TRANSMISSION OF VIBRATION ABOUT THE KNEE

Trentham Furness, Corey Joseph, Bianca Share, Geraldine Naughton, Wayne Maschette & Christian Lorenzen

Centre of Physical Activity Across the Lifespan, Australian Catholic University, Melbourne, Australia

The purpose of this study was to examine and describe effects of knee flexion angle, stance width and vibration platform frequency on the transmission of vertical acceleration about the knee. Fifteen adults were exposed to various vibration conditions while standing on a side-to-side vibration platform. Vertical acceleration data, expressed as transmission, were shown to be attenuated for all vibration conditions. A larger degree of knee flexion however, was conducive to greater attenuation about the knee. Such information may be used to develop vibration training programs with a more thorough understanding of effects of vibration.

KEYWORDS: transmission, vibration, root mean square acceleration

INTRODUCTION: The mechanistic understanding of improved performance following vibration is uncertain. Specifically, the transmission of vibration throughout the body is not thoroughly understood. When someone stands on a vibration platform, a transmission value can be calculated to assist with the description of the magnitude of the vibration imposed on body landmarks. Generally, a transmission value does not discriminate between wobbling masses and ridged bodies, yet the value may be useful in identifying the rate of vibration absorption inter- and intra-individually.

Previously, transmission has been calculated by placing accelerometers on a vibration platform and the knee (Harazin & Grzesik, 1998), head (Abercromby et al., 2007), shank and thigh (Cook et al., 2010), pelvis and spine (Mansfield & Griffin, 2002) or directly into bone (Nsiah et al., 2006). Some methods are more invasive than others, yet an acknowledged error is created when accelerometers are mounted to skin. A data correction method to eliminate effects of local tissue-accelerometer resonance from surface measurements of vibration about the spine was proposed (Kitazaki & Griffin, 1995), yet since then, correction methods have not always been used.

Recently, skin-mounted accelerometers were shown to minimally affect impact accelerations during gait compared with bone-mounted accelerometers (Nsiah et al., 2006). As such, skin-mounted accelerometers were thought of as a good predictor of skeletal impact accelerations. Another study used a three-dimensional motion analysis system to measure transmission of vibration in order to eliminate error associated with skin-mounted accelerometers (Smith, Bressel & Snyder, 2009). For field work however, laboratory procedures are often unsuitable. Therefore, field studies generally acknowledge the limitation of skin-mounted accelerometers but implement their use because of ease of operation and transportability.

Our previous pilot study had validated accelerometers for measuring vibration platform frequency (Joseph & Furness, 2009). To further that work, the purpose of this study was to explore and describe effects of knee angle, stance width and platform frequency on transmission of vibration measured by skin mounted accelerometers.

METHODS: Fifteen healthy females and males (mean age = 19.6 years ± 1.4, stature = 1.76 m ± 0.08, mass = 70.5 kg ± 10.6) freely consented to participate in the study. Participants were free from muscular injury in the previous month and had no known joint injuries. Each participant randomly received 6 bouts of side-to-side vibration delivered by a sinusoidal oscillating vibration platform (Vibro-Trainer Semi-Commercial, Amazing Super Health, AUS). Each bout lasted 60 seconds and consisted of a predetermined stance posture and stance width while vibration platform frequency was randomly assigned. Stance posture consisted of

20º, 40º and 60º knee flexion, where 0º knee flexion corresponded with full knee extension. Stance width was 10 cm and 20 cm from the axis of rotation for each leg. Vibration platform frequency was 20 Hz, 25 Hz and 30 Hz. Data were collected for five seconds at each frequency after platform steady state had been achieved. The project had University Human Research Ethics Committee approval.
The independent variables were; (1) vibration platform frequency (20 Hz, 25 Hz, 30 Hz), (2) stance width (10 cm, 20 cm) and knee flexion angle (20º, 40º, 60º). The dependent variable, transmission, was calculated from the ratio of root mean square (RMS) knee acceleration (K_{RMS}) to RMS platform (P_{RMS}). A transmission value of 1.00 represented parity between the platform and knee. A transmission value less than 1.00 represented a larger P_{RMS} than K_{RMS} (figure 1).

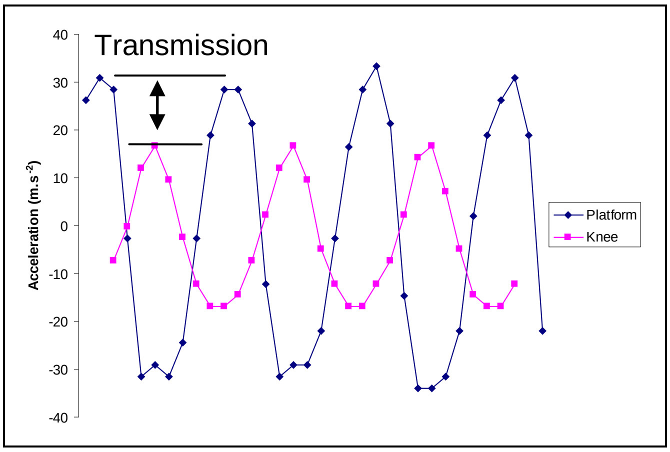

Figure 1. An example of transmission, where the maximum acceleration about the knee is less than the maximum acceleration of the platform. For this example, the transmission value would be < 1.00. Note, data are m.s^{-2} rather than RMS since negative values are squared when calculating RMS values.

Two 25 *g* tri-axial accelerometers (CXL25GP3, Crossbow Technology, San Jose, USA) sampling at 250 Hz were used to quantify vibration platform vertical acceleration and knee vertical acceleration. The mass of each accelerometer was 46 gm. One accelerometer was attached to the vibration platform with double sided adhesive tape. Another accelerometer was firmly taped to the left patella of a participant to reduce skin movement. Knee flexion angle was constant for each vibration bout and checked with a manual goniometer. The accelerometer was checked for vertical alignment during each vibration bout.
Knee flexion angle was filmed with a digital camcorder (NV-GS11, Matsushita Electric Industrial Co., Osaka JPN) and digitised with Siliconcoach Pro 7 (Siliconcoach, San Francisco, USA). Small reflective markers (1 mm diameter) were adhered on the skin to the right; greater trochanter, lateral condyle and lateral malleolus. Data were filmed for each knee flexion angle independent of stance width and vibration platform frequency.
Left leg length was measured with the ‘total true shortening’ method (McRae, 1999). A tape was placed from the left anterior superior iliac spine to the left medial malleolus. The participant lay in the supine position. The average of two reading was recorded. These data were recorded since it was thought leg length may affect vibration transmission.
Data were imported to SPSS 17.0 for Windows (SPSS Inc., Chicago, USA). Descriptive statistics were calculated to quantify sample statistics, root mean square, knee angle and vibration transmission.

RESULTS: Sample descriptive statistics are shown in table 1. Acceleration about the knee and platform are shown in table 2. Acceleration was 28.55 m.s^{-2} for 40º knee flexion, 20 cm stance width and 30 Hz platform frequency.

Table 1. Sample Descriptors

Sex	n	Stature (m)		Mass (kg)		Left leg length (cm)	
		mean	SD	mean	SD	mean	SD
Female	7	1.72	0.08	63.76	7.16	88.71	4.69
Male	8	1.80	0.07	76.35	9.71	93.19	3.93

Table 2. Knee and Platform Acceleration for Vibration Platform Frequencies, Stance Widths and Stance Postures

	20 Hz		25 Hz		30 Hz	
	10 cm	20 cm	10 cm	20 cm	10 cm	20 cm
	mean (SD)	mean (SD)	mean (SD)	mean (SD)	mean (SD)	Mean (SD)
20º	7.85 (3.63)	10.30 (2.06)	14.42 (5.10)	20.01 (2.16)	17.27 (4.91)	28.35 (7.26)
40º	8.53 (2.35)	12.07 (2.84)	10.10 (2.16)	22.96 (6.38)	24.62 (6.08)	28.55 (7.85)
60º	5.89 (1.96)	9.52 (3.14)	13.34 (5.59)	16.09 (5.40)	17.36 (3.43)	24.03 (5.49)
Platform	19.13 (1.57)		30.02 (3.92)		47.19 (4.02)	

Transmission of vibration about the knee is shown in table 3. At 30 Hz, for example, a 20 cm stance width and 60º knee flexion angle caused a transmission value of 0.53. Generally, the 60º knee flexion stance posture elicited greater transmission about the knee.
Table 4 shows variability of pre-determined stance postures during each vibration bout. Although the 20º knee flexion stance posture was most accurately maintained, variability across all stance postures was almost identical.

Table 3. Transmission of Vibration About the Knee for Various Vibration Platform Frequencies, Stance Widths and Stance Postures

	20 Hz		25 Hz		30 Hz	
	10 cm	20 cm	10 cm	20 cm	10 cm	20 cm
20º	0.73	0.67	0.87	0.74	0.57	0.68
40º	0.80	0.69	0.54	0.80	0.83	0.64
60º	0.57	0.57	0.77	0.55	0.57	0.53

Table 4. Pre-determined Stance Postures and Actual Knee Flexion Angles by 'Siliconcoach'

Pre-determined knee flexion angle	Exact	
	Mean	SD
20º	22.1º	4.2º
40º	36.6º	4.1º
60º	54.7º	4.2º

DISCUSSION: The major finding of this study was that knee angle, stance width and vibration platform frequencies concurrently affected transmission when standing upon a vibration platform (table 3). The 60º knee flexion stance posture generally caused the lowest transmission values suggesting that vibration was attenuated about the lower limbs to a greater extent than other stance postures. Knee angle however, was varied (table 4). The finding may be supported by previous work of electromyogram (EMG) data. Several authors have reported increased EMG activity of vastus lateralis during vibration with an isometric squat of 55º knee flexion (Roelants et al., 2006; Cardinale & Lim, 2003). Future research should concurrently investigate transmission and EMG activity to further understand biological responses to vibration.
Methods of this study allowed quantification of transmission despite the known limitation of skin-mounted accelerometers. The accelerometers as such, were sufficiently sensitive enough to detect such transmission attenuation. Though we did not quantify the error of

potential skin-accelerometer resonance, the error appeared consistent rather that sporadic and may explain the variance of acceleration (table 2).

Since a common goal of vibration exercise was to improve muscular strength and power in various target populations, future research should first justify a training protocol and second monitor the effectiveness of the protocol throughout the intervention. To date, reports of vibration transmission pre-, during- and post-intervention are not reported in the literature. Such knowledge may enhance understanding of biological mechanisms manipulated by vibration training.

Since we have shown that various independent variables concurrently affect vibration transmission, we propose it should be reported and monitored in all vibration protocols. Not surprisingly, effects of vibration training on transmission are unknown about the knee and other body landmarks.

CONCLUSION: Collectively knee flexion angle, stance width and vibration platform frequency affect transmission of vibration. Future research should measure vibration transmission about various body landmarks and in both healthy and sub-optimal health populations in an effort to determine the most appropriate vibration training protocol.

REFERENCES:

Abercromby, A., Amonette, W., Layne, C., McFarlin, B., Hinman, M., & Paloski, W. (2007). Variation exposure and biodynamic responses during whole-body vibration training. *Medicine & Science in Sports & Exercise, 39*(10), 1794-1800.

Cardinale, M., & Lim, J. (2003). Electromyography activity of vastus lateralis muscle during whole-body vibrations of different frequencies. *Journal of Strength and Conditioning Research, 17*(3), 621-624.

Cook, D., Mileva, K., James, D., Zaidell, L., Goss, V., & Bowtell, J. (2010). Triaxial modulation of the acceleration induced in the lower extremity during whole-body vibration training: A pilot study. *Journal of Strength and Conditioning Research,* (in-press).

Harazin, B., & Grzesik, J. (1998) The transmission of vertical whole-body vibration to the body segments of standing subjects. *Journal of Sound and Vibration, 215*(4), 775-787.

Joseph, C., & Furness, T. (2009). Concurrent validity of an accelerometer to quantify vibration platform frequency. *Proceedings of the 7th Australasian Biomechanics Conference*, November 30-December 1, Gold Coast; ISBN: 978-0-646-52474-0, page 44.

Kitazaki, S., & Griffin, M. (1995). A data correction method for surface measurement of vibration on the human body. *Journal of Biomechanics, 28*(7), 885-890.

Mansfield, N., & Griffin, M. (2002) Effects of posture and vibration magnitude on apparent mass and pelvis rotation during exposure to whole-body vertical vibration. *Journal of Sound and Vibration, 253*(1), 93-107.

McRae, R. (1999). Pocketbook of orthopaedics and fractures. Edinburgh: Churchill Livingston.

Nsiah, B., Edwards, B., Meardon, S., Ward, E., Derrick T., & Sharp, R. (2006). Spectral analysis of impact accelerations using bone versus surface mounted accelerometers. *Medicine & Science in Sports & Exercise, 38*(5), S267.

Roelants, M., Verschueren, S., Delecluse, C., Levin, O., & Stijnen, V. (2006). Whole-body-vibration-induced increase in leg muscle activity during different squat exercises. *Journal of Strength and Conditioning Research, 20*(1), 124-129.

Smith, G., Bressel, E., & Snyder, E. (2009). Whole body vibration: Mapping of transmission with high speed motion analysis. *Medicine & Science in Sports & Exercise, 41*(5), 88.

Acknowledgement

The authors would like to thank Sofie Synahiris of Amazing Super Health for the use of the vibration platform.