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Neuromuscular and functional adaptations to whole body vibration exercise in older adults

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BA (Human Movement Studies) (Hons)

This thesis is submitted to fulfill the requirements for the degree of Doctor of Philosophy at the University of Technology, Sydney, September, 2008.

Certificate of Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written solely by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Dedication

This thesis is dedicated to Mum and Dad.

Abstract

The ageing process is associated with sarcopenia; a reduction in muscle mass, strength and power. Sarcopenia is responsible for diminished physical performance; it affects the ability to perform activities of daily living and can severely impact quality of life in older age. There is potentially no age group that can benefit more from interventions to combat reduced muscle strength and power than an older population. Whole body vibration (WBV) is a relatively new exercise intervention. WBV is suggested to improve strength and power by stimulating the neuromuscular system and inducing reflex muscle contractions. The potential for WBV to be used as a strength training intervention for an older population was the rationale behind this thesis.

Study one was an investigation of the effects of eight weeks WBV on a range of physical performance measures in a healthy, older population. Forty three, older adults (73.5 ± 4.5 yr, 168.2 ± 10.5 cm, 74.5 ± 11.1 kg) were divided into three groups: 15 to a WBV group (VIB), 13 to an exercise without vibration group (EX) and 15 into a control group (CONT). The VIB and EX group interventions consisted of three sessions per week for eight weeks. Outcome measures included isokinetic flexor and extensor strength of the hip, knee and ankle, one-legged postural steadiness (OLPS), sit-to-stand performance (STS), fast walk time and stair mobility.

Following the eight week intervention, the VIB group significantly improved OLPS compared to the EX and CONT groups ($p<0.05$). The improvements in OLPS were

significantly affected by baseline values, with the largest changes evident for VIB participants with a poorer initial score ($p<0.01$). WBV exercise can improve OLPS in a healthy, older population. As improvements in OLPS were related to baseline values, WBV as an intervention would appear to serve the most benefit for those that exhibit diminished postural control.

The VIB group significantly improved ankle plantar flexor strength compared to the EX and CONT group (18.2%, 5.0%, 0.9%) ($p<0.05$). The VIB and EX groups both significantly improved knee extension strength compared to the CONT (8.1%, 7.2%, -2.0%) ($p<0.05$). There were no effects for hip flexor or extensor strength. The VIB and EX groups both showed improved STS (12.4%, 10.2%) and 5m fast walk (3.0%, 3.7%) compared to the control ($p<0.05$). There were no effects for stair mobility performance. While WBV exercise can be considered a plantar flexor strength training intervention, it appears to have a disproportional effect on lower limb strength. WBV did not facilitate knee extensor strength or physical performance measures to a greater degree than the same exercise program without vibration. The comparable change in physical performance measures between the VIB and EX groups appears linked to similar gains in knee extensor strength. Further, these similar knee extensor strength improvements appears linked to the same body weight squats performed by both the VIB and EX groups.

To explore the disproportional change in lower limb strength found in study one, study two was designed to investigate the neuromuscular activation of the ankle, knee and hip flexors and extensors during WBV. Ten healthy, older male participants (70.4 ± 4.9 yr, 176.9 ± 7.8 cm, 78.6 ± 12.0 kg) completed a number of static exercises with

and without WBV. Activation of the soleus, gastrocnemius, tibialis anterior, vastus medialis, rectus femoris, biceps femoris, iliopsoas and gluteus maximus were recorded unilaterally with electromyography (EMG). EMG amplitude was normalised and analysed with respect to each individual's maximum isometric strength values. The absolute increases in EMG with vibration, above the non-vibration condition, were compared between muscle groups and exercise conditions. The increase in neuromuscular activity with WBV was significantly larger in the soleus and gastrocnemius than muscles higher up the leg ($p<0.05$). Furthermore, the increase in gastrocnemius neuromuscular activity was greatest when participants maintained a heel raise position. It appears that WBV should be prescribed as an exercise intervention that intends to specifically train the triceps surae musculature.

The results of study one and two suggested WBV be considered a localised strength training intervention for older individuals which predominately targeted the plantar flexors. The aim of study three was to examine the efficacy of WBV for a frail, elderly population; to validate plantar flexor strength improvement with WBV and examine the neuromuscular mechanisms associated with this adaptation. Seventeen frail, older participants (88.2 ± 3.6 yr, 166.8 ± 8.2 cm, 71.7 ± 11.4 kg) were divided into two groups: ten to a WBV group (VIB) and seven to a control group (CONT). The VIB group undertook WBV three times per week for four weeks. Outcome measures included isometric and isokinetic plantar flexor strength, single leg balance performance and EMG of the gastrocnemius. The EMG signal was analysed for amplitude and median power frequency. EMG amplitude was normalised with respect to each individual's maximum isometric strength values.

WBV had no effects on single leg balance performance in a frail, older population. This result is in contrast to study one that found significant improvements in OLPS in a population of healthy, older adults. In contrast to study one participants, the frail older adults in study three were unable to exercise on the WBV platform without firmly grasping the handlebars for support. The difficulty maintaining balance whilst undertaking WBV exercise is suggested to be a mediating factor behind the improvements in balance observed in study one but not three.

Following the WBV intervention, the VIB group significantly improved isometric (40.5%) and isokinetic (32.4%) plantar flexor strength compared to the CONT group (1.5%, 2.9% respectively) group ($p<0.05$). The WBV group displayed a significant 32.3% increase and a 8.3% decrease in right medial gastrocnemius EMG peak amplitude and EMG median power frequency respectively during isometric plantar flexion ($p<0.05$). WBV can be considered an effective training intervention to improve plantar flexor strength in frail, older adults. It is speculated that increased plantar flexor strength with WBV exercise be explained at least in part by an improvement in motor unit synchronisation and efficiency.

KEYWORDS: Ageing, whole body vibration, exercise, strength training, balance.

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List of Abbreviations

ABS	Australian Bureau of Statistics
AGS	American Geriatric Society
ADL	Activities of daily living
ANOVA	Analysis of variance
ATP	Adenosine triphosphate
ATP_{ase}	Adenosine triphosphatase
bpm	Beats per minute
CONT	Control group
cm	Centimeter
CNS	Central nervous system
CSA	Cross sectional area
DLLE	Dynamic lower limb exercises
EMG	Electromyography
EMG_{rms}	Electromyography root mean square
ES	Effect size
EX	Group undertaking exercise without vibration training
F_{med}	Median frequency
g	Gravitational force - Earth's gravitational acceleration at sea level
GTO	Golgi tendon organ
Hz	Hertz
ICC	Intraclass correlation coefficient
ISO	International Organisation for Standardisation
kg	Kilogram

min	Minute
mm	Millimetre
mM	Millimoles
ms	Milli seconds
mmHg	Millimetres of mercury
Nm	Newton meters
$Nm \cdot kg^{-1}$	Newton meters per kilogram
OLS	One-legged stance
OLPS	One-legged postural steadiness
r	Correlation
RFD	Rate of force development
ROM	Range of motion
RPE	Rating of perceived exertion
s	Seconds
SD	Standard deviation
SF-36v2	Short form 36 question health survey version two
STS	Sit to stand
SWBK	Standing with bent knees
TEM%`	Technical error of measurement percentage
TUG	Timed up and go test
TVR	Tonic vibration reflex
VIB	Group undertaking whole body vibration training
WBV	Whole body vibration
yr	Year
%BW	Percentage of body weight

List of Publications

Sven Rees, Aron Murphy and Mark Watsford (2007). Effects of vibration exercise on muscle performance and mobility in an older population. *Journal of Aging and Physical Activity*, 15(4), 367-381

Sven Rees, Aron Murphy and Mark Watsford (2008). Effects of vibration exercise on postural steadiness in an older population. *Journal of Science and Medicine in Sport,* doi:10.1016/j.jsams.2008.02.002

Sven Rees, Aron Murphy and Mark Watsford (2008). The effects of whole body vibration exercise on lower extremity muscle strength and power in an older population: A randomized clinical trial. *Physical Therapy*, 88(4), 1-9

Conference Presentations

Sven Rees, Aron Murphy, Mark Watsford and Robert Lockie. The effects of vibration training on postural steadiness in a healthy, older population. Australian Association for Exercise and Sports Science Conference, September/October 28-1, 2006

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