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The Effects of Whole-Body Vibration Training on Jump Performance in Handball Athletes

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Abstract**—**This study examined the effects of eight weeks of whole-body vibration training (WBVT) on vertical and decuple jump performance in handball athletes. Sixteen collegiate Level I handball athletes volunteered for this study. They were divided equally as control group and experimental group (EG). During the period of the study, all athletes underwent the same handball specific training, but the EG received additional WBVT (amplitude: 2 mm, frequency: 20 - 40 Hz) three time per week for eight consecutive weeks. The vertical jump performance was evaluated according to the maximum height of squat jump (SJ) and countermovement jump (CMJ). Single factor ANCOVA was used to examine the differences in each parameter between the groups after training with the pretest values as a covariate. The statistic significance was set at $p < .05$. After 8 weeks WBVT, the EG had significantly improved the maximal height of SJ (40.92 ± 2.96 cm vs. 48.40 ± 4.70 cm, $F = 5.14$, $p < .05$) and the maximal height CMJ (47.25 ± 7.48 cm vs. 52.20 ± 6.25 cm, $F = 5.31$, $p < .05$). 8 weeks of additional WBVT could improve the vertical and decuple jump performance in handball athletes. Enhanced motor unit synchronization and firing rates, facilitated muscular contraction stretch-shortening cycle, and improved lower extremity neuromuscular coordination could account for these enhancements.

Keywords**—**Muscle strength, explosive power, squat jump, and countermovement jump.

I. Introduction

TEAM handball is a dynamic sport characterized by highly developed motor skills such as speed and agility, reaction speed, explosive power, strength, as well as its coordination A handball match involves a large number of repeated accelerations, sprints, jumps, blocking, pushing and rapid changes in moving directions, i.e. side cutting [2], [3]. It is estimated that male elite handball players often play 50 min in a 60-min match (2 halves of 30 min each-the time spend on the bench) with an average distance of 3.6km covered, of which 10.1% was done at high intensity, and the average intensity during a premier league match is 69% of VO^2max estimated from heart rate recordings (corresponding to 157 beat/min, Michalsik, 2004).

Whole body vibration training (WBVT) is a neuromuscular training method that exposes the entire body to mechanical vibrations as the individual stands on a vibrating platform which has been recently developed and introduced as a as a training tool in athletic settings [4], [5]. The transmission of mechanical oscillations (20–50 Hz) to the body has a strong sensory stimulatory effect on the muscle that can stimulates many biological systems which in turn may lead to physiological changes at numerous levels including stimulation of muscle spindles, joint mechanoreceptors, changes in cerebral activity and changes in neurotransmitter [6], therefore, can affect muscle strength and power, soft tissue flexibility, body balance, neuromuscular conditions, gait parameters and mechanical properties of bones [7].

It has been suggested that strength and power are two important factors in elite handball players [2]. The ability to exert high maximal muscle force and vertical jump height are both of vital importance in modern elite handball match play, however, there is little information in the scientific literature whether WBV may exert an ergogenic effect on jump performance in handball athletes. Therefore, the aim of this study was to determine the effects of a WBVT program with regular handball practice on vertical and decuple jump performance in handball athletes.

II. Methods

Sixteen healthy male elite handball athletes from the Taiwan Level 1 Collegiate league were recruited and volunteered as participants. The study was designed as a controlled, randomized intervention study which all participants were divided equally as control group (CG, mean height: 175.6 ± 5.2 cm, mean mass: 69.9 ± 5.6 kg, mean age: 19.4 ± 0.9 yrs, handball experience: 7.6 ± 3.4 yrs) and WBVT group (WBVTG, mean height: 173.3 ± 4.0 cm, mean mass: 73.3 ± 8.2 kg, mean age: 23.0 ± 4.5 yrs, handball experience: 10.3 ± 3.7 yrs). All participants gave their informed consent and the conditions of the study were approved by the local ethics committee, and fulfilled the following inclusion criteria: competitive athletes of collegiate level, no previous or concomitant injury or surgery on the relevant knee and other joints, no history of surgery or traumatic injuries to the contra lateral limb, full range of motion in the knee, no history of medical problems such as heart disease that limited activities

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and no history of WBVT contraindications for participants of the WBVT group. Persons who were already participating in another strength program were excluded from the study as well.

During the period of the study, all participants underwent the same handball specific training five sessions (4 training and 1 game) per week, but the EG received additional WBVT (amplitude: 2 mm, frequency: 20 - 40 Hz) three time per week for eight consecutive weeks. Each handball training sessions last about 2 h per week, including the warm-up, shooting practice (single and multi-people), position running, group strategy & attack tactic, attack & defense formation, and cool-down. Both groups trained for 6 weeks at a frequency of 3 times a week, with at least 1 day of rest between sessions. Participants were familiarized with testing procedures 2 days before the testing session. In all sessions, each subject was dressed in shorts, without shoes and socks. Our evaluating systems were calibrated before the sessions in accordance with the manufacturer's instructions. The testing session started with a 10 min jogging warm-up program on a treadmill and lower body stretching exercises. Participants were instructed not to eat the last 1.5 h before testing and not to engage in any vigorous training the day before testing. During all tests, participants were allowed to drink water. All players were tested at the same location (research laboratory) to ensure the test environment remained constant. Before participation, all subjects gave their informed written consent

Each player performed a series of jumps tests which included a bilateral standing vertical squat jump (SJ) and count movement jump (CMJ). For these tests, the participant stood stationary on both legs, with the toes aligned level with the start line, before jumping as far forward as possible. Participants were allowed the use of a countermovement with arms and body swing. Two different bilateral standing vertical jumps were used for data recording: squat jump (SJ) and countermovement jump (CMJ). The SJ is a test used to assess lower-body power as well as the ability to recruit motor units. It is performed from the half squat position with a knee angle of 90 degree; after a brief pause, the subject performing the test jumps upward as high as possible. The CMJ is a test used to assess explosive strength with reutilization of elastic energy and takes advantage of the myotatic reflex. The test starts with a preparatory movement of knee extension going down to a 90 degree knee flexion and, without pausing, jumping upward as high as possible. Maximum jump height was assessed on a force plate (Kistler 9281 B, Winterthur, Switzerland) and the vertical ground reaction force signal (Fz) was fed from the Kistler amplifier to a 12-bit A/D converter (2400T, Noraxon, USA) at a 1500Hz sampling rate and stored on a PC as described previously described by Caserotti *et al.* [8], which applying the laws of ballistics: h =1/2g t2; where ''h'' is height, and ''g'' is gravitational acceleration (9.81 m/s2).

Vibration loading was carried out on a WBV platform (DKN Extreme PRO, Taiwan) in a standing position. The program consisted of squatting, deep squatting, wide-stance squatting, 1-legged squatting, calf raises, inversion/eversion movements, jumps onto the plate, and light jumping. After each exercise, the participants were allowed to rest for 2 minutes before starting the following exercise. Training intensity was increased over the 8 weeks by fixed amplitude (2 mm) but increasing the frequency from 20 to 40 Hz of the vibration, the duration of the exercise, and the number of repetitions. Also, the number of repetitions of 1 exercise and the number of different exercises increased systematically over the 8-week training period. During all training sessions, the subjects completed a personal exercise diary and were under the strict supervision of a physiotherapist.

All statistical procedures were performed by using SPSS version for Windows 12 (Chicago, IL, USA). Single factor ANCOVA was used to examine the differences in each parameter between the groups after training with the pretest values as a covariate. Intra-class correlation coefficients (ICC) assessed the test-retest reliability of comparing the mean of the dependent variables between testing sessions. For all analyses, the level of statistical significance was set at $P < .05$.

III. Results

The compliance rate for training program participation was 92%. The ICC test-retest reliability analyses revealed that jump height of SJ (0.82) and CMJ (0.93) were consistent between sessions. Fig. 1 details the SJ and CMJ performance (maximum jump height) before and after training for each group. Comparisons were made between groups pre- and post-training for SJ and CMJ conditions. The results of the ANCOVA for the SJ maximum height indicated a significant differences between groups with post-training scores significantly higher than pre-training scores in the WBVT group (pre: 40.92 ± 2.96 cm vs. post: 48.40 ± 4.70 cm, $F = 5.14$, $p < .05$). In addition, the results of the ANCOVA for CMJ maximum height also indicated a significant differences between the groups with post-training performance being significantly better than pre-training in the WBVT group (pre: 47.25 ± 7.48 cm vs. post: 52.20 ± 6.25 cm, $F = 5.31$, $p < .05$).

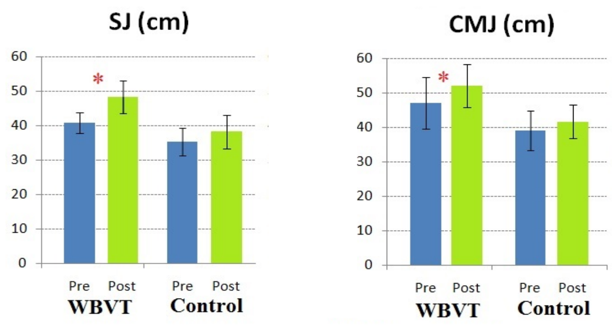

Fig. 1 The jump performance for each parameter between groups before and after training. (Mean ± SD, * represented statistically significant, p < .05)

IV. Discussion

The maximal vertical jump is a common test and a functional measure of lower limb muscular power used by conditioners and coaches in a variety of game sports to monitor the effects of training and/or rehabilitation. It is an established measure of lower body explosive power and, as such, it should be used as part of a battery of tests for assessing the handball player [1], [2]. Additionally, jumping movements generally involve arm drive, so information regarding vertical jump performance with arm countermovement (arm countermovement vertical jump) after WBVT is required and meaningful. Although the significant improvement in jump height (18%, 10%, and 5% improvements in the SJ, CMJ and DJ) seen in this study cannot be directly extrapolated to predict field handball performance, it would have relevance in game situations such as 1-step jumping shoot, changing direction, lunging, and acceleration, where maximal explosive power is important. The fact that the protocol of the present study enhanced jump performance to a greater degree than in previous studies [9], [10] is difficult to explain. In this context, the enhancements in neuromuscular control are needed to provide the necessary edge in elite competition. Moreover, previous studies showing either no change [11], or an increase [9], [12] on jump performance following regular WBVT. Nevertheless, improper control, differences in participants, vibration duration, frequency, and amplitudes, lack of or use of a warm up, and differing exercise positions, may explain the discrepancies in these studies.

WBVT is a novel training intervention performed on a oscillations platform which produce a vertical ground reaction force to each foot that can improved the muscular properties [13]. The rapidly repeating eccentric-concentric contractions presumably evoked, result in muscular work evidenced by a significant improvements in this study. In the present study, WBVT exposure elicits both concentric and eccentric contractions. This study not only utilized the traditional, simple squat jump, but also utilized the arm countermovement vertical and horizontal jump which involves activation of the stretch-shortening cycle, where the stretch receptors are activated under the eccentric loading phase. Given the significant enhancement of jump performance by WBV which demonstrated in this study, it could be speculated that the additional effect of WBV might be due to the eccentric stimuli it provides.

This study demonstrated that regular handball practice with extra WBVT for 8 weeks can significantly improve the vertical (SJ, CMJ) and horizontal (DJ) jump performance about 5-18%. These improvements have been attributed to reflex muscle contractions as a result of a tonic vibration reflex. This reflex contraction is caused by an excitation of muscle spindles, leading to enhanced activity of the Ia loop [14], [15]. In addition, the enhanced muscle power observed following acute vibration is suggested to occur via potentiation of the neuromuscular system whereby stimulation of muscles spindles (Ia afferents) results in reflex activation of motor neurones with increased spatial recruitment [16]. The continued enhancement of the stretch-reflex pathway can also be attributed to the γ motor neuron input causing an increase in sensitivity of the primary endings. Furthermore, the tonic vibration reflex can recruit additional motor units via muscle spindle and polysynaptic activation [10], then 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 [17]. Furthermore, Torvinen *et al.* [12] randomized 56 young adults to either a vibration group or a control (no training) group. Jumping power was enhanced 8.5% after a 4-month WBV intervention. More recently, investigators [4], [18], [19] demonstrated that WBV training has the potential to induce strength gains to the same extent as a traditional resistance training program. Consequently, on the basis of these studies, we can conclude that WBV is a training method equivalent to conventional resistance training.

In conclusion, for the male collegiate handball athletes studied here, implementing a 8-week extra WBVT had positive effects on jump performance, not only improving the maximum vertical jump height in the SJ and CMJ test with only 10 minutes of additional training three times a week. Enhanced motor unit synchronization and firing rates, facilitated muscular contraction stretch-shortening cycle, and improved lower extremity neuromuscular coordination could account for these enhancements. This study demonstrates significant benefits of a 8-week WBVT program, highlight the potential of extra WBVT during the off-season and/or pre-season to improve the jump performance in handball athletes.

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