THE EFFECT OF TWO DIFFERENT CONDITIONS OF WHOLE-BODY VIBRATION ON FLEXIBILITY AND JUMPING PERFORMANCE ON ARTISTIC GYMNASTS

George Dallas[1], Paschalis Kirialanis[2]

[1] National and kapodistrian University of Athens, Department of PE and Sport Science, Greece

[2] Demokritus University of Thrace, Department of Physical education and Sport Science

Original research article

Abstract

*The purpose of this study was to examine the effect of different conditions of Whole Bode Vibration (WBV) on flexibility and jumping performance on artistic gymnasts. Twelve well trained gymnasts volunteered to participate in this study. They were performed under two different condition protocols. The first was examined as WBV combined with static stretching condition (WBVSS) and the second was examined as WBV. Flexibility and explosive strength tests were performed initially (Pre), immediately after the intervention (Post 1), 15 minutes (Post 15) and 30 minutes after the end of the intervention program (Post 30). A two-way ANOVA (condition * trials) with repeated measures on both factors was used. The level of significance was set at $p < 0.05$. Univariate analyses with Bonferroni adjustments (0.05/6) were selected as post hoc tests. The results revealed no significant interaction between conditions and trials in all examined variables ($p>0.05$). However, significant difference was found with respect to Sit&Reach test between pre and post 1 measurement ($p=0.002$). Further, the percentage improvement of WBV was greater in SJ and CMJ variables compared to WBVSS condition. Conclusively, both conditions (WBVSS and WBV) were effective on flexibility and jumping performance on artistic gymnasts and that each of them has a specific effect on the examined variables.*

Keywords: *vibration, flexibility, muscle strength, stretching, gymnastics.*

INTRODUCTION

The ability of the neuromuscular system to produce maximal power output is of critical importance in artistic gymnastics (AG). This ability requires optimal combinations of muscle strength, balance and flexibility to maximize gymnastics performance. Two of the six apparatus in artistic gymnastics, floor exercises and vaulting, are based, mainly, on muscular strength and flexibility of lower limbs to perform successfully the corresponding requirements in these events. Several methods have been used to improve flexibility (Abdulrahim et al, 2012; Bacurau et al, 2009; Bradley et al, 2007; Behm & Chaouachi, 2011; Christensen & Nordstrom, 2008; Covert et al, 2010; Davis et al, 2005; Hindle et al, 2012; Samuel et al, 2008), and explosive strength of lower limbs (Bacurau et al, 2009; Bazett-Jones et al, 2008; Behm, et al, 2006; Behm, Kibele, 2007; Delecluse et al, 2003). Further, previous findings showed that stretching has been used to improve gymnasts' split leap leg positions (Sands & McNeal, 2000; Sands, McNeal, Stone, Russell, & Jemni, 2006), whereas associated with an acute loss of maximal strength and power (McNeal & Sands, 2003; Sands, 2002). In addition, other studies support that gymnasts improved their split range of motion after vibration exposure (Sands et al, 2008). On the contrary, simultaneous vibration and stretching may improve flexibility while not altering explosive strength (Kinser et al, 2008).

Artistic Gymnastics relies on the gymnast's ability to produce a large amount of muscular force and to achieve limb positions that are beyond the norm. This sport uses a large range of motion (ROM) to achieve certain techniques and to increase score based on special body positions. According to Sands (2002) flexibility has been defined as the ROM in a joint or a related series of joints. Previous findings support that acute stretching as part of a warm-up, particularly slow and static stretching (SS) can cause a loss of maximum strength, rate of force development, power and explosive performance (McNeal & Sands, 2003; Stone et al 2006). Moreover, according to Di Cagno (2008) SS before physical activity is detrimental when performance requires subsequent maximal force and power production (Di Cagno, 2008). As Kinser and her colleagues stated, the potential stretching-induced decrease in explosiveness could reduce performance capabilities. Thus, a warm-up method that could allow ROM enhancement while enhancing or maintaining explosiveness would be quite applicable (Kinser et al, 2008).

Whole Body Vibration (WBV) is a neuromuscular method that uses a low-to moderate-vibration stimulus to enhance flexibility (Cochrane & Stannard, 2005; Fagnani et al, 2006; Jacobs & Burns, 2009), muscular strength and power (Bosco et al, 2000; Torvinen et al, 2002) and may produce benefits which can be useful in training and has been reported to be an effective method to enhance athletic performance (Cardinale & Wakeling, 2005; Rittweger et al, 2000). In addition, WBV training can be artificially produced when a person stands upon vibration platform that generates side to side alternating vertical sinusoidal mechanical vibration at a frequency between 30-50Hz. This may produce benefits which can be useful in training and has been reported to be an effective method to enhance athletic performance (Cardinale & Wakeling, 2005; Rittweger et al, 2000). The main argument for using vibration for muscle training has been based on the assumption that strength improvements can be easily achieved during a short duration vibration exposure (Cardinale and Bosco, 2003).

A lot of studies showed that WBV training resulted in improved muscle strength or muscle performance (Bosco et al, 2000; Delecluse et al, 2003; Gerodimos et al, 2010; Roelants et al, 2004), increase explosive strength of lower limbs (Cochrane & Stannard, 2005; Cormie et al, 2006), flexibility with or without stretching (Dallas et al, 2012; Jacobs & Burns, 2009; Kinser et al, 2008; Sands et al, 2006; 2008). In addition, studies that are referred to gymnastics sports have examined mainly the vibration effect on flexibility in high level gymnasts (Kinser et al, 2008; Sands et al, 2006; Sands et al, 2008) or elite female synchronized swimmers (Sands et al, 2008). However, few studies involved stretching during vibration (Issurin et al, 1994; Sands et al, 2006; Sands et al, 2008). Further, other studies had examined the acute effect of a WBV program on muscle performance of female athletes (Bullock et al, 2008; Cochrane & Stannard, 2005; Fagnani et al, 2006; Kinser et al, 2008). Previous data support that vibration may enhance measures of explosiveness (Ronnestand, 2004), and that vibration is most effective in muscles with increased length or tension (Rohmert et al, 1989). In this sense, a combination of vibration and stretching as part of the warm-up enhanced ROM and caused no loss (Kinser et al, 2008; Stone et al, 2006). Although, a great number of studies referred on flexibility and explosive strength enhancement with vibration on young artistic gymnasts, there is no scientific evidence on the efficacy on well trained artistic gymnasts that possess a high level of flexibility and explosive strength after many years of training. Therefore, the purpose of this study was to examine whether a single bout of Whole-Body-Vibration condition (WBV) or WBV combined with static Stretching (WBVSS) can be use as a warm-up activity that leads to short-term changes.

METHODS

Experimental Approach to the Problem

This investigation was designed to assess the possible beneficial effects of WBV or the WBVSS on well trained artistic gymnasts. Flexibility test (sit and reach test (S & R), and Explosive strength of lower limbs [Squat jump (SJ)], and counter movement jump (CMJ) were examined.

Subjects

Twelve well trained artistic gymnasts (Age: M = 21.88, SD = 1.05 years; Body Mass: M = 65.76, SD = 7.33 kg; Body Height: 170.53, SD = 6.76 cm; and percent body fat; M = 16.62, SD =1.864) volunteered to participate in the present study. All subjects had 8 to 10 years of experience in training, at least four days per week, three hours per day, with no previous experience in WBV. Further, they had experience in competing, both nationally and internationally, from six to eight years. Three days before the study, they had a familiarization training session and reproduced experimental procedures regarding the flexibility and explosive strength testing, and measurements of anthropometric characteristics (age, body mass, body height, percent body fat) were performed, as well. The study was approved by the local institutional Review Board and all procedures were in accordance with the Helsinki declaration of 1975 as revised in 1996. The vibration protocol consisted of a single bout WBV condition with and without stretching, which will be discussed in detail herein. The subjects were informed extensively about the experiment procedures and the possible risks or benefits of the project, and a written consent was obtained and they were instructed to refrain from any other activity during experimental procedure of this study.

Procedures

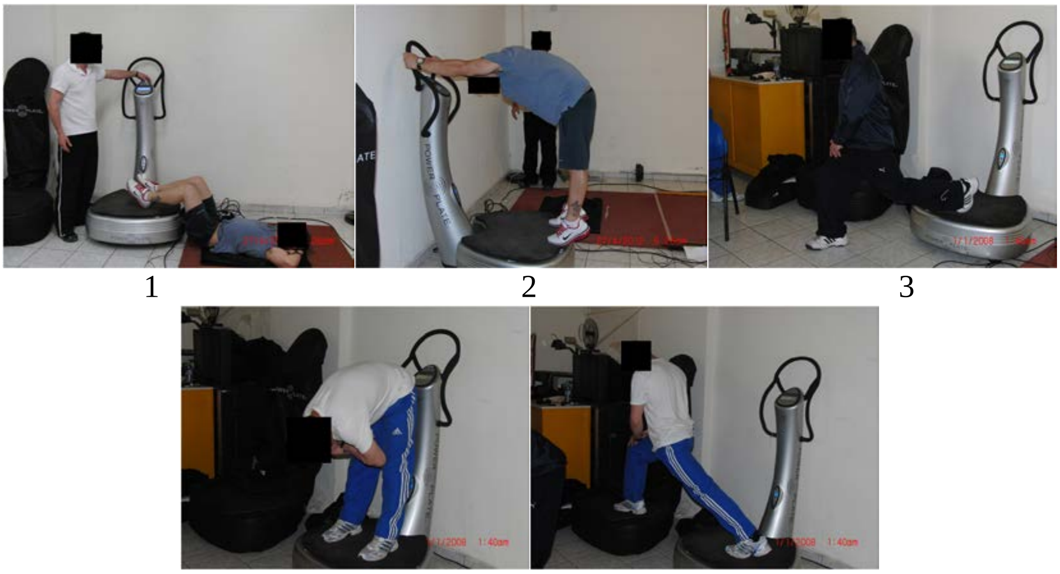
WBV Treatment

Subjects on both conditions were trained on a WBV platform (Power Plate®) that produced vertical sinusoidal oscillations. The frequency and the amplitude used in this study were 30-Hz and 2mm, respectively. The duration of the total stimuli was 75 seconds, which consisted of one set of 15 seconds for each one of five different exercises. The rest interval between each exercise for both groups was defined at 15 seconds. Subjects had to report to the lab on two separate days. On each testing condition, subjects performed a five-minute warm-up on a cycle ergometer without resistance at a self-selected moderate pace speed ranging from 4.0 to 5.0 km x h^{-1}). Immediately after the warm-up, the subjects completed a series of measurements for: flexibility (sit & reach test: SR) and legs' explosive strength (Squat Jump: SJ and Counter Movement Jump: CMJ) in a randomized order. A battery of tests was performed at baseline (pre), immediately after the end of the trial (post1) and 15 minutes after the end of the trial (Post15). The participants were informed about the test procedures and were asked to perform all tests at maximum intensity. All testing sessions were conducted at the same time of day (13:00 to 16:00). Verbal encouragement was given throughout testing trials.

On first day in WBV condition, during the first and second exercises, subjects from upright position flexed their knees to a squat position, to contract knee extensors. During the third exercise, subjects from supine position on the floor, put their flexed leg at the knee on the platform and simultaneously push downward against to contract their hamstrings (photo 1). During the fourth and fifth exercises, subjects from upright position, they were supported on their toes to contract plantar flexors (calf muscles) (photo 2).

On second day in WBVSS condition, during the first and second exercises, subjects put their free leg on the floor, while the other leg was supported on the platform to stretch the knee extensors muscles (photo 3). The third exercise had the subjects flex their torsos forward over the working leg on the platform such that the position stretched the hamstring muscles (photo 4). During the fourth and fifth exercises, subjects put their free leg on the platform that was turn off, while the other leg was supported with foot on the platform that was turn on, trying to press downward the hell to stretch calf muscles (photo 5).

The 15 sec exercise is used to hopefully improve the performance enhancement found by Cormie et al (2006). During the vibration-training session, the participants wore the same gymnastics shoes to avoid bruises and standardize the damping of the vibration caused by foot wear. As there are no scientifically-based WBV programs the training program in the present study was based on similar protocols that resulted in significant changes in muscle performance (Delecluse et al., 2003; Torvinen et al., 2002). The rest intervals between exercises, for both conditions, were 15 seconds.



1 2 3

4 5

Photos.

Flexibility test (Sit & Reach)

Flexibility was assessed using the sit and reach test using a Flex-Tester box (Cranlea, UK). Participants were instructed to remove their shoes and sit with their legs extended in front of them against the box. The subjects then placed one hand over the other and stretched forward slowly a far as possible along the top of the box until they could stretch no further, holding this position for 2 seconds (Fagnani et al, 2006) (photo 6). The test was repeated twice with a rest period of 10 seconds (Cochrane and Stannard, 2005) and the best trial of the two allowed was recorded to the nearest 1.0cm for further analysis.

Photo 6.

Explosive strength

Explosive strength of lower limbs was assessed by SJ, and CMJ using a switch mat (Bosco, Luhtanen, & Komi 1983) connected to a digital timer (accuracy±0.001s, Ergojump, Psion XP, MA.GI.CA. Rome, Italy), which recorded the flight time (t_f) of each single jump. In order to avoid upper body work and to minimize horizontal and lateral displacements the hands were kept on the hips through the tests (photo 7). The subjects were jumping from a semi-squatting position without counter movement (SJ). Two trials were performed, the best score was considered for statistical analysis.

Photo 7.

Statistical analysis

A two-way ANOVA (condition * trials) with repeated measures on both factors was used. The level of significance was set at $p<0.05$. Univariate analyses with Bonferroni adjustments (.05/6) were selected as post hoc tests. The significant level for the tests was set at $p< 0.05$ and the data was presented as mean ±SD. Further, percent changes in all examined variables from base-line following WBV exercise were calculated. All analyses were executed using the statistical package PASW 18.

RESULTS

The interaction effect between condition * trials was not significant with respect to S&R test (F= 1.351, p= .319, n^2=.310). Further, the condition main effect was not significant as well (F= 2.482, p= .143, n^2=.184). The trial main effect however was significant (F= 11.074, p= .002, n^2=.787) and the post hoc analysis with Bonferroni adjustment (.05/6) revealed significant differences between: a) pre vs post 1 (F= 38.833, p= .000). Inspection of mean scores revealed that the means S & R score at post1 was significantly higher compared to mean scores at pre test (table 1).

Table 1. *Means and SDs (M ± SD) in various tests across condition and trials with respect to the measurements used.*

	WBV			WBVSS		
	S & R (cm)	SJ (cm)	CMJ (cm)	S & R (cm)	SJ (cm)	CMJ (cm)
Pre	38.83±3.54	30.72±6.46	32.44±6.40	37.75 ±3.84	30.61 ±7.44	32.35±6.84
Post 1	39.92±3.23*	31.32±6.85	33.13±6.94	39.58±4.01*	30.76±6.69	32.52±7.22
Post 15	40.58±2.64*	31.08±6.51	32.57±6.81	39.75±3.69*	30.62±7.19	31.80±6.61
Post 30	41.08±2.39*	30.70±6.66	32.53±7.01	39.92±3.50*	30.69±6.67	32.29±6.52

No significant interaction effect between condition and trials was found with respect to SJ (F= 0.339, p= .798, n^2=.102). Further, main effect were no significant for condition (F=.618, p= .449, n^2=.053) and trials (F= 1.158, p= .378, n^2=.279) and therefore no post hoc analyses was conducted (table 1). No significant interaction effect between condition and trials was found with respect to CMJ (F= 1.212, p= .360, n^2=.288). Further, main effect were no significant for condition (F=.980, p= .343, n^2=.082) and trials (F= 3.103, p= .082, n^2=.508) and therefore no post hoc analyses was conducted. Separate improvement for WBVSS and WBV may be found in table 2. Further, Confidence Intervals (95% CI) are presented in table 3.

Table 2. *Percentage improvements (%) in S&R, SJ, and CMJ of gymnasts exposed to WBV and WBVSS, across time.*

	S&R		SJ		CMJ	
	WBV	WBVS S	WBV	WBVSS	WBV	WBVSS
Pre vs Post 1	2.81%	4.84%	1.72%	0.49%	2.13%	0.52%
Pre vs Post 15	4.51%	5.29%	1.96%	0.03%	0.40%	-1.70%
Pre vs Post 30	5.79%	5.75%	0.00%	0.26%	0.27%	-0.18%
Post 1 vs Post 15	1.65%	0.43%	0.24%	-0.45%	-1.69%	-2.21%
Post 1 vs Post 30	2.90%	0.86%	-1.69%	-0.23%	-1.81%	-0.71%
Post 15 vs Post 30	1.23%	0.43%	-1.93%	0.23%	-0.12%	1.54%

Table 3. *95% Confidence Intervals in various tests across trials*.

Trials	95% CI (S & R)	95% CI (SJ)	95% CI (CMJ)
Pre	36.02 – 40.55	26.85 – 35.05	28.24 – 36.55
Post 1	37.53 – 41.97	26.78 – 35.30	28.37 – 37.29
Post 15	28.28 – 42.05	26.54 – 35.16	27.97 – 36.39
Post 30	37.73 – 42.26	26.50- 34.88	28.14 – 36.68

DISCUSSION

The selection of well trained artistic gymnasts was based on the desire to determine whether vibration training and Static Stretching on the vibration platform could enhance range of motion and explosive strength of lower limbs in these athletes who were accustomed to intense flexibility training and had participated in static stretching and strength training for periods ranging from months to years before the investigation. According to the results the only significant difference was observed in S & R test that means both conditions were equally effective to improve flexibility in this particular group of gymnasts. However, the percentage improvement was greater in WBVSS condition compared to WBV condition in Post1 and Post15 but in Post30 WBV condition showed higher improvement compared to WBVSS condition (figure 1).

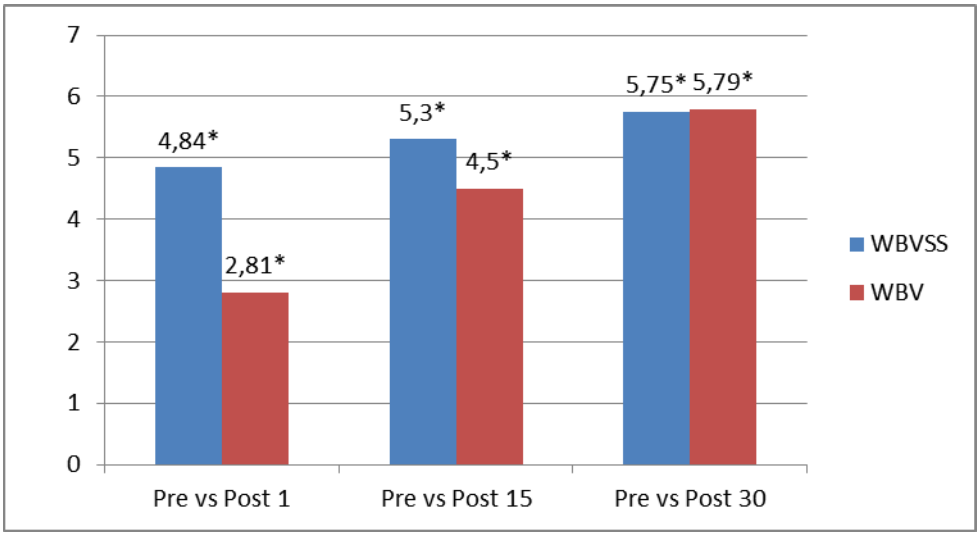


Figure 1. *Percentage (%) improvements in S & R test by two different conditions.*

These results are in congruence with those of Cochrane & Stannard (2005) and Jacobs & Burns (2009) which state that an acute bout of WBV have shown to improve flexibility and may be a more efficient warm-up method. Further, our results reinforce previous data of Sands and his colleagues (2006) that revealed an increase in ROM in forward split flexibility in high trained male gymnasts and those of Sands et al, which found that vibration combined with stretching had significant influence on passive forward split flexibility in elite female synchronized swimmers (Sands et al, 2008). In addition, beneficial effects of WBV on flexibility were maintained for at least 30 min, a finding that supports previous data of Gerodimos et al (2010). According to Issurin (2005) a possible explanation for the enhanced flexibility after a single bout of WBV involves circulatory, thermoregulatory, and neural mechanisms.

Previous data support that vibration enhances the stretch reflex loop through the activation of the primary endings of the muscle spindle, which influences agonist muscle contraction while antagonists are simultaneously inhibited (Rothmuller & Cafarelli, 1995). Further, according to Cardinale & Bosco (2003), the acute enhancement of neuromuscular performance after vibration is probably related to an increase in the sensitivity of the stretch reflex. Furthermore, vibration appears to inhibit activation of antagonist muscles through Ia-inhibitory neurons, thus altering the intramuscular coordination patterns leading to a decreased braking force around the joints stimulated by vibration.

Although no significant differences was found in jumping performance in gymnasts that exposed in WBVSS and WBV condition the percentage improvement of WBV was greater in SJ and CMJ variables compared to WBVSS condition (figure 2). The WBVSS revealed a slight improvement by 0.49% and 0.52% in SJ and CMJ, respectively a finding that opposed those of Kinser et al (2008) which found that vibration stretching group showed a decrease by -0.9% and -0.6% in SJ and CMJ, respectively in young female gymnasts.

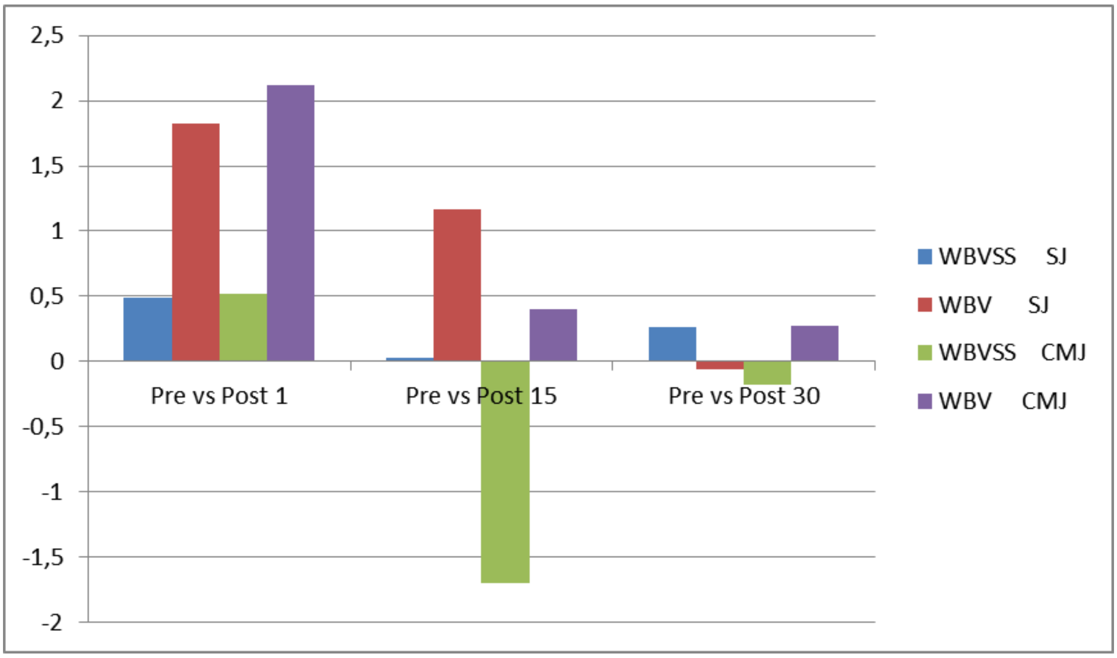


Figure 2. *Percentage improvements in SJ and CMJ test by two different conditions.*

Moreover, the no significant difference in explosive strength of lower limbs between pre and post measurements in WBV condition verify previous finding of Kinser et al (2008) that found an improvement by 0.4% in CMJ but a decrease by -0.9% in SJ. The corresponding improvement in our study was 1.82% and 2.12% respectively, for the SJ and CMJ measurements. In addition, our findings support results of previous studies (Armstrong et al, 2010; Cormie et al, 2006) that found a slight increase in CMJ after a 30- until 60-second vibration treatment, and those of Wyon et al, 2010, which suggest that WBV training has a beneficial effect on vertical jump height. Moreover, it is mentioned that negative effects of vibration is reported only after 2-8 hours daily use, whereas studies that have shown evidence for an elevated risk of health are referred to long term exposure to WBV and not on those that examine the acute effect of WBV on different kinds of subjects.

CONCLUSIONS

In conclusion, this study demonstrates that both conditions (WBVSS and WBV) can enhance flexibility, while at the same time their jumping performance not only was detrimental but maintained for at least 15 minutes. Additionally, the lack of any detrimental WBVSS effect of this method in jumping performance, suggests that this approach seems to be effective and can be applied from gymnasts in pre event activities & in sport performance. Further, the fact that WBV enhance flexibility may be useful in some settings as a neuromuscular warm-up in preparation for explosive sport events.

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Corresponding author:

Dallas George, National and Kapodistrian University of Athens, Department of Physical education and Sport Science

E-mail: gdallas@phed.uoa.gr

Address: Chloes & Chrisoupoleos, 19002 Paiania, Athens Greece

Mobile phone: +0030 6936 592 665

FAX: +0030 210 727 6028