretch-shortening cycle (SSC) mechanism and therefore, practice SJ is important to enhance power production in extensor's leg muscles, as part of the jump training process (Bosco et al., 1982; Bosco, Tihanyi, Atteri, Fekete, Apor & Rusko, 1986). The SJs were performed from a sitting position on a chair, with hands swinging.

Figure 17. Squat jump (SJ)

- **Plyometric jump** (PT) – oppose to SJ, PT stimulates and enhances SSC mechanism which results in increasing utilization of the elastic energy in the muscle-tendon system and increasing motor units' recruitment at the concentric phase of SSC (de Villarreal et al., 2009; Bobbert., 1990; Markovic., 2007). The assumption was that the plyometric jumps, by strengthening the SSC effect, would enhance VJ, and we will be able to notice this effect, by enhancing the plyometric jumps height.

Figure 18. Plyometric jumps (PT)

Although we did not find any research of VJ enhancement that emphasizes this amount of maximum VJ height for VJ enhancement, we encouraged the subjects to jump every jump out of the 80, as high as they can. This was made possible by the immediate feedback of the jump height obtained by the VERT Wearable Jump Monitor (Mayfonk Athletic, Florida, USA) that created a basis for comparison and high motivation for high VJ.

Endurance running measurement by the yo-yo intermittent endurance test/run level 1

The endurance run at increasing speed was performed by the YYIE1 (chapter 2). For this study the YYIE1 was used as part of the training program in a way of repeating itself many times. In this study the YYIE1 was performed until reaching 95-100% of VO2max, in aim to stimulate and enhance maximal aerobic capacity.

Vertical jump measurement

The VJ height was measured using VERT Wearable Jump Monitor, as explained in chapter 2. VERT Wearable Jump Monitor was found to by a valid VJ measurement instrument. (Charlton et al., 2017; Borges et al., 2017; MacDonald et el., 2017).

Statistical analysis

To test this study hypotheses (No. 4, 5, 6), an ANOVA with repeated measures (time (3) X group (3)) was conducted in aim to compare the performances of VBJ and VAJ results at the three tests between the 3 groups; ANOVA with repeated measures (grouping (4) X group (2)) was conducted in aim to compare the performances of PT and SJ results; Change in the aerobic and lactic-anaerobic capacity until the end of the intervention program, according to the distance results of YYIE1 95-100%, was compared by *t*-test, and paired *t*-test was used to compare R-group performance in main time and follow-up; ANOVA with repeated measures (time (2) X periodical test (3)) was conducted in order to compare the performance of VAJ and VBJ results at YYIE1 80% and YYIE1 100% at the 2 times between the 3 periodical tests; The percentage changes of both VBJ and VAJ results, among the three groups was performed using the formula: $\frac{Test\ 3 - Test\ 1}{Test\ 1} X\ 100$; Pearson Correlations between age and VJ was performed; Post hoc test were computed using Bonferoni correction.

Results

Chronic change of volleyball block jump and volleyball attack jump height

Three tests terms of VBJ and VAJ were conducted in the intervention program: Before the beginning of the intervention program (baseline test), between the two terms of the program (mid-program test) and after the program was completed (end-program test). In aim to examine the chronic change of the VJs without the direct effect of the YYIE1, **only the VJs after CWU of the tests were calculated in aim to find if there is a chronic effect**. Then comparisons were made in aim to find whether there was a difference between the times of the pre-tests of the tests. Three research groups were tested: Two experimental groups, Y-group and R-group, and a control group. ANOVA with repeated measures was performed for each of the two variables (VBJ and VAJ) separately (group x time) (table 25, table 26):

Volleyball block jump

Table 25. Means and standard deviations of volleyball block jumps heights (cm), in accordance to the research groups.

		Control group** N=21		R-group N=13		Y-group N=12	
Time*		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
#1 Baseline test	**VBJ**	48.2	8.6	47.92	9.79	46.95	10.61
#2 Mid-program test	**VBJ**	50.94	8.97	56.42	10.09	54.02	11
#3 End-program test	**VBJ**	52.11	8.99	62.17	10.8	56.79	10.9

*Time effect $P < 0.001$. **Interaction $P < 0.001$.

VBJ = volleyball block jump

The mean VBJ height difference of each group, compared to the others at time #1 (baseline), was similar and was found statistically insignificant. In the control group, the enhancement between the three times was small and no significant difference was found between them. In addition, Post Hoc tests showed: In R-group, VBJ height at times #2 (mid-program) and #3 (end-program), was found significantly higher than time #1 (*P* < 0.05) and time #3 was found significantly higher than time #2 (*P* < 0.05); In Y-group, VBJ height at time #2 and #3, was found significantly higher than time #1 (*P* < 0.05), but the VBJ enhancement between time #2 to time #3 was small and no statistical significance was found; At time #2, mean VBJ height of R-group, was found significantly higher than mean VBJ height of control group (*P* < 0.05); At time #3, VBJ height of R-group, was found significantly higher than mean VBJ height of control group (*P* < 0.05). Other changes in mean VBJ height between the groups at times #2 and #3, were found insignificant. The percentage enhancement between baseline test to end-program test was: Y-group: 22.10% (*P* < 0.001), R-group: 31.37% (*P* < 0.001) and in control group: 8.23%.

Volleyball attack jump

Table 26. Means and standard deviations of VAJ heights (cm), in accordance to the research groups.

		Control group** N=21		R-group N=13		Y-group N=12	
Time*		**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
#1 Baseline test	**VAJ**	59.45	10.09	59.46	12.37	59.36	13.26
#2 Mid-program test	**VAJ**	62.4	10.33	67.31	11.7	69.69	11.88
#3 End-program test	**VAJ**	63.55	10.46	75.47	13.36	72.45	12.37

*Time effect *P* < 0.001. **Interaction *P* < 0.001.

VAJ = Vertical attack jump

The mean VAJ height difference of each group, compared to the others at time #1 (baseline test), was similar and was found statistically insignificant. In the control group, the enhancement between the three times was small and no significant difference was found between them. In addition, Post Hoc tests showed: In R-group, VAJ height at times #2 (mid-program test) and #3(end-program test), was found significantly higher than time #1 (*P* < 0.05) and time #3 was found significantly higher than time #2 (*P* < 0.05). In Y-group, VAJ height in time #2 and #3, was found significantly higher than time #1 (*P* < 0.05), but the VAJ enhancement between time #2 to time #3 was small and no statistical significance was found. At time #2 mean VAJ height of Y-group, was found significantly higher than mean VAJ height of control group (*P* < 0.05). At time #3 mean VAJ height of R-group and the mean VAJ height of Y-group, were found significantly higher than mean VAJ height of control group (*P* < 0.05). Other changes in mean VAJ height between the groups in times #2 and #3, was found insignificant. The percentage enhancement between baseline-test to the end-program test was: Y-group: 23.88% (*P* < 0.001), R-group: 28.21% (*P* < 0.001) and in control group: 7.02%.

Chronic change of squat jump and plyometric jump height

In addition to VBJ and VAJ, we asked to analyze the change tendency of two more VJ styles- PT and SJ, which were measured also in each one of the VJ training sessions. In each training term we grouped the results of the first three training units (grouping #1 & #3) and the last three training units (grouping #2 & #4) of PT and SJ. Then we calculated the mean height result of each grouping, separately for PT and SJ and comparisons were made in aim to find whether there was a difference between the groupings in each training term, for SJ and PT separately. Another comparison was made between grouping #1 in the first training term and grouping #4 in the second training term, in aim to find whether there was a difference between the beginning and the end of the intervention program, for SJ and PT separately. Because the control group did not perform the training program, the comparison was made only between R-group and Y-group only. ANOVA with repeated measures was performed for each of the two variables (SJ and PT) separately (group x time) (table 29, table 31):

Plyometrics

Table 29. Means and standard deviations of plyometric jump height (cm) results, of R-group and Y-group, in accordance to all the four groupings, as shown in table 28.

		R-group N=12		**Y-group N=12**	
Grouping		**Mean**	**SD**	**Mean**	**SD**
#1	**PT**	42.06	9.48	38.4	7.34
#2	**PT**	44.03	9.08	41.02	7.79
#3	**PT**	44.77	8.09	41.57	8.52
#4	**PT**	46.31	8.38	42.09	9.05

PT = plyometric jumps

No significant differences were found between R-group to Y-group, but significant enhancement was found in mean PT height from the beginning of the intervention program (grouping #1) to the end of the program (grouping #4), in both R-group and Y-group ($P < 0.001$). The percentage enhancement between baseline to the end of program was among the two experimental groups only: Y-group - 9.61% ($P < 0.001$), in R-group 10.1% ($P < 0.001$).

Squat jump

Table 31. Means and standard deviations of squat jump height (cm) results, of R-group and Y-group, in accordance to all the four groupings, as shown in table 30.

		R-group N=13		Y-group N=12	
Grouping		**Mean**	**SD**	**Mean**	**SD**
#1	**SJ**	55.39	9.17	50.5	9.79
#2	**SJ**	57.96	10.3	54.04	8.42
#3	**SJ**	60.04	9.96	55.23	9.41
#4	**SJ**	63.69	12.46	57.15	8.82

SJ = Squat jump

A significant enhancement was found in mean SJ height from the beginning of the intervention program (grouping #1) to the end of the program (grouping #4) ($P < 0.001$) in both R-group and Y-group. In addition, despite no significant difference between R-group and Y-group in grouping #1, #2, #3, Post Hoc test showed significant advantage for R-group upon Y-group in grouping #4 ($P < 0.05$). The percentage enhancement between grouping #1 to grouping #4 was: in Y-group: 13.17% ($P < 0.001$), in R-group 14.98% ($P < 0.001$).

*The control group did not take part in the VJ training program, therefore doesn't have plyometrics and squat jumps results.

Discussion and conclusions

Hypothesis 4: "The intervention program will affect Chronic enhancement of volleyball players vertical jump height". This hypothesis was found correct. While the control group did not significantly enhance between the beginning of the intervention program and end of the program, the enhancement of the R-group and the Y-group, between the baseline of the intervention program (test 1) and the end of the intervention program (test 3), was found significant. The results were found even higher than those in the reviewed studies (Markovic, 2007; de Villarreal et al., 2009; Mirzaei et al., 2014; Fatouros, Jamurtas, Leontsini, Taxildaris, Aggelousis, Kostopoulos, 2000; Maffiuletti, Gometti, Amiridis, Martin, Pousson, & Chatard, 2000; Malatesta, Cattaneo, Dugnani, & Maffiuletti, 2003; Herrero et al., 2006; Maffiuletti, Dugnani, Folz, Di & Mauro, 2002; Stanganelli et al., 2008). This method was found very efficient to enhance VJ of volleyball players of regional and national level.

Hypothesis 5: "If the intervention program enhances vertical jump height, then the reason will be the execution of the Yo-Yo Intermittent Endurance Run/test level 1 immediately before the vertical jump training, and the vertical jump training without the preliminary Yo-Yo Intermittent Endurance Run/test level 1 will only have a negligible effect on vertical jump enhancement of volleyball players". This hypothesis was found partially correct. By the end of the first training term (test 2), The enhancement range of VBJ of the Y-group (began each training unit with YYIE1) was found lower than the enhancement range of the R-group (began each training unit with CWU). However, by the end of the second training term (test 3), the trend reversed and higher effect of YYIE1 was observed in R-group (in second term began each training unit with YYIE1). Therefore, we can conclude that both YYIE1 and the VJ training that stands by itself, have a significant influence on VJ enhancement of volleyball players of regional and national level. The enhancement range of VAJ was always higher in the groups that began each training unit with YYIE1.

Hypothesis 6: "The intervention program will continue to show chronic vertical jump enhancement, during the second training period and will continue into the games season". Although the Y-group did not significantly enhance both VBJ and VAJ in the second term, that was performed during the game season, R-group significantly enhanced VBJ and VAJ in this term. Therefore, we can conclude that the pattern of CWU before VJ training at the preparation season and YYIE1 before VJ training at the games term, has either greater effect and can also be utilized by volleyball players of regional and national level, into the games season.

The enhancement trend of the experimental groups throughout the entire intervention program

Figure 29 shows the mean enhancement trend of each of the two experimental groups (Y-group and R-group). According to the figure, it appears that at the first training term, the YYIE1 95-100%, directly impaired VBJ and VAJ height of the Y-group at the first training sessions. Therefore, the opening conditions between this group and R-group, at the beginning of the intervention program, were not equal, despite the overall progress that was observed between first and last trainings. In addition, a sharp increase in VBJ and VAJ height was observed at the test that was performed a week after the end of the first training term.

In fact, as can be seen in all the tests, after the first training term (test 2) and after the end of the program (test 3), there is an increase in VBJ and VAJ height. However, the increase in the jump height after a training term with YYIE1 95-100% prior to each VJ training session, was even sharper. This is probably due to overcompensation reaction in which catabolism and reducing resources may create a future over anabolism and over increased resources recruitment and in other words: the intensity of the athlete workouts and the way she or he distribute them over time, will determine their future sports performance (Malatesta et al., 2003; Cintia, Pappalardo & Pedreschi, 2014).

Figure 29 is including the three VJ tests (pre-tests only) and all the training sessions of the two training terms (1-12- first term, 13-24- second term) of the intervention program. The black line in the graph emphasizes the sharp increase in the results of test 2 and test 3, that performed after the training terms in which each training unit began with YYIE1.

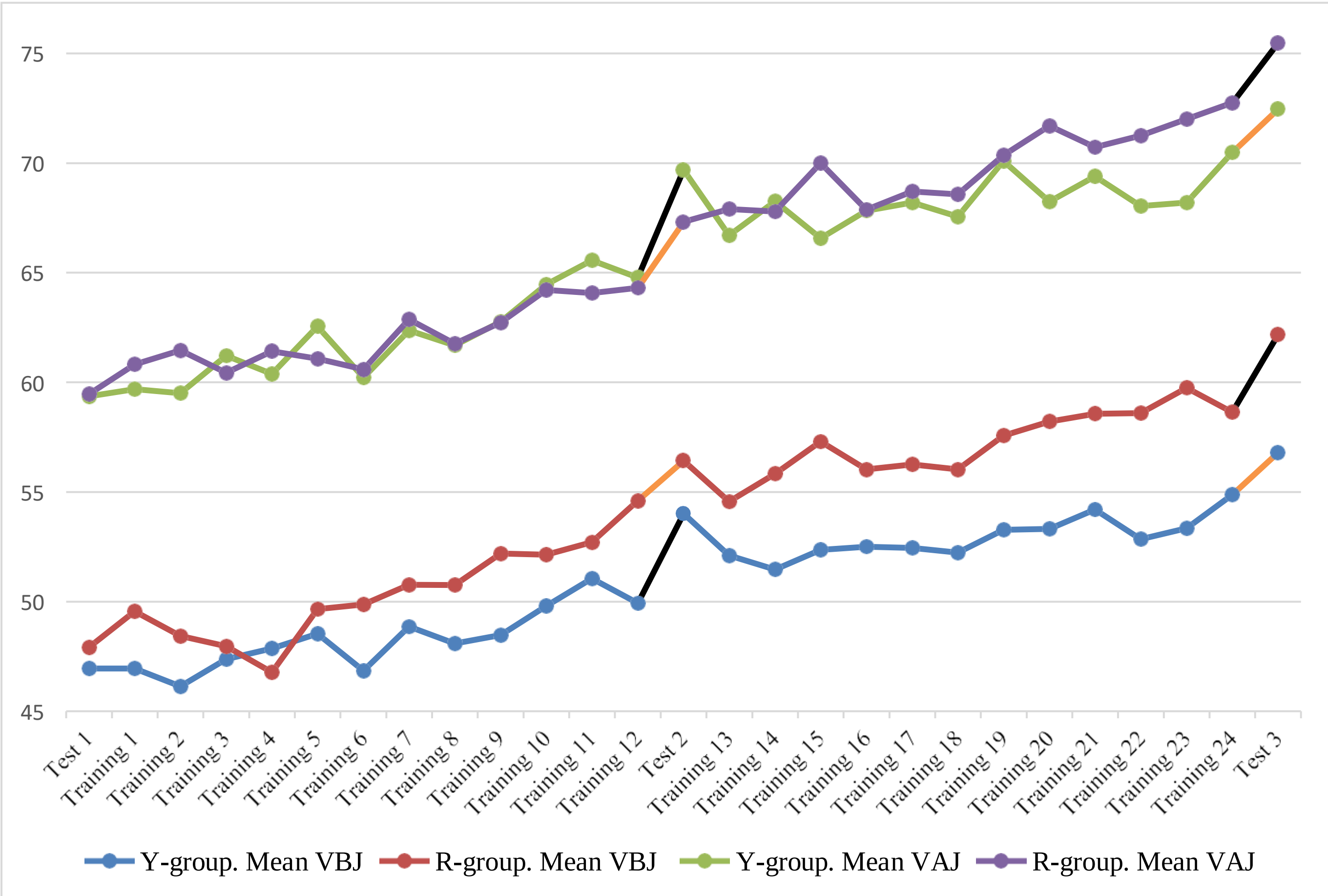

Figure 29. The volleyball block jump (VBJ) and volleyball attack jump (VAJ) enhancement tendency of each of the two experimental groups (Y-group and R-group) throughout the entire intervention program.

Additional findings

Both squat jumps (SJ) and plyometric jumps (PT) were enhanced significantly, however, the PT enhanced the least of all the four types of VJ in the study. This finding raises questions regarding to the use of PT in this intervention program: What was the rate of contribution of the PT to the overall VJ enhancement in this intervention program? Can PT affect VBJ and VAJ without being affected? Further research is needed to answer these questions.

The contribution of this study to the theoretical knowledge

The contribution of this study to the theoretical knowledge is in the integration of two types of physical activity, from both ends of the physical fitness spectrum: Endurance run at increasing speed until exhaustion or near-exhaustion and an explosive force production as it manifested by VJ, when under certain conditions, this integration can act to enhance chronic VJ. Until now, the prevailing view is that this type of running has a negative effect on the height of the VJ in any way of integration, if the attempt to perform such an integration is about to be carried out frequently and in a period of weeks. The originality of this research is that it discovers the conditions under which it is possible to turn this effect to positive and take advantage of it, in aim to chronically enhance VJ capacity. The following aspects also represent an originality and contribution to theoretical knowledge:

Multi repetition of endurance run at increasing speed immediately before vertical jump training, induces vertical jump enhancement among volleyball players from regional and national levels

Despite the reviewed studies of the phenomenon of exhausting or near-exhausting endurance run, which induces acute VJ enhancement (chapter 1.4.) (Vuorimaa et al., 2006; Boullosa & Tuimil, 2009; Boullosa et al., 2011; Juarez et al., 2011; Cortis et al., 2011; García-Pinillos et al., 2015; García-Pinillos et al., 2016), the intervention program (chapter 4) is the first study to examine whether repeated performance of this phenomenon, as a training program, is chronically enhancing VJ among population of athletes like volleyball players, that for them high VJ capacity is an important and major characteristic.

Because this is the first study that engages with this issue, its primary purpose was to discover the existence of the phenomenon among the volleyball players. According to the findings of this thesis, this phenomenon exists, and this discovery brings a contribution and originality. However, this effect cannot be occurred under any condition, and certain conditions are required for the occurrence of this affect. According to the research, the optimal way to take advantage of this phenomenon, in aim to create the "window of opportunity" for VJ enhancement, is not at the preparatory season but after approximately two months of VJ trainings to maximum height and then continue the VJ training with the additional endurance run at increasing speed, like YYIE1, before each VJ training.

Another contribution of the research is the training platform for both enhancing VJ and aerobic and lactic-anaerobic capacity, which is integrated during the games season, towards to the end of the season and play-off time. This contribution is not obvious, because players and coaches are usually planning to achieve the enhancement in these parameters, during the preparation term and only maintain and preserve them, during the games term.

A training of eighty-jumps to maximum height that stands by itself and enhancing chronic vertical jump height

The literature of enhancing VJ capacity engages with the integration of RT, PT and EMS training. As far as we know, no study has been found to examine the effect of VJ training, consisted of eighty VJ to maximum height (detailed in table 24), which stands by itself and enhances VJ capacity, without the methods of RT and/or EMS. The significant positive effect of this training of an 80 VJs to maximum height, that stands by itself, will also be considered as an originality and contribution of this research.

The innovativeness of the study

This research raises many research questions related to the effect of endurance run at increasing speed until reaching exhaustion or near-exhaustion, and the effect of a training of multiple VJs to maximum height, both regarding to VJ enhancement. These questions can open the door to much research on these issues and may even contribute not only for volleyball players, but to any athlete which explosive force activity is important to her or him, in aim to reach achievements and improve results.

5. THE EFFECT OF THE ATTENTION TO THE BALL ON THE HEIGHT OF VOLLEYBALL BLOCK JUMP AND VOLLEYBALL ATTACK JUMP OF VOLLEYBALL PLAYERS

Introduction

It seems logical that enhancing the overall vertical jumps (VJ) will affect the enhancement of VJ while referring to the ball at volleyball block jump (VBJ) and volleyball attack jump (VAJ) during volleyball drills or games. However, as far as we know, this assumption was not examined yet, due to the lack of measurement means. Therefore, the purpose of this study was to find if there are differences between VBJ and VAJ with an attention to the ball (VBJW, VAJW), to free VBJ and VAJ without the attention to the ball (VBJF, VAJF).

This study was conducted after the data collection of the study "The effect of repeated performances of yo-yo intermittent endurance test/run level 1 (YYIE1) preceding to an immediate VJ training, on chronic enhancement of VJ among volleyball players" (intervention program). This in aim to find whether there are differences between these jumps of the experimental group, to the control group of experienced volleyball players, which performed these jumps with and without the attention to the ball. The control group underwent the same program of volleyball trainings and volleyball games as the experimental group, but without participating in the intervention program.

The importance and the originality of this study

The current approach in the volleyball world is that conditioning training should be performed, as much as possible, with an attention to the ball and imitates as possible, volleyball actions. This is including VJ training. However, if this present study will show a reduction in VBJ and VAJ with an attention to the ball, comparing to VBJ and VAJ, without the attention to the ball, then it will support the integration of VJs to maximum possible height, without the attention to the ball into the general volleyball training program. This in aim to stimulate VJ enhancement, as it presented in the intervention program in chapter 4.1.

Methods

In this study the experimental group was an integration of the Y-group and the R-group from the previous study. The control group was consisted mainly of the control group of the intervention program plus another three volleyball players who stopped the VJ trainings at the beginning of the intervention program. Integrating the two experimental groups to one large group was made possible by the significant VJ enhancement of both groups, at the end of the intervention program in the previous study, despite the difference between the two. Fifty experienced female and male volleyball players, from regional and national levels, volunteered to participate in this study. All of them participated also in the previous study.

Data collection

The data collection of the study was conducted at the beginning of April 2018, after the intervention program was ended. The data collection was lasted five weeks. The VJ tests were conducted over the regular volleyball training sessions. Each VJ test was conducted as the third part of a volleyball training unit. The test was preceded by 10 minutes of routine warm-up without a ball, that included an aerobic part followed by an anaerobic part, then another 10 minutes of continuous pepper drill (volleyball passes by pairs). This preparatory activity is accepted throughout the world as a pre-game warm-up.

Each volleyball player was tested twice in two training units, in at least two-days break between the first test to the second. First test conducted for VBJ and second test for VAJ. The test was performed in two parts which were performed twice. Each part concluded volleyball VJ (Either VBJ or VAJ) with an attention and without the attention to the ball. Each test was performed in next order: 1) 8-10 volleyball VJ with an attention to the ball; 2) Free 8-10 volleyball VJ without the attention to the ball; 3) 8-10 volleyball VJ with an attention to the ball; 4) Free 8-10 volleyball VJ without the attention to the ball (table 40). The mean results of each of VBJW, VAJW, VBJF and VAJF was calculated.

Table 40. Order of the tests of volleyball vertical jumps, without and with an attention to the ball, for each one of the subjects.

Order of the test	**First day**	**At least two-days break**	**Second day**
1	Ten minutes of routine warm-up without a ball and Ten minutes of pepper drill (volleyball passes by pairs).		Ten minutes of routine warm-up without a ball and Ten minutes of pepper drill (volleyball passes by pairs).
2	Eight to ten volleyball VBJW		Eight to ten volleyball VAJW
3	Two minutes interval		Two minutes interval
4	Eight to ten volleyball VBJF		Eight to ten volleyball VAJF
5	Two minutes interval		Two minutes interval
6	Eight to ten volleyball VBJW		Eight to ten volleyball VAJW
7	Two minutes interval		Two minutes interval
8	Eight to ten volleyball VBJF		Eight to ten volleyball VAJF

VBJW = Volleyball block jump with an attention to the ball, VBJF = Free volleyball block jump without the attention to the ball, VAJW = Volleyball attack jump with an attention to the ball, VAJF = Free volleyball attack jump without the attention to the ball

Volleyball vertical jumps without and with an attention to the ball

- Volleyball block jump with an attention to the ball (figure 31). Usually it is performed by side steps, in order to jump in the most effective place to block the ball. The jump rarely performed without any steps. In this test we tried to minimize the side steps, which was very difficult to eliminate.

Figure 31. Volleyball block jump with an attention to the ball (VBJW)

- Free volleyball block jump, without the attention to the ball (figure 32). Was performed from a standing position, without side steps.

Figure 32. Free volleyball block jump without the attention to the ball (VBJF)

- Volleyball attack jump with an attention to the ball (figure 33). Was performed by three steps approach, with arm swing. Volleyball attack jump is executed from both legs. The attention to the ball during the jumping approach and jump requires precise timing, which sometimes requires changes in running speed, steps size, arm swing and therefore, perhaps also height of jump.

Figure 33. Volleyball attack jump with an attention to the ball (VAJW)

- Free volleyball attack jump, without the attention to the ball (figure 34). The volleyball player has no limitations to perform her/his optimal jumping approach, with optimal running speed, steps size and arm swing and jumping the highest she or he can.

Figure 34. Free volleyball attack jump without the attention to the ball (VBJF)

Two study comparisons: within groups and between groups

Two comparisons were made in this study (tables 41, 42): 1) The difference between VJs with an attention to the ball and VJs without the attention to the ball, **within** the experimental group and **within** the control group; 2) The difference **between** the experimental group and the control group in VJs with an attention to the ball and **between** the groups in free VJs without the attention to the ball. The comparisons were made twice, separately for VBJ and for VAJ.

Table 41. Comparisons of **volleyball block jumps** within and between the experimental and the control groups.

Experimental group		Control group
Mean result of volleyball block jump **with** an attention to the ball (VBJW)	Compared to (between):	Mean result of volleyball block jump **with** an attention to the ball (VBJW)
Compared to (within):		Compared to (within):
Mean result of free volleyball block jump **without** the attention to the ball (VBJF)	Compared to (between):	Mean result of free volleyball block jump **without** the attention to the ball (VBJF)

VBJW = Volleyball block jump with an attention to the ball
VBJF = Volleyball block jump without the attention to the ball

Table 42. Comparisons of **volleyball attack jumps** within and between the experimental and the control groups.

Experimental group		Control group
Mean result of volleyball attack jumps **with** an attention to the ball (VAJW)	Compared to (between):	Mean result of volleyball attack jumps **with** an attention to the ball (VAJW)
Compared to (within):		Compared to (within):
Mean result of free volleyball attack jumps **without** the attention to the ball (VAJF)	Compared to (between):	Mean result of free volleyball attack jumps **without** the attention to the ball (VAJF)

VAJW = Volleyball attack jump with an attention to the ball

VAJF = Volleyball attack jump without the attention to the ball

VJ measurement

The VJ height was measured using VERT Wearable Jump Monitor, as explained in chapter 2. VERT Wearable Jump Monitor was found to by a valid VJ measurement instrument. (Charlton et al., 2017; Borges et al., 2017; MacDonald et el., 2017).

Statistical design

To test the research hypothesis, an ANOVA with repeated measures (group (2) X condition (2)) was performed in order to compare the performance of VBJW and VAJW, and VBJF and VAJF, in the control and the experimental groups. Post hoc test were computed using Bonferroni correction t-test.

Results

In aim to examine the difference between VBJW and VAJW versus VBJF and VAJF, both groups- Experimental (Y-group and R-group together) and control, performed two tests for volleyball VJs in two different days. One for VBJ and one for VAJ, according to tables 43, 44. Comparisons were made between the mean height of VJs with and without the attention to the ball, using an ANOVA with repeated measures was performed for each of the two variables (VBJ and VAJ) separately (group x time). For statistical definition, we used the term "condition" to define VJs (VBJ and VAJ) with and without the attention to the ball, together:

Volleyball block jump with an attention to the ball versus volleyball block jump without the attention to the ball

Table 43. Means and standard deviations of the height of volleyball block jumps with and without an attention to the ball.

	Control group N=24		**Experimental group N=26**	
Condition	Mean	SD	Mean	SD
Volleyball block jump with an attention to the ball	47.87	8.42	56.4	11.56
Volleyball block jump without the attention to the ball	48.87	8.45	56.82	11.16

No statistical differences were found between VBJW and VBJF in each one of the groups (**within groups**). However, VBJW and VBJF height, was found significantly higher in the experimental group, comparing to the control group ($P < 0.05$) (**between groups**).

Volleyball attack jump with an attention to the ball versus volleyball attack jump without the attention to the ball

Table 44. Means and standard deviations of the height of volleyball attack jumps with and without the attention to the ball.

	Control group N=24		**Experimental group N=26**	
Condition	Mean	SD	Mean	SD
Volleyball attack jump with an attention to the ball	58.14	11.6	62.69	11.68
Volleyball attack jump without the attention to the ball	61.43	10.9	71.72	13.65

Statistical differences were found between VAJW and VAJF in both control and experimental groups ($P < 0.05$ and $P < 0.001$, respectively) (**within groups**). In addition, VAJW and VAJF height, was found significantly higher in the experimental group, by comparison to the control group ($P < 0.05$ and $P < 0.001$, respectively) (**between groups**).

The percentage difference rate <u>within</u> each group the experimental group to the control group in volleyball block jump and volleyball attack jump

Table 45. The percentage difference rate between volleyball block jump to volleyball attack jump, with and without the attention to the ball (within groups).

	Δ %. VBJW to VBJF	**Δ %. VAJW to VAJF**
Experimental group	0.74	14.42
Control group	2.09	5.66

VBJW = volleyball block jump with an attention to the ball, VBJF = volleyball block jump without the attention to the ball, VAJW = volleyball attack jump with an attention to the ball, VAJF = volleyball attack jump without the attention to the ball

The percentage difference rate between the experimental group to the control group in volleyball block jump and volleyball attack jump

Table 46. The level of significance and the percentage difference rate, between the mean height results (in cm) in volleyball vertical jumps with and without the attention to the ball, in the control group and the experimental group.

	Control group	**Experimental group**	**Level of significance**	**Δ %**
VBJW	47.87	56.4	$P < 0.05$	17.82
VBJF	48.87	56.82	$P < 0.05$	16.27
VAJW	58.14	62.69	$P < 0.05$	7.83
VAJF	61.43	71.73	$P < 0.001$	16.77

VBJW = Volleyball block jump with an attention to the ball, VBJF = Free volleyball block jump without the attention to the ball, VAJW = Volleyball attack jump with an attention to the ball, VAJF = Free volleyball attack jump without an attention to the ball

Discussion and conclusions

***Hypothesis 7*:** "The height of volleyball block jumps and volleyball attack jumps with attention to the ball will be lower than the height of volleyball block jumps and volleyball attack jumps without attention to the ball, among regional and national level volleyball players regardless of participation in the intervention program". This hypothesis was found partially correct. No significant difference was found between VBJW to VBJF, **within** the control and **within** the experimental groups. However, on the other hand, significant difference was found between VAJW to VAJF, **within** the control and **within** the experimental groups.

It is not clear why insignificant difference was found between VBJW and VBJF in both groups. There are two proposed reasons: 1) As opposed to standing VBJF, which technically was easily performed, VBJW is difficult to perform without certain legs movements. These legs movements are assisting to increase VJ height. 2) Maybe the motivation in VBJW was higher than VBJA. Further research is needed regarding to this issue.

The contribution of this study to the theoretical knowledge

As found in this research, the VAJW are lower than VAJF, even among volleyball players who are skilled in VAJ approach and technique. For the first time, the VAJW height could be measured, thanks to the sophisticated measuring instrument- VERT Wearable Jump Monitor. Until today, the tendency of the coaches is to reduce as much as possible, volleyball activity without the attention to the ball, and as much as possible, activating the players while referring to the ball. If we understand that in aim to enhance VJ height, it is necessary to jump to maximum height, then there are many volleyball players who do not do so, and all their VAJs, since they were children, have been done with an attention to the ball. Therefore, another contribution of this research is in that it shows the importance of the performance of VAJF to maximum height, in aim to create the stimulation to enhance this capability.

Practical implications and recommendations

The research indicates the importance of performing VAJF in addition to the VAJW, in aim to stimulate VAJ enhancement. This is not obvious due to the world-wide approach, in which volleyball exercise should be performed as much as possible, with an attention to the ball. These jumps can be performed regardless of the VJ training as a part of the intervention program. These jumps can be simply integrated into the volleyball training itself (figure 8). However, while performing these jumps, it is important that the players understand the importance of reaching maximum height in each VJ, in aim to create a stimulus for VJ enhancement.

Regarding to VBJ, and according to the findings, it is obvious that these VJs should be integrated into the intervention program. However, it is not certain that VBJ should be performed without the attention to the ball, because a significant difference in VBJ height with or without the attention to the ball, was not found. However, it is still recommended to perform VBJF, either because it requires less organization and can easily be integrated into the 20-minutes VJ training unit, or because VBJF was still found a little bit higher than VBJW and therefore do creates stimulation for enhancing VBJ capacity.

GENERAL CONCLUSIONS

- VJ and agility are enhanced when performed immediately after YYIE1 80%, compared to VJ and agility which are performed immediately after CWU, in the acute level.
- Trainings of VJs for maximum height, that stand by themselves (without RT), are significantly enhancing chronic VJ capacity.
- After approximately two months of trainings of VJs for maximum height after CWU, continuing the trainings with the addition of a YYIE1 immediately before each VJ training, enables significant continuation of the VJ height enhancement, even into the games season. This reveals that under appropriate preparation term, endurance run at increasing speed, which is performed by YYIE1, significantly has positive influence on the VJ training effect, when performed continuously over a training period of at least two months.
- VAJW was found significantly lower than VAJF. Thus, VAJW is providing less stimulation for VAJ enhancement.

References

Aagaard, P. (2003). Training-induced changes in neural function. *Exercise and Sport Sciences Reviews, 31*(2), 61-67.

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Neural adaptation to resistance training: changes in evoked V-wave and H-reflex responses. *Journal of Applied Physiology, 92*(6), 2309-2318.

Adams, K., O'Shea, J. P., O'Shea, K. L., & Climstein, M. (1992). The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *The Journal of Strength & Conditioning Research*, *6*(1), 36-41.

Arabatzi, F., Kellis, E., & De Villarreal, E. S. S. (2010). Vertical jump biomechanics after plyometric, weight lifting, and combined (weight lifting+ plyometric) training. *The Journal of Strength & Conditioning Research*, *24*(9), 2440-2448. DOI: 10.1519/JSC.0b013e3181e274ab.

Babault, N., Cometti, G., Bernardin, M., Pousson, M., & Chatard, J. C. (2007). Effects of electromyostimulation training on muscle strength and power of elite rugby players. *Journal of Strength and Conditioning Research*, *21*(2), 431.

Baker, D. (1996). Improving Vertical Jump Performance Through General, Special, and Specific Strength Training: A Brief Review. *The Journal of Strength & Conditioning Research*, *10*(2), 131-136.

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Medicine*, *38*(1), 37-51.

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes. *Sports Medicine*, *36*(9), 781-796.

Batista, M. A., Ugrinowitsch, C., Roschel, H., Lotufo, R., Ricard, M. D., & Tricoli, V. A. (2007). Intermittent exercise as a conditioning activity to induce postactivation potentiation. *The Journal of Strength & Conditioning Research*, *21*(3), 837-840.

Bauer, T., Thayer, R. E., & Baras, G. (1990). Comparison of training modalities for power development in the lower extremity. *The Journal of Strength & Conditioning Research*, *4*(4), 115-121.

Bergman, J., Kramer, A., & Gruber, M. (2013). Repetitive Hops Induce Postactivation Potentiation in Triceps Surae as well as an Increase in the Jump Height of Subsequent Maximal Drop Jumps. *PLoS ONE 8(10): e77705.* . DOI: 10.1371/journal.pone.0077705.

Behm, D. G., & Chaouachi, A. (2011). A review of the acute effects of static and dynamic stretching on performance. *European Journal of Applied Physiology*, *111*(11), 2633-2651. DOI 10.1007/s00421-011-1879-2.

Behm, D. G., Bambury, A., Cahill, F., & Power, K. (2004). Effect of acute static stretching on force, balance, reaction time, and movement time. *Medicine and Science in Sports and Exercise*, *36*, 1397-1402. DOI: 10.1249/01.MSS.0000135788.23012.5F.

Behm, D. G., Button, D. C., & Butt, J. C. (2001). Factors affecting force loss with prolonged stretching. *Canadian Journal of Applied Physiology*, *26*(3), 262-272.

Berthoin, S., Baquet, G., Rabita, J., & Blondel, N. (1999). Validity of the Universite de Montreal Track Test to assess the velocity associated with peak oxygen uptake for adolescents. *Journal of Sports Medicine and Physical Fitness*, *39*(2), 107.

Bishop, D. (2003). Performance changes following active warm-up and how to structure the 574 warm-up. *Sports Medicine*, *33*(483-498), 575.

Bobbert, M. F. (1990). Drop jumping as a training method for jumping ability. *Sports Medicine*, *9*(1), 7-22.

Bobbert, M. F., Hollander, A. P., & Huijing, P. A. (1986). Factors in delayed onset muscular soreness. *Medicine and Science in Sports and Exercise*, *18*, 75-81.

Lima, J. B., Marin, D., Barquilha, G., Da Silva, L., Puggina, E., Pithon-Curi, T., & Hirabara, S. (2011). Acute effects of drop jump potentiation protocol on sprint and countermovement vertical jump performance. *Human Movement*, *12*(4), 324-330. DOI: 10.2478/v10038-011-0036-4.

Borges, T. O., Moreira, A., Bacchi, R., Finotti, R. L., Ramos, M., Lopes, C. R., & Aoki, M. S. (2017). Validation of the VERT wearable jump monitor device in elite youth volleyball players. *Biology of Sport*, *34*(3). DOI: 10.5114/biolsport.2017.66000.

Borràs, X., Balius, X., Drobnic, F., & Galilea, P. (2011). Vertical jump assessment on volleyball: a follow-up of three seasons of a high-level volleyball team. *The Journal of Strength & Conditioning Research*, *25*(6), 1686-1694. DOI: 10.1519/JSC.0b013e3181db9f2e.

Bosco, C., Tihanyi, J., Latteri, F. L., Fekete, G., Apor, P., & Rusko, H. (1986). The effect of fatigue on store and re-use of elastic energy in slow and fast types of human skeletal muscle. *Acta Physiologica Scandinavica*, 128(1), 109-117.

Bosco, C., Viitasalo, J. T., Komi, P. V., & Luhtanen, P. (1982). Combined effect of elastic energy and myoelectrical potentiation during stretch-shortening cycle exercise. *Acta Physiologica Scandinavica*, *114*(4), 557-565.

Boullosa, D. A., & Tuimil, J. L. (2009). Postactivation potentiation in distance runners after two different field running protocols. *The Journal of Strength & Conditioning Research*, *23*(5), 1560-1565. DOI: 10.1519/JSC.0b013e3181a3ce61.

Boullosa, D. A., Tuimil, J. L., Alegre, L. M., Iglesias, E., & Lusquiños, F. (2011). Concurrent fatigue and potentiation in endurance athletes. *International Journal of Sports Physiology and Performance*, *6*(1), 82-93.

Bradley, P. S., Bendiksen, M., Dellal, A., Mohr, M., Wilkie, A., Datson, N., ... & Krustrup, P. (2014). The Application of the Yo-Yo Intermittent Endurance Level 2 Test to Elite Female Soccer Populations. *Scandinavian Journal of Medicine & Science in Sports*, 24(1), 43-54. DOI.org/10.1111/j.1600-0838.2012.01483.x.

Bradley, P. S., Olsen, P. D., & Portas, M. D. (2007). The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *The Journal of Strength & Conditioning Research*, *21*(1), 223-226.

Burkett, L. N., Phillips, W. T., & Ziuraitis, J. (2005). The best warm-up for the vertical jump in college-age athletic men. *The Journal of Strength & Conditioning Research*, *19*(3), 673-676.

Castagna, C., Impellizzeri, F. M., Belardinelli, R., & Abt, G. (2006). Cardiorespiratory responses to Yo-Yo Intermittent EnduranceTest in nonelite youth soccer players. *Journal of Strength and Conditioning Research*, *20*(2), 326.

Chambers, C., Noakes, T. D., Lambert, E. V., & Lambert, M. I. (1998). Time course of recovery of vertical jump height and heart rate versus running speed after a 90-km foot race. *Journal of Sports Sciences*, *16*(7), 645-651.

Channell, B. T., & Barfield, J. P. (2008). Effect of Olympic and traditional resistance training on vertical jump improvement in high school boys. *The Journal of Strength & Conditioning Research*, *22*(5), 1522-1527.
DOI: 10.1519/JSC.0b013e318181a3d0.

Charlton, P. C., Kenneally-Dabrowski, C., Sheppard, J., & Spratford, W. (2017). A simple method for quantifying jump loads in volleyball athletes. *Journal of Science and Medicine in Sport*, *20*(3), 241-245. DOI: 10.1016/j.jsams.2016.07.007.

Chatzopoulos, D. E., Michailidis, C. J., Giannakos, A. K., Alexiou, K. C., Patikas, D. A., Antonopoulos, C. B., & Kotzamanidis, C. M. (2007). Postactivation potentiation effects after heavy resistance exercise on running speed. *The Journal of Strength & Conditioning Research*, *21*(4), 1278-1281.

Church, J. B., Wiggins, M. S., Moode, F. M., & Crist, R. (2001). Effect of warm-up and flexibility treatments on vertical jump performance. *The Journal of Strength & Conditioning Research*, *15*(3), 332-336.

Cintia, P., Pappalardo, L., & Pedreschi, D. (2014, June). Mining efficient training patterns of non-professional cyclists. In *22nd Italian Symposium on Advanced Database Systems* (SEBD 2014), 1–8.

Cornwell, A., Nelson, A. G., Heise, G. D., & Sidaway, B. (2001). Acute effects of passive muscle stretching on vertical jump performance. *Journal of Human Movement Studies*, *40*(4), 307-324.

Cortis, C., Tessitore, A., Lupo, C., Pesce, C., Fossile, E., Figura, F., & Capranica, L. (2011). Inter-limb coordination, strength, jump, and sprint performances following a youth men's basketball game. *The Journal of Strength & Conditioning Research*, *25*(1), 135-142. DOI: 10.1519/JSC.0b013e3181bde2ec.

Costa, G., Afonso, J., Brant, E., & Mesquita, I. (2012). Differences in game patterns between male and female youth volleyball. *Kinesiology*, 44(1), 60-66.

Costa, P. B., Graves, B. S., Whitehurst, M., & Jacobs, P. L. (2009). The acute effects of different durations of static stretching on dynamic balance performance. *The Journal of Strength & Conditioning Research*, *23*(1), 141-147. DOI: 10.1519/JSC.0b013e31818eb052.

Cramer, J. T., Beck, T. W., Housh, T. J., Massey, L. L., Marek, S. M., Danglemeier, S., ... & Egan, A. D. (2007). Acute effects of static stretching on characteristics of the isokinetic angle–torque relationship, surface electromyography, and mechanomyography. *Journal of Sports Sciences*, *25*(6), 687-698. DOI:10.1080/02640410600818416.

de Villarreal, E. S. S., González-Badillo, J. J., & Izquierdo, M. (2007). Optimal warm-up stimuli of muscle activation to enhance short and long-term acute jumping performance. *European Journal of Applied Physiology*, *100*(4), 393-401. DOI: 10.1007/s00421-007-0440-9.

de Villarreal, E. S. S., Kellis, E., Kraemer, W. J., & Izquierdo, M. (2009). Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. *The Journal of Strength & Conditioning Research*, *23*(2), 495-506. DOI: 10.1519/JSC.0b013e318196b7c6

De Vries, H. A. (1966). Quantitative electromyographic investigation of the spasm theory of muscle pain. *American Journal of Physical Medicine & Rehabilitation*, *45*(3), 119-134.

Dello Iacono, A., Padulo, J., Eliakim, A., Gottlieb, R., Bareli, R., & Meckel, Y. (2015). Post activation potentiation effects on vertical and horizontal explosive performances of young handball and basketball athletes. *The Journal of Sports Medicine and Physical Fitness, 56*(12):1455-146.

Dello Iacono, A., Martone, D., & Padulo, J. (2016). Acute effects of drop-jump protocols on explosive performances of elite handball players. *Journal of strength and conditioning research*, *30*(11), 3122-3133.

Dupont, G., Defontaine, M., Bosquet, L., Blondel, N., Moalla, W., & Berthoin, S. (2010). Yo-Yo intermittent recovery test versus the Universite de Montreal Track Test: relation with a high-intensity intermittent exercise. *Journal of Science and Medicine in Sport*, *13*(1), 146-150. DOI: 10.1016/j.jsams.2008.10.007. DOI.org/10.1016/j.jsams.2008.10.007.

Dwyer, J., & Bybee, R. (1983). Heart rate indices of the anaerobic threshold. *Medicine & Science in Sports & Exercise*, *15*(1), 72-76.

Eldred, E., Granit, R., & Merton, P. A. (1953). Supraspinal control of the muscle spindles and its significance. *The Journal of physiology*, *122*(3), 498.

Enoka R. M. (2002). *Neuromechanics of Human Movement*. (3rd ed.). Champaign (IL): Human Kinetics.

Enoka, R. M. (1988). Muscle strength and its development. *Sports Medicine*, *6*(3), 146-168. DOI: 10.2165/00007256-198806030-00003.

Evangelos, B., Georgios, K., Konstantinos, A., Gissis, I., Papadopoulos, C., & Aristomenis, S. (2012). Proprioception and balance training can improve amateur soccer players' technical skills. *Journal of Physical Education and Sport*, *12*(1), 81.

Evetovich, T. K., Nauman, N. J., Conley, D. S., & Todd, J. B. (2003). Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. *The Journal of Strength & Conditioning Research*, *17*(3), 484-488.

Fatouros, I. G., Jamurtas, A. Z., Leontsini, D., Taxildaris, K., Aggelousis, N., Kostopoulos, N., & Buckenmeyer, P. (2000). Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. *The Journal of Strength & Conditioning Research*, *14*(4), 470-476.

Fletcher, I. M., & Jones, B. (2004). The effect of different warm-up stretch protocols on 20 meter sprint performance in trained rugby union players. *The Journal of Strength & Conditioning Research*, *18*(4), 885-888.

Folland, J. P., & Williams, A. G. (2007). Methodological issues with the interpolated twitch technique. *Journal of Electromyography and Kinesiology*, *17*(3), 317-327. DOI: org/10.1016/j.jelekin.2006.04.008

Fontani, G., Ciccarone, G., & Giulianini, R. (2000). Nuove regole di gioco ed impegno fisico nella pallavolo. *SDS*, *19*(50), 14-20.

Gabbe, B. J., Bennell, K. L., Finch, C. F., Wajswelner, H., & Orchard, J. W. (2006). Predictors of hamstring injury at the elite level of Australian football. *Scandinavian Journal of Medicine & Science in Sports*, *16*(1), 7-13. DOI: 10.1111/j.1600-0838.2005.00441.x.

Gabbett, T., & Georgieff, B. (2007). Physiological and anthropometric characteristics of Australian junior national, state, and novice volleyball players. *Journal of Strength and Conditioning Research*, *21*(3), 902.

García-Pinillos, F., Molina-Molina, A., & Latorre-Román, P. Á. (2016). Impact of an incremental running test on jumping kinematics in endurance runners: can jumping kinematic explain the post-activation potentiation phenomenon? *Sports Biomechanics*, *15*(2), 103-115. DOI: 10.1080/14763141.2016.1158860.

García-Pinillos, F., Soto-Hermoso, V. M., & Latorre-Román, P. A. (2015). Acute effects of extended interval training on countermovement jump and handgrip strength performance in endurance athletes: postactivation potentiation. *The Journal of Strength & Conditioning Research*, *29*(1), 11-21. DOI: 10.1519/JSC.0000000000000591.

Garhammer, J. (1993). A Review of Power Output Studies of Olympic and Powerlifting: Methodology, Performance Prediction, and Evaluation Tests. *The Journal of Strength & Conditioning Research*, *7*(2), 76-89.

Garhammer, J., & Gregor, R. (1992). Propulsion Forces as a Function of Intensity for Weightlifting and Vertical Jumping. *The Journal of Strength & Conditioning Research*, *6*(3), 129-134.

Gondin, J., Guette, M., Ballay, Y., & Martin, A. (2005). Electromyostimulation training effects on neural drive and muscle architecture. *Medicine & Science in Sports & Exercise*, 37(8), 1291-1299. DOI: 10.1249/01.MSS.0000175090.49048.41.

Gorostiaga, E. M., Izquierdo, M., Ruesta, M., Iribarren, J., Gonzalez-Badillo, J. J., & Ibanez, J. (2004). Strength training effects on physical performance and serum hormones in young soccer players. *European Journal of Applied Physiology*, *91*(5-6), 698-707. DOI 10.1007/s00421-003-1032-y.

Güllich, A., & Schmidtbleicher, D. (1996). MVC-induced short-term potentiation of explosive force. *New Studies in Athletics*, *11*, 67-84.

Hamada, T., Sale, D. G., MacDougall, J. D., & Tarnopolsky, M. A. (2000). Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles. *Journal of Applied Physiology*, *88*(6), 2131-2137. DOI: 10.1152/jappl.2000.88.6.2131.

Harman, E. A., Rosenstein, M. T., Frykman, P. N., & Rosenstein, R. M. (1991). The effects of arms and countermovement on vertical jumping. *Journal of Strength & Conditioning 13*(3), 38-39.

Hasegawa, H., Dziados, J., Newton, R. U., Fry, A. C., Kraemer, W. J., & Häkkinen, K. (2002). Periodized training programs for athletes. In W. J. Kraemer & K. Hakkinen *Strength Training for Sport*, 69-134. Oxford: Blackwell Science

Heang, L. J., Hoe, W. E., Quin, C. K., & Yin, L. H. (2012). Effect of plyometric training on the agility of students enrolled in required college badminton programme. *International Journal of Applied Sports Sciences, 24*(1), 18-24.

Henschke, N., & Lin, C. C. (2011). Stretching before or after exercise does not reduce delayed-onset muscle soreness. *British Journal of Sports Medicine*, 45(15), 1249-1250.

Herbert, R.D., de Noronha, M., & Kamper, S. J. (2011). Stretching to prevent or reduce muscle soreness after exercise. *The Cochrane Database of Systematic Reviews*, *6*(7), CD004577.

Herbert, R. D., & Gabriel, M. (2002). Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. *BMJ*, *325*(7362), 468. DOI: 10.1136/bmj.325.7362.468.

Herda, T. J., Cramer, J. T., Ryan, E. D., McHugh, M. P., & Stout, J. R. (2008). Acute effects of static versus dynamic stretching on isometric peak torque, electromyography, and mechanomyography of the biceps femoris muscle. *The Journal of Strength & Conditioning Research*, *22*(3), 809-817. DOI: 10.1519/JSC.0b013e31816a82ec.

Herrero, J. A., Izquierdo, M., Maffiuletti, N. A., & Garcia-Lopez, J. (2006). Electromyostimulation and plyometric training effects on jumping and sprint time. *International Journal of Sports Medicine*, *27*(07), 533-539. DOI: 10.1055/s-2005-865845.

Hindle, K. B., Whitcomb, T. J., Briggs, W. O., & Hong, J. (2012). Proprioceptive neuromuscular facilitation (PNF): Its mechanisms and effects on range of motion and muscular function. *Journal of Human Kinetics*, *31*, 105. DOI: 10.2478/v10078-012-0011-y.

Hodgson, M., Docherty, D., & Robbins, D. (2005). Post-activation potentiation: underlying physiology and implications for motor performance potentiation. *Sports Medicine*, *35*(7), 585-595. DOI: 10.2165/00007256-200535070-00004.

Hough, P. A., Ross, E. Z., & Howatson, G. (2009). Effects of dynamic and static stretching on vertical jump performance and electromyographic activity. *The Journal of Strength & Conditioning Research*, *23*(2), 507-512. DOI: 10.1519/JSC.0b013e31818cc65d.

Jamtvedt, G., Herbert, R. D., Flottorp, S., Odgaard-Jensen, J., Håvelsrud, K., Barratt, A., ... & Oxman, A. D. (2010). A pragmatic randomised trial of stretching before and after physical activity to prevent injury and soreness. *British Journal of Sports Medicine*, *44*(14), 1002-1009. DOI: 10.1136/bjsm.2009.062232.

Juarez, D., Lopez de Subijana, C., Mallo, J., & Navarro, E. (2011). Acute effects of endurance exercise on jumping and kicking performance in top-class young soccer players. *European Journal of Sport Science*, *11*(3), 191-196. DOI: 10.1080/17461391.2010.500335.

Khamoui, A. V., Brown, L. E., Coburn, J. W., Judelson, D. A., Uribe, B. P., Nguyen, D., ... & Noffal, G. J. (2009). Effect of potentiating exercise volume on vertical jump parameters in recreationally trained men. *The Journal of Strength & Conditioning Research*, *23*(5), 1465-1469. DOI: 10.1519/JSC.0b013e3181a5bcdd.

Kokkonen, J., Nelson, A. G., & Cornwell, A. (1998). Acute muscle stretching inhibits maximal strength performance. *Research Quarterly for Exercise and Sport*, *69*(4), 411-415.

Komi, P. V. (1984). Physiological and biomechanical correlates of muscle function: effects of muscle structure and stretch-shortening cycle on force and speed. *Exercise and Sport Sciences Reviews*, *12*(1), 81-122.

Komi, P. V. (2000). Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. *Journal of Biomechanics*, *33*(10), 1197-1206. DOI.org/10.1016/S0021-9290(00)00064-6.

Komi, P. V. (Ed.). (2011). *The Encyclopaedia of Sports Medicine, Neuromuscular Aspects of Sports Performance* (Vol. 17). Chichester: John Wiley & Sons.

Komi, P. V., & Bosco, C. (1978). Utilization of stored elastic energy in leg extensor muscles by men and women. *Medicine and Science in Sports*, *10*(4), 261-265.

Kraemer, W. J., & Newton, R. U. (1994). Training for improved vertical jump. *Sports Science Exchange/Gatorade Sports Science Institute*, *7*(6)., 1-12.

Leger, L. & Boucher, R. (1980). An indirect continuous running multistage field test: the Universite de Montreal track test. *Canadian Journal of Applied. Sports Sciences*, *5*, 77-84.

Leger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences*, *6*(2), 93-101.

Lepers, R., Pousson, M. L., Maffiuletti, N. A., Martin, A., & Van Hoecke, J. (2000). The effects of a prolonged running exercise on strength characteristics. *International Journal of Sports Medicine*, *21*(04), 275-280.

Linder, E. E., Prins, J. H., Murata, N. M., Derenne, C., Morgan, C. F., & Solomon, J. R. (2010). Effects of preload 4 repetition maximum on 100-m sprint times in collegiate women. *The Journal of Strength & Conditioning Research*, *24*(5), 1184-1190. DOI: 10.1519/JSC.0b013e3181d75806.

MacDonald, K., Bahr, R., Baltich, J., Whittaker, J. L., & Meeuwisse, W. H. (2017). Validation of an inertial measurement unit for the measurement of jump count and height. *Physical Therapy in Sport*, *25*, 15-19. DOI: 10.1016/j.ptsp.2016.12.001.

Maffiuletti, N. A., Dugnani, S., Folz, M., Di, E. P., & Mauro, F. (2002). Effect of combined electrostimulation and plyometric training on vertical jump height. *Medicine and Science in Sports and Exercise*, *34*(10), 1638-1644. DOI: 10.1249/01.MSS.0000031481.28915.56.

Maffiuletti, N. A., Gometti, C., Amiridis, I. G., Martin, A., Pousson, M., & Chatard, J. C. (2000). The effects of electromyostimulation training and basketball practice on muscle strength and jumping ability. *International Journal of Sports Medicine*, *21*(06), 437-443.

Maffiuletti, N. A., Minetto, M. A., Farina, D., & Bottinelli, R. (2011). Electrical stimulation for neuromuscular testing and training: state-of-the art and unresolved issues. *European Journal of Applied Physiology*, *v.111, p.2391–2397*. DOI: 10.1007/s00421-011-2133-7.

Malatesta, D., Cattaneo, F., Dugnani, S., & Maffiuletti, N. A. (2003). Effects of electromyostimulation training and volleyball practice on jumping ability. *The Journal of Strength & Conditioning Research*, *17*(3), 573-579.

Malisoux, L., Jamart, C., Delplace, K., Nielens, H., Francaux, M., & Theisen, D. (2007). Effect of long-term muscle paralysis on human single fiber mechanics. *Journal of Applied Physiology*, *102*(1), 340-349. DOI: 10.1152/japplphysiol.00609.2006.

Marek, S. M., Cramer, J. T., Fincher, A. L., & Massey, L. L. (2005). Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. *Journal of Athletic Training*, *40*(2), 94.

Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British Journal of Sports Medicine*, 41(6), 349-355. DOI.org/10.1136/bjsm.2007.035113.

Marques, M. C., van Den Tillaar, R., Vescovi, J. D., & González-Badillo, J. J. (2008). Changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. *The Journal of Strength & Conditioning Research*, *22*(4), 1147-1155. DOI: 10.1519/JSC.0b013e31816a42d0.

McGrath, R. P., Whitehead, J. R., & Caine, D. J. (2014). The effects of proprioceptive neuromuscular facilitation stretching on post-exercise delayed onset muscle soreness in young adults. *International Journal of Exercise Science*, 7(1), 14.

McHugh, M. P., & Cosgrave, C. H. (2010). To stretch or not to stretch: the role of stretching in injury prevention and performance. *Scandinavian Journal of Medicine & Science in Sports*, *20*(2), 169-181.

McIntyre, J. P., Mawston, G. A., & Cairns, S. P. (2012). Changes of whole-body power, muscle function, and jump performance with prolonged cycling to exhaustion. *International journal of sports physiology and performance*, *7*(4), 332-339.

Meckel, Y., Gottlieb, R., & Eliakim, A. (2009). Repeated sprint tests in young basketball players at different game stages. *European journal of applied physiology*, *107*(3), 273. DOI 10.1007/s00421-009-1120-8.

Melrose, D. R., Spaniol, F. J., Bohling, M. E., & Bonnette, R. A. (2007). Physiological and performance characteristics of adolescent club volleyball players. *Journal of Strength and Conditioning Research*, *21*(2), 481.

Miller, M. G., Herniman, J. J., Ricard, M. D., Cheatham, C. C., & Michael, T. J. (2006). The effects of a 6-week plyometric training program on agility. *Journal of Sports Science & Medicine*, *5*(3), 459.

Millet, G. Y., & Lepers, R. (2004). Alterations of neuromuscular function after prolonged running, cycling and skiing exercises. *Sports Medicine*, *34*(2), 105-116. DOI: 10.2165/00007256-200434020-00004.

Millet, G. P., & Vleck, V. E. (2000). Physiological and biomechanical adaptations to the cycle to run transition in Olympic triathlon: review and practical recommendations for training. *British Journal of Sports Medicine*, *34*(5), 384-390. DOI: 10.1136/bjsm.34.5.384.

Mirzaei, B., Norasteh, A., de Villarreal, E., & Asadi, A. (2014). Effects of six weeks of depth jump vs. Countermovement jump training on sand on muscle soreness and performance. *Kineziologija*, *46*(1), 97-108.

Moore, J. C. (1984). The Golgi tendon organ: a review and update. *American Journal of Occupational Therapy*, *38*(4), 227-236.

Moore, R. L., & Stull, J. T. (1984). Myosin light chain phosphorylation in fast and slow skeletal muscles in situ. *American Journal of Physiology-Cell Physiology*, *247*(5), C462-C471. DOI: 10.1152/ajpcell.1984.247.5.c462.

Needham, R. A., Morse, C. I., & Degens, H. (2009). The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. *The Journal of Strength & Conditioning Research*, *23*(9), 2614-2620. DOI: 10.1519/JSC.0b013e3181b1f3ef.

Newton, R. U., Kraemer, W. J., & Häkkinen, K. (1999). Effects of ballistic training on preseason preparation of elite volleyball players. *Medicine and Science in Sports and Exercise*, *31*, 323-330.

Newton, R. U., Rogers, R. A., Volek, J. S., Häkkinen, K., & Kraemer, W. J. (2006). Four weeks of optimal load ballistic resistance training at the end of season attenuates declining jump performance of women volleyball players. *Journal of Strength and Conditioning Research*, *20*(4), 955.

Nicol, C., Avela, J., & Komi, P. V. (2006). The stretch-shortening cycle. *Sports Medicine*, *36*(11), 977-999.

Nicol, C., Komi, P. V., & Marconnet, P. (1991). Fatigue effects of marathon running on neuromuscular performance - I. Changes in muscle forcé and stiffness characteristics. *Scandinavian Journal of Medicine & Science in Sports*, *1*(1), 10-17.

Nummela, A. T., Heath, K. A., Paavolainen, L. M., Lambert, M. I., Gibson, A. S. C., Rusko, H. K., & Noakes, T. D. (2008). Fatigue during a 5-km running time trial. *International Journal of Sports Medicine*, *29*(09), 738-745. DOI: 10.1055/s-2007-989404.

Oliver, J., Armstrong, N., & Williams, C. (2008). Changes in jump performance and muscle activity following soccer-specific exercise. *Journal of Sports Sciences*, *26*(2), 141-148. DOI: 10.1080/02640410701352018.

Opar, D. A., Williams, M. D., & Shield, A. J. (2012). Hamstring strain injuries. *Sports Medicine*, *42*(3), 209-226. DOI: 10.2165/11594800-000000000-00000.

Paavolainen, L., Nummela, A., Rusko, H., & Häkkinen, K. (1999). Neuromuscular characteristics and fatigue during 10 km running. *International Journal of Sports Medicine*, *20*(08), 516-521.

Pearce, A. J., Kidgell, D. J., Zois, J., & Carlson, J. S. (2009). Effects of secondary warm up following stretching. *European Journal of Applied Physiology*, *105*(2), 175-183. DOI 10.1007/s00421-008-0887-3.

Pereira, G., Almeida, A. G., Rodacki, A. L., Ugrinowitsch, C., Fowler, N. E., & Kokubun, E. (2008). The influence of resting period length on jumping performance. *The Journal of Strength & Conditioning Research*, *22*(4), 1259-1264. DOI: 10.1519/JSC.0b013e318173932a.

Pereles, D., Roth, A., & Thompson, D. (2010). A Large, Randomized, Prospective Study of the Impact of a Pre-Run Stretch on the Risk of Injury on Teenage and Older Runners. *USATF Press Release, 2012*. Retrieved from http://www.usatf.org/stretchStudy/StretchStudyReport.pdf

Peterson, M. D., Alvar, B. A., & Rhea, M. R. (2006). The contribution of maximal force production to explosive movement among young collegiate athletes. *Journal of Strength and Conditioning Research*, *20*(4), 867.

Pope, R. P., Herbert, R. D., Kirwan, J. D., & Graham, B. J. (2000). A randomized trial of preexercise stretching for prevention of lower-limb injury. *Medicine and Science in Sports and Exercise*, *32*(2), 271-277.

Proske, U., & Morgan, D. L. (2001). Muscle damage from eccentric exercise: mechanism, mechanical signs, adaptation and clinical applications. *The Journal of Physiology*, *537*(2), 333-345.

Quinn, T. J., & Coons, B. A. (2011). The Talk Test and its relationship with the ventilatory and lactate thresholds. *Journal of Sports Sciences*, *29*(11), 1175-1182. DOI.org/10.1519/ JSC.0b013e3181c02bce. DOI.org/10.1080/02640414.2011.585165.

Rack, P. M., & Westbury, D. R. (1974). The short-range stiffness of active mammalian muscle and its effect on mechanical properties. *The Journal of Physiology*, *240*(2), 331-350.

Reed, J. L., & Pipe, A. L. (2014). The talk test: a useful tool for prescribing and monitoring exercise intensity. *Current Opinion in Cardiology*, *29*(5), 475-480. DOI: 10.1097/HCO.0000000000000097.

Reed, J. L., & Pipe, A. L. (2016). Practical approaches to prescribing physical activity and monitoring exercise intensity. *Canadian Journal of Cardiology*, *32*(4), 514-522. DOI.org/10.1016/j.cjca.2015.12.024.

Robbins, D. W. (2005). Postactivation potentiation and its practical applicability: a brief review. *Journal of Strength and Conditioning Research*, *19*(2), 453.

Robbins, J. W., & Scheuermann, B. W. (2008). Varying amounts of acute static stretching and its effect on vertical jump performance. *The Journal of Strength & Conditioning Research*, *22*(3), 781-786. DOI: 10.1519/JSC.0b013e31816a59a9.

Rodríguez-Marroyo, J. A., Villa, J. G., García-López, J., & Foster, C. (2013). Relationship between the talk test and ventilatory thresholds in well-trained cyclists. *The Journal of Strength & Conditioning Research*, *27*(7), 1942-1949. DOI: 10.1519/JSC.0b013e3182736af3.

Rosenbaum, D., & Hennig, E. M. (1995). The influence of stretching and warm-up exercises on Achilles tendon reflex activity. *Journal of Sports Sciences*, *13*(6), 481-490.

Rousanoglou, E. N., Noutsos, K., Pappas, A., Bogdanis, G., Vagenas, G., Bayios, I. A., & Boudolos, K. D. (2016). Alterations of vertical jump mechanics after a half-marathon mountain running race. *Journal of Sports Science & Medicine*, *15*(2), 277.

Sahin, H. M. (2014). Relationships between acceleration, agility, and jumping ability in female volleyball players. *European Journal of Research Biology*, *4*(1), 303-308.

Sale, D. G. (2002). Postactivation potentiation: role in human performance. *Exercise and Sport Sciences Reviews*, *30*(3), 138-143.

Sargent, D. A. (1921). The physical test of a man. *American Physical Education Review*, *26*(4), 188-194.

Sassi, R. H., Dardouri, W., Yahmed, M. H., Gmada, N., Mahfoudhi, M. E., & Gharbi, Z. (2009). Relative and absolute reliability of a modified agility T-test and its relationship with vertical jump and straight sprint. *The Journal of Strength & Conditioning Research*, *23*(6), 1644-1651. DOI: 10.1519/JSC.0b013e3181b425d2.

Sattler, T., Sekulic, D., Hadzic, V., Uljevic, O., & Dervisevic, E. (2012). Vertical jumping tests in volleyball: reliability, validity, and playing-position specifics. *The Journal of Strength & Conditioning Research*, *26*(6), 1532-1538. DOI: 10.1519/JSC.0b013e318234e838.

Semenick, D. M., & Adams, K. O. (1987). SPORTS PERFORMANCE SERIES: The vertical jump: a kinesiological analysis with recommendations for strength and conditioning programming. *Strength & Conditioning Journal*, *9*(3), 5-11.

Sharman, M. J., Cresswell, A. G., & Riek, S. (2006). Proprioceptive neuromuscular facilitation stretching. *Sports Medicine*, *36*(11), 929-939. DOI: 10.2165/00007256-200636110-00002.

Sheppard, J. M., Cronin, J. B., Gabbett, T. J., McGuigan, M. R., Etxebarria, N., & Newton, R. U. (2008). Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. *The Journal of Strength & Conditioning Research*, *22*(3), 758-765. DOI: 10.1519/JSC.0b013e31816a8440.

Sheppard, J. M., Dingley, A. A., Janssen, I., Spratford, W., Chapman, D. W., & Newton, R. U. (2011). The effect of assisted jumping on vertical jump height in high-performance volleyball players. *Journal of Science and Medicine in Sport*, *14*(1), 85-89. DOI: 10.1016/j.jsams.2010.07.006.

Shield, A., & Zhou, S. (2004). Assessing voluntary muscle activation with the twitch interpolation technique. *Sports Medicine*, *34*(4), 253-267. DOI: 10.2165/00007256-200434040-00005.

Sim, A. Y., Dawson, B. T., Guelfi, K. J., Wallman, K. E., & Young, W. B. (2009). Effects of static stretching in warm-up on repeated sprint performance. *The Journal of Strength & Conditioning Research*, *23*(7), 2155-2162. DOI: 10.1519/JSC.0b013e3181b438f3.

Šimek, S., Milanović, D., & Jukić, I. (2008). The effects of proprioceptive training on jumping and agility performance. *Kinesiology: International Journal of Fundamental and Applied Kinesiology, 39*(2), 131-141.

Simic, L., Sarabon, N., & Markovic, G. (2013). Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scandinavian Journal of Medicine & Science in Sports, 23*(2), 131-148. DOI.org/10.1111/j.1600-0838.2012.01444.x.

Stanganelli, L. C. R., Dourado, A. C., Oncken, P., Mançan, S., & da Costa, S. C. (2008). Adaptations on jump capacity in Brazilian volleyball players prior to the under-19 World Championship. *The Journal of Strength & Conditioning Research*, *22*(3), 741-749. DOI: 10.1519/JSC.0b013e31816a5c4c.

Stanley, S. N., & McNair, P. J. (1995). The effects of stretching on series elastic muscle stiffness and passive range of motion. In *ISBS-Conference Proceedings Archive* (Vol. 1, No. 1). And in *T. Bauer (Ed.) Proceedings of the XI International Symposium of Biomechanics in Sports* (pp. 189-192). Thunder Bay, Ontario: Lakehead University.

Sweeney, H. L., Bowman, B. F., & Stull, J. T. (1993). Myosin light chain phosphorylation in vertebrate striated muscle: regulation and function. *American Journal of Physiology-Cell Physiology*, *264*(5), C1085-C1095. DOI.org/10.1152/ajpcell.1993.264.5.C1085.

Thacker, S. B., Gilchrist, J., Stroup, D. F., & Kimsey Jr, C. D. (2004). The impact of stretching on sports injury risk: a systematic review of the literature. *Medicine & Science in Sports & Exercise*, *36*(3), 371-378. DOI: 10.1249/01.MSS.0000117134.83018.F7.

Thompson, G. A., Kraemer, W. J., Spiering, B. A., Volek, J. S., Anderson, J. M., & Maresh, C. M. (2007). Maximal power at different percentages of one repetition maximum: influence of resistance and gender. *The Journal of Strength & Conditioning Research*, *21*(2), 336-342.

Tillin, N. A., & Bishop, D. (2009). Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Medicine*, *39*(2), 147-166. DOI.org/10.2165/00007256-200939020-00004.

Torres, R., Ribeiro, F., Duarte, J. A., & Cabri, J. M. (2012). Evidence of the physiotherapeutic interventions used currently after exercise-induced muscle damage: systematic review and meta-analysis. *Physical Therapy in Sport, 13*(2), 101-114. DOI.org/10.1016/j.ptsp.2011.07.005.

Toumi, H., Best, T. M., Martin, A., & Poumarat, G. (2004a). Muscle plasticity after weight and combined (weight+ jump) training. *Medicine and Science in Sports and Exercise*, 36(9), 1580-1588. DOI: 10.1249/01.MSS.0000139896.73157.21.

Toumi, H., Best, T. M., Martin, A., F'guyer, S., & Poumarat, G. (2004b). Effects of eccentric phase velocity of plyometric training on the vertical jump. *International Journal of Sports Medicine*, *25*(05), 391-398. DOI: 10.1055/s-2004-815843.

Tricoli, V., Lamas, L., Carnevale, R., & Ugrinowitsch, C. (2005). Short-term effects on lower-body functional power development: weightlifting vs. vertical jump training programs. *The Journal of Strength & Conditioning Research*, *19*(2), 433-437.

Turner, A. N., & Jeffreys, I. (2010). The stretch-shortening cycle: Proposed mechanisms and methods for enhancement. *Strength & Conditioning Journal*, *32*(4), 87-99.

Voigt, H. F., & Vetter, K. (2003). The value of strength-diagnostic for the structure of jump training in volleyball. *European Journal of Sport Science*, *3*(3), 1-10.

Vuorimaa, T., Virlander, R., Kurkilahti, P., Vasankari, T., & Häkkinen, K. (2006). Acute changes in muscle activation and leg extension performance after different running exercises in elite long distance runners. *European Journal of Applied Physiology*, *96*(3), 282-291. DOI 10.1007/s00421-005-0054-z.

Wallmann, H. W., Mercer, J. A., & McWhorter, J. W. (2005). Surface electromyographic assessment of the effect of static stretching of the gastrocnemius on vertical jump performance. *The Journal of Strength & Conditioning Research*, *19*(3), 684-688.

Wilson, G. J., Murphy, A. J., & Giorgi, A. (1996). Weight and plyometric training: effects on eccentric and concentric force production. *Canadian Journal of Applied Physiology*, *21*(4), 301-315.

Wilson, G. J., Murphy, A. J., & Pryor, J. F. (1994). Musculotendinous stiffness: its relationship to eccentric, isometric, and concentric performance. *Journal of Applied Physiology*, *76*(6), 2714-2719. DOI.org/10.1152/jappl.1994.76.6.2714.

Wilson, G. J., Newton, R. U., Murphy, A. J., & Humphries, B. J. (1993). The optimal training load for the development of dynamic athletic performance. *Medicine and Science in Sports and Exercise*, *25*(11), 1279-1286.

Wilson, J. M., Duncan, N. M., Marin, P. J., Brown, L. E., Loenneke, J. P., Wilson, S. M., ... & Ugrinowitsch, C. (2013). Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. *The Journal of Strength & Conditioning Research*, *27*(3), 854-859. DOI: 10.1519/JSC.0b013e31825c2bdb.

Wilson, J. M., Hornbuckle, L. M., Kim, J. S., Ugrinowitsch, C., Lee, S. R., Zourdos, M. C., Sommer, B., & Palton, L. B. (2010). Effects of static stretching on energy cost and running endurance performance. *The Journal of Strength & Conditioning Research*, *24*(9), 2274-2279. DOI: 10.1519/JSC.0b013e3181b22ad6.

Xenofondos, A., Laparidis, K., Kyranoudis, A., Galazoulas, Ch., Bassa, E., & Kotzamanidis C. (2010). Post-activation potentiation: Factors affecting it and the effect on performance. *Journal of Physical Education and Sport*, 28(3), 32-38.

Yamaguchi, T., & Ishii, K. (2005). Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. *The Journal of Strength & Conditioning Research*, *19*(3), 677-683.

Yamaguchi, T., Ishii, K., Yamanaka, M., & Yasuda, K. (2007). Acute effects of dynamic stretching exercise on power output during concentric dynamic constant external resistance leg extension. *The Journal of Strength & Conditioning Research*, *21*(4), 1238-1244.

Young, W. (1993). RESISTANCE TRAINING: Training for Speed/Strength: Heavy vs. Light Loads. *Strength & Conditioning Journal*, *15*(5), 34-43.

Young, W. B. (2006). Transfer of strength and power training to sports performance. *International Journal of Sports Physiology and Performance*, *1*(2), 74-83.

Young, W. B., & Behm, D. G. (2002). Should Static Stretching Be Used During a Warm-Up for Strength and Power Activities? *Strength & Conditioning Journal*, *24*(6), 33-37.

Young, W. B., & Behm, D. G. (2003). Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *Journal of Sports Medicine and Physical Fitness*, *43*(1), 21.

Zhi, G., Ryder, J. W., Huang, J., Ding, P., Chen, Y., Zhao, Y., ... & Stull, J. T. (2005). Myosin light chain kinase and myosin phosphorylation effect frequency-dependent potentiation of skeletal muscle contraction. *Proceedings of the National Academy of Sciences of the United States of America*, *102*(48), 17519-17524. DOI.org/10.1073/pnas.0506846102.

Ziv, G., & Lidor, R. (2010). Vertical jump in female and male volleyball players: a review of observational and research studies. *Scandinavian Journal of Medicine & Science in Sports*, *20*(4), 556-567. DOI.org/10.1111/j.1600-0838.2009.01083.x.