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Effects of Whole Body Vibration on Spinal Proprioception in Normal Individuals

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Abstract— **Low back pain (LBP) is a common health problem with high reoccurrence rate. While most LBP cases are classified as non-specific, patients in general often present impaired proprioception. Whole body vibration (WBV) has been proven to improve muscle function and proprioception in the lumbo-pelvic region. The aim of this study was to determine whether WBV would affect spinal proprioception. Eleven young normal individuals were recruited. Their body alignment, lumbar repositioning error and lumbo-pelvic coordination during dynamic motion were assessed before and after 5 minutes WBV (18Hz, 6mm amplitude). Assessments were conducted before, immediately after, 30 minutes after and 1 hour after WBV. Subjects were found to have improved lumbo-pelvic coordination and flexibility without any adverse effect on the neuromuscular system after WBV. However, WBV had no significant immediate effect on lumbar repositioning ability and body alignment. Future studies of the effects of different WBV protocols on LBP patients are recommended.**

I. INTRODUCTION

Low back pain (LBP) is a common and costly musculoskeletal disorder with lifetime prevalence around 50-70% and about 80% of patients are classified as having non-specific LBP [1]. With the etiology of LBP still largely unknown and most treatments only moderately effective, reoccurrence rate is high [2].

Spinal proprioception is the perception of spine position and motion, which is essential for spinal motor control [3]. Researchers have hypothesized that proprioception of patients with LBP is likely impaired, based on observed differences between normal and LBP subjects in lumbo-pelvic movement strategy [4], repositioning ability [5] and balancing ability [6]. Proprioceptive deficit would cause excessive joint movement due to delayed muscle reflexes, which may increase chance of injury and LBP reoccurrence [5].

Whole body vibration (WBV) has been widely used as a training exercise in the sport and rehabilitation fields [7, 8]. It has been proposed that WBV could stimulate the muscle spindle primary afferent fibers of the proprioceptive receptors [9, 10]. As muscle function could be improved by WBV [11] and muscle stiffness and joint stability could be modified by mechanoreceptor activity through gamma efferent stimulation [12], WBV has potential for delivering proprioception training.

WBV (6mm, 18Hz) with progressive duration for 3 consecutive months has been shown to be able to relieve pain in LBP patients [13]. It was also shown that there was a significant improvement in repositioning accuracy in pelvic tilting while standing, after receiving 5 minutes of 18 Hz approximately 4mm WBV in normal individuals [14]. As the effects of WBV on spinal dynamic motor control are still not known and whether WBV could be used as a proprioception training for reducing the reoccurrence rate of LBP, this study was proposed. Spinal proprioception of normal individuals was evaluated by a functional reach test and functional spinal stability was assessed using the Dynamical Systems Theory (DST) approach [15, 16]. Moreover, changes in body alignment and repositioning accuracy after WBV were also documented.

It was hypothesized that WBV could improve spinal proprioception, and could be a proprioception training for reducing reoccurrence rate in patients with LBP.

II. MATERIALS AND METHODS

Body alignment, repositioning error and functional reach were measured in male participants before, immediately after, 30 minutes after and 1 hour after WBV. Ten healthy male subjects without known spinal pathologies and other diseases were recruited. Their mean (SD) age, body height and weight were 23.2 (1.2) years, 172.1 (6.3) cm and 63.2 (3.9) kg, respectively. Subjects were not allowed to eat or drink two hours before the study to minimize possible effects of a distended stomach on abdominal region mechanical receptors, and also not to engage in strenuous exercise 24 hours prior to the experiment. Consent forms were obtained from all subjects and ethical approval was obtained from the University Human Ethics Committee before conducting the study.

See-saw type WBV was delivered using a Galileo sport platform (Novetec, Pforzheim, Germany). Subjects underwent WBV at 18 Hz, 6mm amplitude for 5 minutes while maintaining a normal standing posture on the vibrating platform with knees slightly flexed. Amplitude was adjusted to 6mm by setting foot distance 33cm apart and equidistant from the central axis. Subjects were allowed to hold the handle bar if they felt insecure.

An eight-camera motion analysis system (Vicon Nexus, MXF40 cameras, Oxford Metric, UK) was used to monitor positions of spherical retro-reflective markers (15mm diameter) attached to the subjects. Subjects wore only a pair of bicycle shorts during the experiment. All data were sampled at 100 Hz and low-pass filtered at 3 Hz [17]. Static and dynamic calibrations of the motion analysis system were conducted prior to every experiment with mean average error less than 0.25mm.

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Body alignment measurement included spinal curvature and lower limb posture. Spinal curvature was measured using markers attached on the chin and the spinous processes of C7, T2, T5, T7, T12, L3 and S1 [18]. Pelvic tilt, knee and ankle angles were measured by markers attached bilaterally to the anterior superior iliac spines and posterior superior iliac spines as well as great trochanter, femoral condyle, lateral malleolus, heel and second metatarsal head (Fig.1). Subjects were instructed to stand in their normal upright stance with hands rested aside and feet separated at a comfortable distance. Feet position was marked on the floor while subjects looked at a target two meters in front of them at eye level. The markers positions were recorded for 3 seconds in this position. The subjects were then asked to walk around a 6-meter loop, returning to the same position and upright stance for another 3 seconds for capturing marker position again. This process was repeated 5 times and the mean angles of the 6 trials were used as spinal curvature and body alignment measurements.

In the repositioning error test, subjects were blindfolded and sat on a rigid stool, with hips and knees kept at 90 degrees, shanks out of contact with the stool legs, feet at shoulder width, and arms on the thighs in a relaxed manner [19]. Subjects were asked to perform three times maximum lumbar flexion, and then positioned by the researcher to a criterion position, which was a neutral upright spinal posture. They were given 5 seconds to remember the criterion position and were asked to relax into full lumbar flexion for 5 seconds then reproduce this position five times. Repositioning error was defined as the difference in lumbar flexion angle relative to the pelvis between the 6 trials and criterion position. Repositioning error was expressed in terms of absolute error, variable error and constant error for denoting the error direction, consistency and magnitude respectively.

In functional reach test, a marker was attached to the ulnar head for defining the onset of each movement cycle. Maximum reach distance of each subjects were first acquired by asking subjects to slide the bar on a yardstick at shoulder height as far as possible without taking a step or losing balance. Two practice trials were given before the mean of 3 subsequent trials was measured as the maximum reach distance, from which the function reach target was determined as the halfway distance of maximum reach distance. Subjects were then asked to reach for the target reaching point using the trunk and pelvis as if reaching over a cupboard without taking a step over a period of 3 seconds, and then restore the upright position in the following 3 seconds with the aid of a metronome. Each movement cycle consists of 6 second reach and return. Subjects would be required to perform an additional cycle if they failed to touch the target or maintain a steady pace of motion. Three cycles were performed within each trial and three warm-up trials were given before the data of the fourth trial were used in data analysis. Angular displacements of the lumbar spine and pelvis in each forward and backward motion were time-normalized to 120 points. Phase angles were calculated by arc tangent of velocity of each body segment divided by its own displacement. Continuous relative phase curves were derived from the phase difference between the lumbar spine and the pelvis. To quantify the change in continuous relative phase curves, two parameters namely mean absolute relative phase (MARP) and deviation phase (DP) were calculated using the equations proposed by Stergiou et al. [20]. These parameters were used to quantify the phasic relationship between the two interested segments and pattern stability throughout the reaching process respectively. Smaller MARP represented more in-phase lumbar-pelvis coordination while smaller DP represented more stable movement pattern and vice-versa.

As only angles in the sagittal plane were analyzed, all the data were firstly projected onto a sagittal plane defined by the bilateral anterior superior iliac spines. Changes in body alignment angles, absolute error, variable error, constant error and maximum reaching distance before, immediately after, 30 minutes after and 1 hour after WBV were analyzed using repeated measure analysis of variance (ANOVA) while 2-way repeated measure ANOVA was used to study the differences in MARP and DP in different movement direction (i.e. forward, backward) and assessment periods. Statistical software (IBM SPSS Statistics 20, Inc., Chicago. IL, IBM, USA) was used for data analysis with level of significance set at p=0.05 and LSD criterion was adopted for post-hoc comparisons.

III. RESULTS

There was no significant change in body alignment and all repositioning errors (Fig. 2, 3 and 4) after WBV. However, maximum reaching distance was significantly increased immediately after WBV (mean=37.7cm; P<0.001), and this increment maintained 30 minutes (mean=37.4cm; P=0.020) and 1 hour after WBV (mean=37.4cm; P=0.020) (Fig. 5) than that before WBV (mean=36.0cm). MARP was significantly decreased immediately (mean=19.3°; P=0.005) and 30 minutes after WBV (mean=19.6°; P=0.017) compared to that before WBV (mean=27.8°) in the forward direction (Fig. 6). In the backward direction, MARP immediately after WBV was significantly increased (mean=22.0°; P=0.029) compared to that before WBV (mean=29.1°). but significantly reduced compare to that 1 hour after WBV (mean=27.1°; P=0.024). There was no significant difference of DP before and after WBV. For both MARP and DP, movement direction and all interactions were not significantly different (Fig. 7).

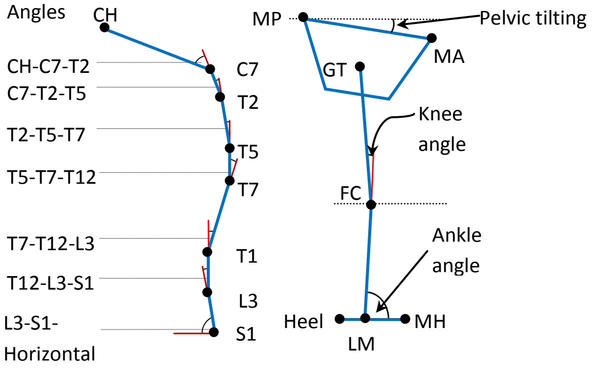

Figure 1. Definitions of various angles of body alignment. Spinal curvature is demonstrated on the left and on the right are lower limb angles. CH = chin; MP = mid-point of posterior superior iliac spines; MA = mid-point of anterior superior iliac spine; GT = great trochanter; FC = femoral condyle; LM = lateral malleolus; MH = second metatarsal head.

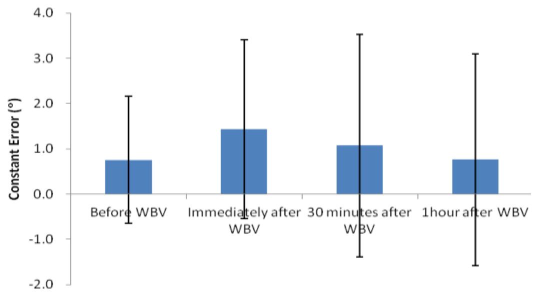

Figure 2. Mean and standard deviation of absolute error before and periods after whole body vibration

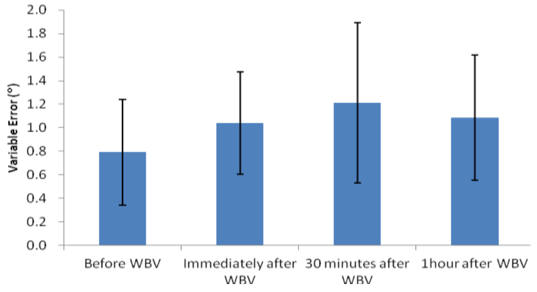

Figure 3. Mean and standard deviation of variable error before and after whole body vibration

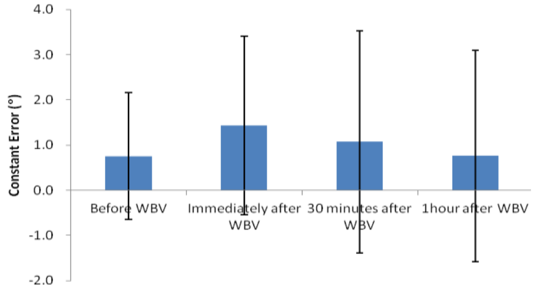

Figure 4. Mean and standard deviation of constant error before and periods after whole body vibration

IV. DISCUSSION

Spinal stability is essential for biomechanical function and is achieved by three subsystems, i.e. active musculoskeletal, passive musculoskeletal and neural feedback subsystems [26]. The neural feedback subsystem consists of mechanical receptors located in the muscles and tendons, which are part of the active and passive musculoskeletal force and motion feedback. These receptors provide proprioception which together with the visual and vestibular systems provides dynamic updates of body position in relation to the environment during locomotion and navigation [26]. These receptors are essential for providing proprioception for spinal motor control. Hence different tests were performed in this study to thoroughly investigate the effects of WBV on spinal proprioception.

As the functional reach test assesses balancing ability and postural activity of the lower limb and trunk muscles [21], significant increase in MRD after WBV demonstrated an improvement in balance and postural control from WBV. This effect persisted 1 hour after WBV. MARP was found to be significantly reduced immediately after WBV. Although the original coordination pattern was restored in 1 hour, the reduced MARP immediately after WBV suggested that the coordination between the lumbar spine and pelvis was improved after WBV, showing that proprioception of the subjects in dynamic motion improved. This may be due to activation of the Ia afferent fibers and α-motor neurons by repetitive stimulation of the back muscles during WBV [22, 23], causing an increment in flexibility. These collective findings may explain the improvement of motor function and pain relief in LBP patients after receiving 12-week WBV treatment, which further justified that WBV is able to modify proprioception in the lumbopelvic region [14]. Moreover, it is of no surprise that WBV did not cause significant change in DP, since significant changes in this value may imply pathology and only healthy subjects were used in this study [16].

Significant change of in body alignment could not be observed before and after WBV. This may suggest that proprioceptive changes caused by WBV in functional reach were not caused by postural changes.

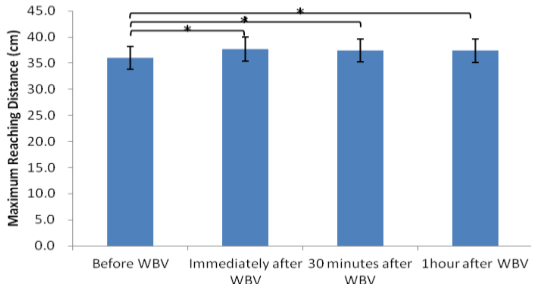

Figure 5. Mean and standard deviation of maximum reaching distance before and periods after whole body vibration

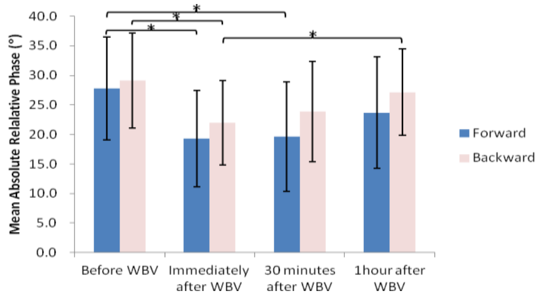

Figure 6. Mean and standard deviation of mean absolute relative phase before and periods after whole body vibration

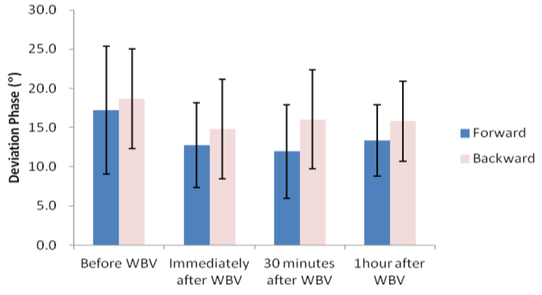

Figure 7. Mean and standard deviation of deviation phase before and periods after whole body vibration

In the repositioning test, subjects were asked to reposition a seated posture in this study instead of standing to eliminate the lower limb afferent input [24]. In this study, significant decrease of repositioning error after WBV could not be observed in normal subjects as compared to Fontana et al. [14]. However, a similar trend could be observed in the mean absolute and constant error in all periods after WBV, in which error initially increased and then decreased to a level lower than that before WBV. This suggests that WBV has some effect on repositioning ability, though this effect was not demonstrated to be significant in this study.

Lack of investigation of long term effects of WBV on the subjects was one of the limitations of this study. Additionally, as normal subjects were used, the positive outcomes of this study are not necessarily applicable for LBP patients. Moreover, paper surgical tape attaching the markers might have provided extra proprioceptive input to the subjects during the repositioning task but minimal tape was used to decrease this issue.

Overall, this preliminary study suggested that 5 minutes of low frequency WBV has an immediate positive effect on proprioception in terms of lumbo-pelvic coordination and reaching function, although this was not demonstrated by seated repositioning ability. No apparent adverse effect was observed after WBV. In future studies, using the same protocol on LBP subject would investigate whether the same positive effects could be used to counteract pain and improve compromised proprioception. Different postures and vibration variable may also be tested for use in therapy.

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