

THE EFFECTS OF WHOLE BODY VIBRATION ON POSTURAL CONTROL: THE FREQUENCY OF STIMULATION

Deniz Simsek^{1*}, İzzetKirkaya, A. RuhiSoylu², OlgunUgurlu, A. OnurCerrah¹, HayriErtan¹

Anadolu University, Faculty of Sports Science, Eskisehir, Turkey¹

School of Medicine, Biophysics Department, Hacettepe University, Ankara, Turkey²

This study investigated the efficacy of high and low-frequency acute whole-body vibration (WBV) on postural control ability. WBV stimulus were applied the following determinants: (1) type (vertical) (2) frequency (30 and 40 Hz), (3) stance position (static squat position), (4) amplitude (4mm mm), (5) knee flexion angle (120°) and time (60s). Motion of the point of application of the vertical component [medio-lateral (ML) and antero-posterior (AP)] of the ground reaction force (center of pressure, COP). The study results showed that static WBV stimuli given at low and high frequencies and 4 mm amplitude resulted in a different postural adaptation ($p < 0.05$). The somatosensory stimulation more rapidly adapted to the vibration at 40 Hz-4 mm.

KEYWORDS: center of pressure, vibration, post-effect, postural orientation.

INTRODUCTION: In the daily life, people need to remain standing for more than a couple of minutes while having a conversation with someone, waiting in line, or working. During such normal standing, the body shows postural changes characterized by whole body motions continuously at low amplitude and slow sway. The center of pressure (COP), occasionally referred to as a force line, is defined as the centroid of the pressure distribution at a series of moments in time as ground reaction is applied over the plantar surface of the foot. Such changes are particularly important during athletic activities, since performing a motor activity during athletic activities requires maintaining balance against the factors that disrupt both the external (such as walking on slippery ground, changes in light, vibration, etc...) and internal (such as muscle stiffness, muscular-skeletal injuries, fatigue, etc...) balance (Maurer et al., 2000; Peterka, 2002; Horak and MacPherson, 1996).

The postural system responds to vibrational body sway by shortening the length of the muscle. The effects of vibration given to the postural muscles depend on the region of application, as well as the magnitude and duration of the vibration (Wierzbicka et al., 1998, Kavounoudias et al., 1999 a,b). In the present study, was aimed to investigate the effects of the duration of the proprioceptive stimuli on postural orientation and postural balance. The hypothesis of present study that postural orientation during whole body vibration is directly associated with the duration and frequency of stimulation.

METHODS: Subjects: Sixteen healthy subjects (age 25.4 ± 5.3 years; weight 70.2 ± 0.01 kg; height 176.9 ± 6.7 cm), who had no contraindication associated with WBV, as per the manufacturer's recommendations (epilepsy, diabetes, gallstones, kidney stones, acute inflammations, joint problems, cardiovascular diseases, joint inflammation, thrombosis, and back problems such as hernias or tumours), were included in the study. The study was approved by the local ethics committee.

Vibration and force data acquisition: Before the experimental protocol, an exercise session was performed with all subjects to adjust them to the WBV sensation. The subjects were asked to perform unloaded static squats with a knee flexion angle of 120° . Knee joint angle changes were monitored by an electronic goniometer and the subjects received instantaneous feedback via a computer screen. All experimental conditions lasted for 60

seconds and the measurements were initiated when the subjects were comfortable to perform a comfortable squat on the platform. Vibration applications were presented to the subjects in random order by dividing the two trials into two blocks of one trial. After each trial, the subjects relaxed for approximately 5 minutes. The subjects were taken on the force platform and the force measurements were performed before and right after the vibration measurements. Anterior-posterior (fx) and Medio-lateral (fy) force values were analysed. During measurements, a 600x400x100 mm "Kistler (Germany) 9281EA" force platform was used. Force data were obtained at 2000 Hz and normalized according to the body weight. The rms (root-mean-square) values of every consecutive 500 ms of post-vibration force data were calculated and normalized by body weight. Then, 10 subject's weight normalized curves were averaged for curve fitting. The first 10 s of normalized and averaged post vibration force data was curve-fitted to an exponential equation, $F = k \cdot \exp(-t/T)$ where F: force, t: time, k and T are positive constants. Similarly, the last 10 s of normalized and averaged post vibration force data was curve-fitted to a linear equation, $F = a \cdot t + b$ where F: force, t: time, a and b are constants.

RESULTS: The results for ground reaction forces are displayed in Figures 1(a-b), with the anterior-posterior (fx) and medio-lateral (fy) force values.

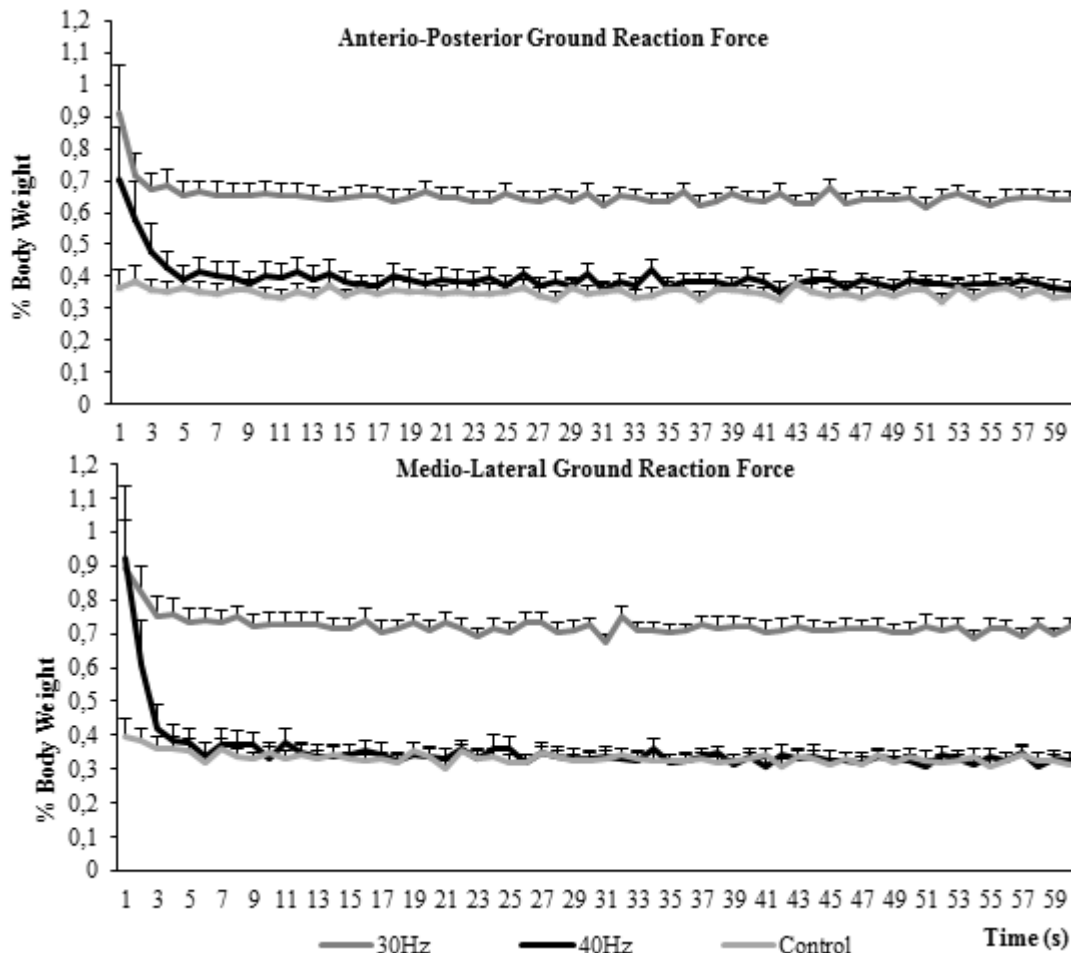


Figure 1. Mean ground reaction forces (expressed as a percentage of body weight) and the standard error of the mean after 30 and 40 Hz frequencies and 4mm amplitude in the AP and ML axis.

DISCUSSION:In the present study, the postural responses representing the effects of whole body proprioceptive input given at 30 Hz, 40 Hz frequencies and 4 mm amplitude on human balance control were analysed. The data revealed a rapid exponential decline in the force platform measurements obtained immediately after whole body vibration given at 30 Hz, 40 Hz frequencies and 4 mm amplitude, within the first 10 seconds. After the initial 10 seconds, Cop position was maintained at the same plateau until the end of the 60-second period. A similar time course was previously presented by Hayashi et al. (1981) and Polonyová and Hlavačka (2001). On the other hand, some researchers argue that a proprioceptive chain extending from the eyes down to the feet underlies the postural sway and postural control caused by vibration, and the afferent signals produced by all interconnected body segments are processed by the sensory system. Following whole body vibration given at different frequencies, the mechanism responsible for the sudden exponential decrease observed in the first 10 seconds of the 60-second Cop sway values and the linear a maintained after then, can be associated with the strong and sustained effects of the 1a sensory discharge and small afferent fibres in the motor system at a postural level. Additionally, these fibres play an important role in the responses caused by vibration. Secondary endings can be easily activated by vibration. It is well known that the secondary endings are well suited to measure the length (changes in the muscle length); however, the primary endings react both to the length and the change ratio. Primary muscle spindle endings represent the major response during the stretching phase but the secondary endings are activated both during stretching and shortening (Burke et al., 1976). Therefore, the primary spindle endings are considered to be responsible for the sharp Cop change observed in the first 10 seconds, whereas the secondary spindle endings are likely mainly associated with the exponential decline seen after the first 10 seconds (Hayashi et al., 1981; Wierzbicka et al. 1998). Not only the effects of vibration on the reflexes given at the spinal level, but also its simultaneous effects on the central motor commands should be considered.

CONCLUSION:In conclusion, the findings of the present study suggest that the body struggles to adapt faster to maintain balance with increasing frequencies of vibration 40 Hz and 30 Hz vibration results in longer use of the neural circuits to maintain the postural control. This study design can be improved by applying a longer duration of vibration and a greater duration of rest between the vibration applications, with isometric contractions. The post-effects of vibration on postural control can be helpful for rehabilitation studies.

REFERENCES:

- Adamcová, N, Hlavačka, F. (2004). Human Postural Responses to Leg Muscle Vibration Altered by Visual Scene Motion. *Physiol Res* 53: 5P, 2004.
- Horak, F.B. Macpherson, J.M. (1996). *Postural Orientation and Equilibrium. Exercise: Regulation and Integration of Multiple Systems. In: Handbook of Physiology*, Shepherd, J. Rowell, L. (eds), Oxford University Press: New York. pp 255-292.
- Kejonen, P. (2002). Body Movements during Postural stabilization. Unpublished Master Thesis, University of Oulu, Oulu, Finland, 2002.
- Maurer, C.Mergner, T. Bolha, B. Hlavačka, F. (2000). Vestibular, Visual and Somatosensory Contributions to Human Control of Upright Stance. *Neurosci Lett* 281: 99-102
- Peterka, R.J. (2002). Sensorimotor Integration in Human Postural Control. *J Neurophysiol* 33: 1097-118, 2002

Acknowledgement

The current study has been supported by Anadolu University (Project number: Anadolu Uni./BAP 1207S116).