Effects of Vibration Training Combined with Plyometric Training on Muscular Performance and Electromyography

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Abstract: backgrounds: Complex training has been recommended as a method of incorporating plyometrics with strength training. However, there are some safety issues during heavy strength training. Purpose: To investigate whether the vibration stimulation can instead strength training as pre-loading method when perform Complex training. **Methods**: there were two experiments. Division I: 12 Subjects are accepted by three kinds of different vibration frequency (20, 30, 40Hz) respectively by two kinds of different amplitude (2-4, 4-6mm). The isokinetic (peak torque) and electric physiological activation (integral EMG, iEMG) are measured for deciding which frequency and amplitude were most suitable in vibration training. Division II: 24 male collegiate athletes were randomly assign to three groups: complex training group (CT, vibration+ plyometrics); plyometrics training group (TP, plyometrics only); control group (C). After eight weeks training, we compared isokinetic strength, power performance and synchronized electromyography activity before and after the period of training separately. **Results:** There were significantly enhancement of the peak torque, and power both in CT and TP. However, iEMG was significantly difference between two experimental groups. **Conclusion**: With 20Hz (frequency) and 4-6mm (amplitude) vibration stimulation are most suitable in vibration training; the vibration stimulation can instead strength training as pre-loading method when perform Complex training; Plyometrics training (depth jump on sandlot) can significantly improve leg muscular performance. [Life Science Journal. 2010; 7(1): 78 – 82] (ISSN: 1097 – 8135).

Keywords: post-activation potentiation, complex training, vibration training, plyometric training, depth jump, muscular performance, Electromyography.

1. Introduction

Twitch torque is increased after a brief submaximal or maximal voluntary contraction (MVC). This occurrence has been attributed to as post-activation potentiation (PAP) [1] enhanced twitch potentiation and reflex potentiation has been reported following contractile activity such as a series of evoked twitches. The probable mechanism responsible for PAP is the phosphorylation of myosin regulatory light chains during the conditioning activation that raises sensitivity of actin-myosin to Ca2+ released by the sarcoplasmic reticulum[2].

In performance conditioning fields, based on the opinion of PAP, alternating a high-load weight training exercise with a dynamic exercise such as plyometrics performance has been used [4]. For example, Young et al. [3] have observed that loaded vertical height was Significant increased 2.8% by achieving a 5 repetitive maximum (RM) half-squat exercise previous to the jump test.

Two methods, resistance and plyometric training, are usually referred to the literature as improving the most powerful strength characteristics (explosive strength). Several investigations have demonstrated the “Complex training” that result from the application of these methods, reporting higher increases in the explosive strength indicators [4].

Complex training has been recommended as a method of unifying plyometrics with strength training. [5] Some research propose that plyometric performance is strengthened after the strength training. Strength training can evoke higher PAP of more motor units to increasing plyometric training effects.

Acute vertical whole-body vibration (WBV), inducing rapid eccentric/concentric effects of the leg extensors [6], improves performance of these muscles in the short-term [7]. This transient effect is thought to be mediated by a rapid reflex-mediated stretch-shortening likely to involve the tonic vibration reflex (TVR), which stimulates the muscle spindles [8]. Nearly, WBV application leads to enhanced anaerobic power [8]. It is possible that acute WBV enhances muscular performance consequently, in part, through PAP; however, this theory remains untested.

Therefore, the aim of this study was to investigate whether the vibration stimulation can instead strength training as pre-loading method when perform Complex training, in terms of PAP and strength effect of conditioning contraction, through recording of power characteristics, voluntary torque, and electromyographic activities of the muscles involved. We hypothesized that PAP affects dynamic torque production performed voluntarily and improving of voluntary dynamic performance.

2. Materials and Methods

2.1 Subject

24 collegiate athletes subjects with no history of orthopedic or neuromuscular disorders volunteered for this study. Basically all the subjects had the squatting ability more than 1.5 times body weight. The subjects were fully informed of the procedures used, the possible risks, and the purpose of the study. Written informed consent was obtained from all subjects prior to the investigation. This study was approved by the ethical committee of the Faculty of Sport Sciences at National

Taiwan Collage of Physical Education and was consistent with their requirement for human experimentation.

2.2 Experimental Protocol

Division I: Optimal vibration combination (frequency × amplitude)

12 Subjects are accepted by three kinds of different vibration frequency (20, 30, 40Hz) respectively by two kinds of different amplitude (4-6mm, 2-4mm). The isometric (peak torque) and electric physiological activation (iEMG) are measured for deciding which frequency and amplitude were most suitable in vibration training. Maximal voluntary contractions of the hamstring and quadriceps muscles occurred in a seated position utilizing the Isokinetic Biodex system 3 (Shirley, NY, USA) testing dominant isometric strength. One MVC was performed before the treatment, and one MVC was performed after the treatment. Single MVC trials were utilized to prevent any confounding effect of additional MVC trials on fatigue and PAP. All MVCs were 3 seconds in duration, and for all trials, subjects were instructed to develop maximal force as quickly as possible.

Division II: Vibration stimulation instead strength training as pre-loading application

24 male collegiate athletes were randomly assigned to three groups: complex training group (CT, vibration+ plyometrics); plyometrics training group (TP, plyometrics only); control group (C). There were twice training courses on Tuesday and Friday every week. The vibration parameters were developed from Division I optimal combination. The depth jump program was dropped from 70 cm height platform to sandlot, whenever feet reached the ground jumping up as high as possible. After eight weeks training, we compare isokinetic strength, power performance and synchronized electromyography activity before and after the period of training separately.

2.3 Isokinetic test

Isokinetic concentric/eccentric knee extension and flexion were measured using a calibrated Biodex system 3 (Shirley, NY, USA). A specially designed chair was used which allowed for the various thigh lengths of the subjects. At all testing sessions, a standardized procedure included a warm-up of 2-min cycling on a Monark cycle ergometer 814E (Monark, Varberg, Sweden) at a moderate intensity and 2 minutes of stretching the hamstring and rectus femoris muscles before the knee test. The dominant limb, determined from kicking preference, was used for assessment. Subjects were prepared for a seated position and the axis of rotation of the dynamometer lever arm was aligned with the lateral epicondyle of the knee. The force pad was placed approximately 3 cm superior to the medial malleolus with the foot in a plantar flexed position. The subject was asked to relax their leg so that passive determination of the effects of gravity on the limb and lever arm could be measured. Ranges of motion (ROM) for the knee test during concentric actions were 90 degrees and 15degrees for eccentric actions, due to the need for an applied preload torque of the eccentric limits. This reduction in ROM for eccentric actions was made necessary by the need for the preload activation torque that could not be performed at the terminal of the ROM, especially in the aged subjects. To ensure full extension, anatomical 0 deg was determined as maximal voluntary knee extension for each subject. Testing occurred at 30 deg·s–1. Subjects were guided to push the lever up, and pull it down, as hard and as fast as possible with extension/flexion undertaken first for concentric actions. For eccentric actions, subjects were instructed to opposing the lever arm with extension as the first movement. The subjects performed three maximal efforts to determine maximal peak torque during CON/CON and ECC/ECC cycles. A 2-min rest period was given between cycles with CON actions tested before ECC actions. All subjects were encouraged to give a maximal effort for each action by using both visual feedback and strong verbal encouragement.

Division I: Optimal vibration combination (frequency × amplitude)

operation	W	S	R	V	R	V	R	V	R	V	R	Knee isometric test
time	5’	5’	2’	1’	2’	1’	2’	1’	2’	1’	2’	+ EMG

Division II: Vibration as pre-loading application

operation	W	S	V	R	V	R	V	R	V	R	P	R	P	R	P	R	P
time	5’	5’	1’	2’	1’	2’	1’	2’	1’	2’	1’	2’	1’	2’	1’	2’	1’

TP ⟷ ⟷
CT ⟷

Ps. W, cycling warming up; S, stretch; V, vibration(optimal vibration combination (frequency × amplitude) in Division I); R, rest; P, plyometrics; F,finish.

Figure 1. Experimental protocols in optimal vibration combination and vibration as pre-loading application.

2.4 Vertical Jumping Testing.

Vertical jump height was determined using a force platform with specifically designed software (jymmy jump platform, Kistler, Switzerland). Jump height was determined as the centre of mass displacement calculated from force development and measured body mass. Two types of vertical jumps were performed: squat (SJ) and counter-movement (CMJ) jumps. SJ was started from a static semi-squatting position with a knee angle of 90 deg of knee flexion, followed by subsequent action, during which the leg and hip extensor muscles contracted concentrically. In CMJ, each subject stood erect on the force platform and performed a preparatory movement down to approximately 90 deg of the knee flexion, stretching the leg extensor muscles (eccentric contraction), followed by an explosive maximal extension in the opposite direction (concentric contraction).

2.5 Electromyography recording.

During the different experimental operation, EMG from the hamstring and quadriceps muscles was measured. The myoelectric signal was collected through the use of a telemetry transmitter (8 channel, 12-bit analog to- digital converter; Noraxon USA, Inc., Scottsdale, AZ). The amplified myoelectric signal was detected by a receiver– preamplifier and then sent to an

A/D card. The signal was full-wave rectified and filtered (6-pole Butterworth notch filter 60 Hz, band pass filter 10–200 Hz). The integrated value (mV϶s) was calculated and then averaged to determine IEMG (mV) for the working operation. Custom designed EMG programs written in Noraxon package program (Noraxon USA, Inc., Scottsdale, AZ) were used for recording and analyzing the EMG data.

2.6 Statistical analyses

Statistic analyses were performed using SPSS for Windows (Version 10.0, SPSS, Inc., and Chicago, Illinois, U.S.A.). Using data from a similar study, the sample sizes in the present study were deemed to be adequate based on the calculated effect sizes (ES = [Post-measurement mean – pre-measurement mean]/pooled standard deviation) [9] and a minimum statistical power of 0.80. Each parameter that had multiple trials was subject to 1-way repeated measures analysis of variance (ANOVA) to produce the most stable representation for that parameter. Bonferroni pairwise comparisons were used as a post hoc analysis if significant differences were found ($p<0.05$). The initial analysis included a 1-way ANOVA to explore baseline (pretest) values for each parameter of interest. If there was a significant group effect, then a Bonferroni pairwise comparison was utilized as a post hoc analysis. Repeated measures (Group*Time point, percent change) analysis of covariance (ANCOVA) performed on percent change values were used if significant group differences were found at baseline for any of the jump parameters to allow for relevant covariates to be added to the analysis. Because the depth jump and squat jump parameters (height [cm], peak power [W], peak power/kg [W/kg], and mean power [W]) were assessed pre– post vibration for three groups, 2-way ANOVA or ANCOVA was used to compare group percent changes in these variables. Percent change was calculated as ([[Post value – pre value]/pre value] ×100). Bonferroni corrections were used when multiple comparisons were calculated to account for inflation of alpha. Statistical significance was set at $p <0.05$.

3.Results

3.1 Optimal Vibration Combination

The isometric force of dominant leg measured in different combinations (20Hz×2-4mm, 20Hz×4-6mm, 30Hz×2-4mm, 30Hz×4-6mm, 40Hz×2-4mm, 40Hz×4-6mm) the first were not different (253.2 Nm, 262.4 Nm, 251.6 Nm, 258.6 Nm, 254.8 Nm, 256.1 Nm; $F=1.203$, $p > .05$) between operation. There were significant different between the means iEMG of rectus femoris (0.296 mV, 0.327 mV, 0.286 mV, 0.267 mV, 0.273 mV, 0.299mV; $F=7.546$, $p < .05$). 20Hz×4-6mm increased significantly

3.2 Vibration as pre-loading application

The isokinetic tests of the knee extensors results indicated statistically significant effects in the same group including maximal concentric force (P=.040; P=.038), and maximal eccentric force (P=.035; P=.062) after 8 weeks CT and TP training. The isokinetic tests of the knee flexors results indicated similar statistically trend. As expected, 8 weeks of training enhance power performance of the muscle: post-training verse pre-training and C values of CT/TP were increased significantly. However, there was no significant indication of improved muscle activation between post-CT and post-TP in flexor.

TABLE 1. Comparision muscular parameters of knee extensor after 8 weeks training.

Parameter	CT(n=8)		TP(n=8)		C(n=8)	
	pre	post	pre	post	pre	post
Maximal concentric force (Nm)	213.0 (49.7)	248.7[ab] (43.9)	221.1 (65.3)	247.2[ab] (50.3)	235.9 (68.8)	237.5 (69.2)
Maximal eccentric force (Nm)	244.3 (44.5)	279.1[ab] (42.1)	249.2 (48.6)	276.3 (56.8)	26.1.4 (73.0)	263.6 (73.4)
Fatigue index (%)	45.2 (6.1)	47.1 (5.9)	44.3 (6.8)	46.6 (5.4)	47.8 (7.2)	48.9 (6.4)
SJ(cm)	44.4 (4.7)	55.5[ab] (7.3)	46.8 (6.7)	51.7[ab] (5.6)	44.6 (7.3)	46.1 (6.3)
CMJ(cm)	51.0 (5.7)	58.3[ab] (7.4)	46.7 (7.1)	53.8[ab] (6.8)	49.5 (6.2)	49.6 (7.5)

Ps. Values are Mean (SEM).

a: vs.pre-in the same group, p<.05; b: vs. post-C, p<.05.

TABLE 2. Comparision muscular parameters of knee flexor after 8 weeks training.

Parameter	CT(n=8)		TP(n=8)		C(n=8)	
	pre	post	pre	post	pre	post
Maximal concentric force (Nm)	115.3 (32.2)	139.8[ab] (38.4)	117.5 (26.3)	138.8[ab] (27.5)	120.2 (41.0)	124.0 (40.9)
Maximal eccentric force (Nm)	128.1 (37.4)	158.8[ab] (41.5)	138.6 (34.3)	163.7[ab] (35.7)	138.7 (41.5)	139.6 (42.1)
Fatigue index (%)	42.5 (5.3)	44.1 (5.1)	44.6 (6.5)	45.4 (5.8)	46.8 (7.5)	47.1 (6.6)

Ps. Values are Mean (SEM).

a: vs.pre-in the same group, p<.05; b: vs. post-C, p<.05.

TABLE 3. Comparision iEMG of knee muscules after 8 weeks training.

Parameter	CT(n=8)		TP(n=8)		C(n=8)	
	pre	post	pre	post	pre	post
rectus femoris (mV · s)	0.284 (0.066)	0.385[abc] (0.083)	0.276 (0.079)	0.311[ab] (0.081)	0.308 (0.095)	0.294 (0.087)
ham string (mV · s)	0.275 (0.082)	0.297[ab] (0.075)	0.278 (0.065)	0.301[ab] (0.075)	0.274 (0.062)	0.270 (0.077)

Ps. Values are Mean (SEM).a: vs.pre-in the same group, p< .05;
b: vs. post-C , p< .05; c: vs. post-TP, p< .05.

4. Discussions

The aim of this study was to investigate the vibration stimulation can instead strength training as pre-loading method when perform complex training. We hypothesized that continuous acute WBV would potentiate the muscle twitch response compared to a centrally mediated effect that would potentiate WBV-induced PAP and perform the plyometrics training effects. Our results support our hypothesis that 20Hz×4-6mm WBV combining explosive power training (CT) induces a higher iEMG level compared to plyometrics only (TP) and Control(C) interventions.

PAP recommended as an increase in muscle performance led by a muscle contractile activity [10] and is estimated by twitch potentiation (TP), or reflex potentiation (RP) [11]. To our knowledge, this is the first time following WBV as pre-loading to enhance explosive power training. The results showed that CT and TP increased muscular concentric/eccentric force and SJ/CMJ, but with no change in fatigue index compared to C. We refer other research that the time approach of TP reached a maximal level 90 s after WBV and returned to base levels after 10 min [12]. It is described that acute WBV improves short-term muscular performance above cycling-only exercise [13]. It means that WBV has the potential to be considered as warm-up modes before explosive power training such as strength, speed and power [13]. Likewise the increase in rate of force development (RFD) from acute WBV is supported by other studies that have reported increases in RFD following high stimulation frequencies (>100Hz) [14]. However, as a result of enhancing RFD, explosive activities such as jumping may be improved if TP is heightened [10, 11]. We set plyometrics training after WBV combined lower frequency (20-40Hz) and interval 1 minute rest in the complex training.

It is well documented that heavy pre-loading exercise regimes such as 3–5 repetition maximum (RM) or MVCs are often implemented prior to short-term activities to induce PAP [3, 16]. Therefore it seems that the pre-loading activity of WBV and plyometrics are needed to be greater magnitude to elicit TP and RP. Our mechanism should be integrated TP and RP. On the basis of molecular level, the solution for PAP has formed around twitch potentiation (TP) and reflex potentiation (RP) [11]. TP is considered to involve the phosphorylation of myosin regulatory light chains making actin and myosin more sensitive to the intracellular Ca2+ signal [15]. This would react more cross-bridge interaction under the same intracellular Ca2+ concentration, which raises the muscle tension for the same absolute level of neural stimulus [16]. However if calcium homeostasis was involved, then one would expect an unbalance change in RFD and PF. It means that WBV could enhance muscle power output.

RP is evoked reflex activity in the spinal cord, by expanding synaptic capacity between Ia afferent terminals and α motoneurones of the muscle [11]. WBV lead muscle contractions through spinal reflexes [6, 13]. It should be intended that WBV is a combination of muscle vibration and voluntary exercise contractions. Therefore, our findings suggest that RP from CT may be more important than TP. Further, it should be noted that using a tendon tap under lower frequency to elicit a stretch reflex response does necessarily provide a extensive measure of spindle sensitivity or its contribution, as there are several factors from which the stretch reflex can be modified either by the excitatory or inhibitory factors of the motoneurone pool and/or the mechanical sensitivity of the muscle spindle itself [17]. We consider that changes in muscle performance from CT are in part caused by neurogenic factors from possible changes in muscle spindle sensitivity [7].

5. Conclusion

In conclusion, we measured the neuromuscular response of working muscles, and our results suggest that CT causes iEMG increasing. Muscular performances studies have shown that weight training induce PAP by heavy pre-load activity which enhances muscular activity [3]. Similarly, CT-WBV is also capable of inducing higher loads through vibration frequency and amplitude that act as a pre-loading movement to activate PAP. With 20Hz (frequency) and 10mm (amplitude) vibration stimulation are most suitable in WBV training; the vibration stimulation can instead strength training as pre-loading method when perform Complex training; Plyometrics training (depth jump on sandlot) can significantly improve leg muscular performance.

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