Eur J Appl Physiol
DOI 10.1007/s00421-011-1984-2

ORIGINAL ARTICLE

Synchronous whole-body vibration increases VO_2 during and following acute exercise

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Received: 14 January 2011 / Accepted: 25 April 2011

Abstract Single bout whole-body vibration (WBV) exercise has been shown to produce small but significant increases in oxygen consumption (VO_2). How much more a complete whole-body exercise session (multiple dynamic exercises targeting both upper and lower body muscles) can increase VO_2 is unknown. The purpose of this study was to quantify VO_2 during and for an extended time period (24 h) following a multiple exercise WBV exercise session versus the same session without vibration (NoV). VO_2 of healthy males ($n = 8$) was measured over 24 h on a day that included a WBV exercise session versus a day with the same exercise session without vibration (NoV), and versus a control day (no exercise). Upper and lower body exercises were studied (five, 30 s, 15 repetition sets of six exercises; 1:1 exercise:recovery ratio over 30 min). Diet was controlled. VO_2 was 23% greater ($P = 0.002$) during the WBV exercise session versus the NoV session (62.5 ± 12.0 vs. 50.7 ± 8.2 L O_2) and elicited a higher ($P = 0.033$) exercise heart rate versus NoV (139 ± 6 vs. 126 ± 11 bpm). Total O_2 consumed over 8 and 24 h following the WBV exercise was also increased ($P < 0.010$) (240.5 ± 28.3 and 518.9 ± 61.2 L O_2) versus both NoV (209.7 ± 22.9 and 471.1 ± 51.6 L O_2) and control (151.4 ± 20.7 and 415.2 ± 51.6 L O_2). NoV was also increased versus control ($P < 0.003$). A day with a 30-min multiple exercise, WBV session increased 24 h VO_2 versus a day that included the same exercise session without vibration, and versus a non-exercise day by 10 and 25%, respectively.

Keywords Vertical vibration training · Energy expenditure · Fat mass loss · Strength training · Oxygen uptake · Metabolic rate

Introduction

Over the past decade, whole-body vibration (WBV) exercise has become an increasingly popular training modality. Although occupational vibration exposure (i.e. sitting driving large equipment) is unhealthy, WBV exercise which involves shorter intermittent exposures at much greater vibration frequencies has been proposed to be beneficial in several ways. In theory, the vertical oscillations generated via a platform induce short and rapid changes in muscle fibre length which stimulate reflexive muscle contractions in a response akin to monosynaptic reflexes (Cardinale and Bosco 2003; Hagbarth and Eklund 1966; Ritzmann et al. 2010). These vertical oscillations may also increase instability (Abercromby et al. 2007) or cause a muscle tuning response via one's attempt to dampen the transmission of the vibration signal (Wakeling and Nigg 2001).

Regardless of the mechanism responsible, acute WBV exercise (both synchronous and side-alternating) has been shown to increase muscle activity, blood flow, and muscle/skin temperature (Abercromby et al. 2007; Cardinale and Lim 2003; Cochrane et al. 2008; Hazell et al. 2007, 2008, 2010; Marin et al. 2009; Ritzmann et al. 2010; Roelants et al. 2006) and has even been reported to increase strength, power, and performance (Bosco et al. 1999; Cormie et al.

Communicated by William J. Kraemer.

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2006; Da Silva-Grigoletto et al. 2009; McBride et al. 2010; Ronnestad 2009; Torvinen et al. 2002a). However, there are also data showing little effect (de Ruiter et al. 2003; Erskine et al. 2007; Guggenheimer et al. 2009; Torvinen et al. 2002b) perhaps indicating that a wide range of exercise intensities are possible with WBV exercise.

Completing static and dynamic squats on a WBV platform (side-alternating) increased measured $VO_2 \sim$ 3–5 ml kg^{-1} min^{-1} compared to the same exercise without vibration (Rittweger et al. 2001). Moreover, we have demonstrated minimal cardiovascular stress (heart rate, blood flow, or mean arterial pressure) with the addition of WBV to a static semi-squat position (Hazell et al. 2008) suggesting that static WBV exercise is not a very strenuous form of exercise. However, dynamic WBV squats at least with an external load (35–40% body mass) can increase VO_2 significantly (up to ~50% of $VO_{2\max}$; Rittweger et al. 2001, 2002) indicating that the stimulus can be substantial. The greatest increase in VO_2 (0.7 ml kg^{-1} min^{-1}) versus NoV during dynamic squatting was seen while performing a 2 s squat cycle (1 s down 1 s up; Garatachea et al. 2007) compared to slower squatting cadences (4 or 6 s cycles). During five sets of loaded (10 repetition max) dynamic squats (11.5 min), the addition of WBV (side-alternating) significantly increased VO_2 (1.7 ml kg^{-1} min^{-1}) versus the same exercise without vibration and by an additional 1.6 ml kg^{-1} min^{-1} during the 5 min of recovery (Da Silva et al. 2007). Although these increases in oxygen consumption during and immediately following WBV exercise versus no vibration exercise are small [only ~2 L O_2 (~45 kJ)] in 16.5 min, they are likely underestimates because recovery collections were so brief that any anaerobic energy contribution would have been missed. How much more strenuous a more complete whole body dynamic exercise session (multiple exercises targeting both upper and lower body muscle groups) is unknown.

The purpose of this study was to quantify VO_2 during and for an extended time period following (24 h) a multiple exercise WBV exercise session versus the same exercise session without the addition of vibration in order to determine the potential of WBV exercise as part of a program to enhance body composition. It was hypothesized that WBV exercise would increase 24 h VO_2 relative to the same exercises without vibration and, of course, to a non-exercise control day.

Methods

Protocol overview

Oxygen consumption of healthy male Kinesiology students ($n = 8$) was measured for 24 h to assess the effect of a WBV exercise session versus the same exercises session without vibration (NoV). Participants (26 ± 2.3 years, 180 ± 8.2 cm, 84 ± 10.1 kg, 17 ± 6.1% body fat) first completed a 24 h VO_2 collection with each of three treatments [WBV, NoV, and no exercise (control)] without measurement during exercise. Subsequently, they repeated the two exercise sessions exactly as before (including the overnight fast and breakfast) but with VO_2 measurement during the exercise. Three individuals were unable to return for the during exercise measurements due to scheduling problems and were replaced with three others of matching gender, age, height, body mass, body composition, and fitness levels (during exercise participants = 26 ± 3.0 years, 179 ± 8.3 cm, 85 ± 7.3 kg, 19.7 ± 6.0% body fat; $n = 8$). To avoid order effects, the three treatments were administered via systematic rotation. No physical activity was performed for at least 24 h prior to participation and both physical activity and diet (see below) were controlled throughout the experiment. All participants were physically active but none were involved in an exercise training program at the time of the data collection or for at least 4 months prior to the study. None had any contraindications to WBV according to the manufacturer's criteria (i.e. diabetes, epilepsy, gallstones, kidney stones, acute inflammations, joint problems, cardiovascular diseases, joint implants, recent thrombosis, back problems such as hernia, tumors, recent operative wounds, or intense migraines) and all passed the PAR-Q health survey (Thomas et al. 1992). The study was completed in winter and spring (January-April). The Health Sciences Office of Research Ethics at The University of Western Ontario approved this study and all participants gave their written informed consent prior to any testing.

Exercise session

The exercises used were dynamic and involved the major muscle groups of both the upper and lower body. A 1:1 exercise to recovery ratio (30 s exercise:30 s recovery) was used. Specifically, participants completed five sets of each of six exercises paced by a metronome at a rate of 15 repetitions in 30 s because a 2-s cycle has been shown previously to increase energy expenditure (Garatachea et al. 2007). This resulted in 15 min of exercise over the 30-min protocol. The exercises for the lower body included squats (feet on the platform), single leg lunges for each leg (lead foot on the platform), and hamstring bridges (laying supine, feet on the platform and repetitions involving elevating the trunk). The upper body exercises included push-ups and triceps dips (hands on the platform). Blocks were utilized for the upper body exercise, lunges, and hamstring bridges so that the hands and feet that were off the platform remained at the same height as the platform. Body mass was the resistance and range of motion was controlled with a goniometer.

The WBV stimulus was applied using a WAVE$^{\mathrm{TM}}$ platform (Whole-body Advanced Vibration Exercise, Windsor, Canada; Koonar 2006). This platform generates a synchronous (vertical; strictly the *z*-axis) vibration stimulus whereby the platform oscillates up and down uniformly (Ritzmann et al. 2010). The WBV stimulus was set at a frequency of 45 Hz and a peak-to-peak displacement of 2 mm (verified via single frame analysis of high speed video) because we have shown previously this protocol increases leg skeletal muscle EMG significantly (Hazell et al. 2007, 2010). Importantly, the platform compensates for differences in individual body mass via a load levelling system® so each subject received the same vibration stimulus. Briefly, this works by placing the vibration platform in the same initial position regardless of body mass, using inflatable air bladders. We have verified system performance with masses up to 180 kg (data not shown). The NoV exercise session was performed on the same platform with the vibration turned off.

Oxygen consumption

All measurements were made by indirect calorimetry using an online breath by breath gas collection system (Vmax Legacy, Sensor Medics, Yorba Linda, USA). The system was calibrated according to the manufacturer's recommendations before testing using gases of known concentration and a 3 L syringe. Subjects were fitted with a silicone gas collection face mask (7400 series Vmask$^{\mathrm{TM}}$, Hans Rudolph Inc., Shawnee, USA) with an attached seal (Sensa Seal$^{\mathrm{TM}}$, Hans Rudolph Inc., Shawnee, USA) to prevent air leakage during the measurement period.

Oxygen consumption (test retest reliability = 0.801) was monitored over eight, 30-min periods before, during, and following the exercise session. Before and following exercise measures were made while subjects were lying supine in a temperature/humidity controlled chamber (21°C, 11% relative humidity). The first 15 min of the 30-min collection was discarded, breath by breath data were averaged over 30 s and expressed as litres of O_2 min^{-1} for each of the collection periods. Exercise measures were taken continuously and also averaged over 30 s. Heart rate (HR) was measured using a HR monitor (Polar RS200sd$^{\mathrm{TM}}$, Polar Electro Inc., Lachine, Canada).

Experimental protocol

Subjects arrived at the laboratory in the morning (0800 h) after an overnight fast (no food/drink, except water after 2000 h the previous day) having limited their physical activity getting to the laboratory (driven and used the elevator). They remained in the laboratory over the next 9 h. Breakfast (0830–0845 h) and lunch (1230–1245 h) were provided and dinner was reproduced for all three conditions (nutrient details below). Oxygen consumption was measured from 0800 to 0830 h (baseline), from 0845 to 0915 h (pre-treatment), from 0915 to 0945 (during exercise or rest), from 0945 to 1015 h (immediately post-treatment), from 1200 to 1230 h (2 h post-treatment), from 1245 to 1315 h (3 h post-treatment), and from 1600 to 1630 (6 h post-treatment) (Fig. 1). Subjects relaxed quietly reading between measures. At 1630 h, subjects were allowed to leave the laboratory but did not perform any further exercise the rest of the day. Finally, the subjects reported back to the laboratory the following morning (0800 h) after another overnight fast and VO_2 was re-measured (recovery baseline). For the control day, subjects repeated the entire protocol exactly but rested quietly from 0915 to 0945 h.

Total oxygen consumed

To determine the total amount of oxygen consumed over 8 and 24 h, the VO_2 (L min^{-1}) was plotted at the midpoint of each collection time period and the trapezoid method was used to calculate the area under the curve for all three treatments (Jacobsen et al. 2005; Melby et al. 1993).

Diet

Dietary control was maintained by providing all subjects with breakfast and lunch in the laboratory. For breakfast, participants consumed a 29 kJ kg^{-1} meal (~72% carbohydrate, 15% fat, and 13% protein) which consisted of yogurt (150 g), orange juice (236 ml), and an appropriate amount of cereal (16 kJ kg^{-1}) determined by their body mass. For lunch, they ate a 46 kJ kg^{-1} meal (~55% carbohydrates, 27% fat, and 18% protein) consisting of a sub-

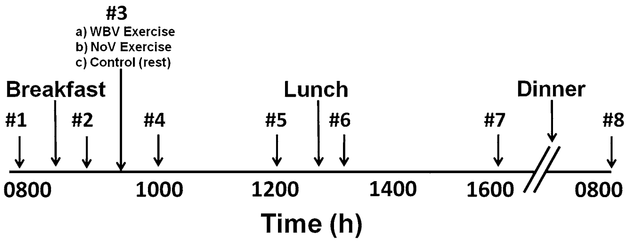

Fig. 1 Protocol timeline. *Arrows* indicate measurement time points. #1: Baseline (0800–0830 h), #2: pre-treatment (0845–0915 h), #3: during exercise or rest (0915–0945 h), #4: immediately post-treatment (0945–1015 h), #5: 2 h post-treatment (1200–1230 h), #6; 3 h post-treatment (1245–1315 h), #7; 6 h post-treatment (1600–1630 h), and #8: recovery baseline (0800–0830 h next day). Breakfast was a 29 kJ kg^{-1} meal at 0830–0845 h, lunch was a 46 kJ kg^{-1} meal at 1230–1245 h and dinner was a 50 kJ kg^{-1} meal in the evening

sandwich (6 in.; meatball), 1% chocolate milk (500 ml), and an appropriate amount of cereal bar (16 kJ kg^{-1}) depending on the body mass. Further, each participant recorded their evening food intake (50 kJ kg^{-1} meal; ~39% carbohydrate, 30% fat, and 31% protein) on the first day and reproduced it for the subsequent treatments.

Familiarization

Prior to any data collection, each participant completed a familiarization trial, with all exercises that were to be utilized during the experimental sessions while wearing the VO_2 collection mask. As part of this session, each participant's body composition was assessed (via air displacement), as described previously (Noreen and Lemon 2006).

Statistics

All data were analyzed using Sigma Stat for Windows (version 3.5, Systat Software Inc., Point Richmond, USA). One-way repeated measures analyses of variance (ANOVA) were used to determine differences among the three treatments (WBV exercise session, NoV exercise session, and control) for total 8 and 24 h VO_2, as well as for average HR and total VO_2 during the exercise sessions. Separate, two-way repeated measures ANOVA (treatment × time) were used to investigate the differences in VO_2 and RER at all measurement time points. The intraclass correlation coefficient (ICC) for VO_2 was 0.73 (95% CI: 0.52–0.92) and for RER the ICC was 0.41 (95% CI: 0.23–0.69). All data are presented as mean ± SD, and the level of statistical significance was set at $P < 0.05$. Post hoc tests were performed using Tukey's HSD tests.

Results

Exercise oxygen consumption

WBV increased the average exercise VO_2 during the exercise session by 19% versus the NoV exercise session (2.082 ± 0.399 vs. 1.689 ± 0.272 L min^{-1}; $P < 0.001$). The total oxygen consumed during the exercise session (including between repetition and set recovery) was also greater with WBV by 23% versus NoV (62.5 ± 12.0 vs. 50.7 ± 8.2 L O_2; $P = 0.002$; Fig. 2).

Average exercise respiratory exchange ratio

Exercise RER appeared to be greater with WBV but the observed difference only approached statistical significance (WBV = 0.99 ± 0.05 vs. NoV = 0.95 ± 0.03; $P = 0.068$).

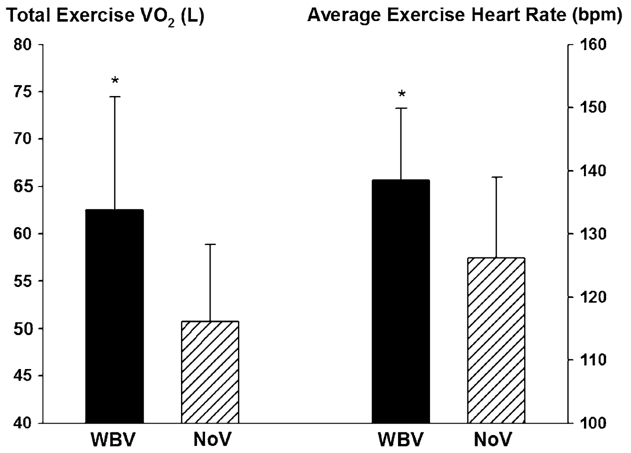

Fig. 2 Total oxygen consumed (L) and average heart rate (bpm) during the WBV and NoV exercise sessions. Subjects performing the WBV exercise session consumed more oxygen (+12 L; $P = 0.002$) and had greater heart rates (+10 bpm; $P = 0.068$) compared to the NoV

Average exercise heart rate

The WBV exercise session elicited a greater HR compared to the NoV exercise session (137 ± 11 vs. 127 ± 13 bpm; $P = 0.022$; Fig. 2).

Oxygen consumption

There was a significant ($P < 0.001$) interaction (treatment × time) for VO_2. Both exercise sessions increased VO_2 versus CTRL over time; however, only the exercise (0915–0945) and the immediately post-exercise measure (0945–1015 h) were statistically significant (Fig. 3). At both these time points, WBV VO_2 was greater than NoV ($P = 0.003$) and CTRL ($P < 0.001$) while NoV VO_2 was greater than CTRL ($P < 0.042$).

Respiratory exchange ratio

There was a significant ($P < 0.001$) interaction (treatment × time) for RER; however, only the immediately post-exercise measure (0945–1015 h) was affected significantly (Fig. 4). At this time point, the WBV (0.68 ± 0.06) RER was significantly lower than both NoV (0.72 ± 0.05; $P = 0.017$) and CTRL (0.86 ± 0.04; $P < 0.001$) and NoV RER was significantly lower than CTRL ($P < 0.001$).

8-h total oxygen consumption

Total VO_2 over 8 h was increased by 15% for WBV versus NoV (240.5 ± 28.3 vs. 209.7 ± 22.9 L O_2; $P = 0.004$) and by 59% over the CTRL day (151.4 ± 20.7 L O_2; $P < 0.001$; Fig. 5a). The NoV condition was 39% greater than CTRL ($P < 0.001$).

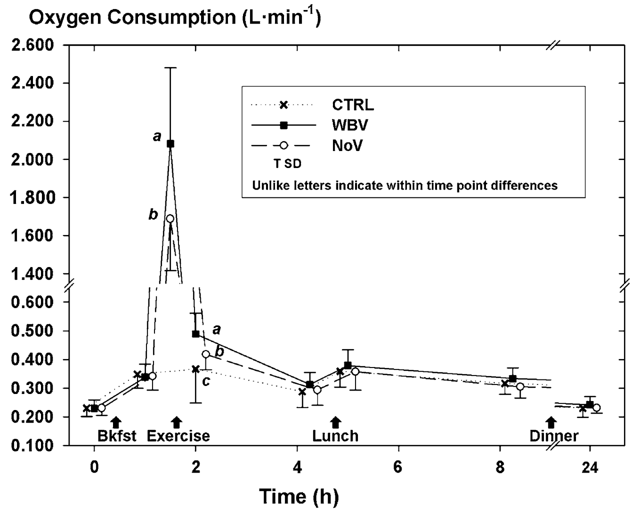

Fig. 3 Oxygen consumption (L min^{-1}) before, during, and following treatments for CTRL, WBV, and NoV. The VO_2 during WBV was increased versus NoV ($P < 0.001$). Immediately post-exercise WBV was increased versus NoV ($P = 0.003$) and CTRL ($P < 0.001$) at 2 h. The VO_2 immediately post-NoV exercise was also greater ($P < 0.001$) than CTRL at 2 h. No other time points reached statistical significance

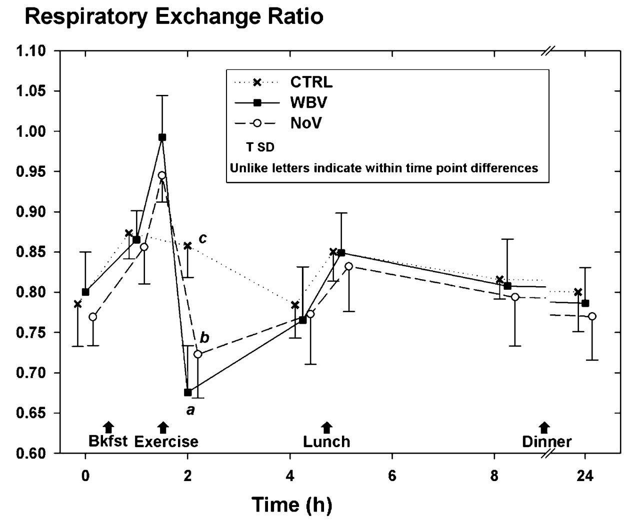

Fig. 4 Respiratory exchange ratio before, during, and following treatments for CTRL, WBV, and NoV. The RER immediately post-WBV exercise was lower versus NoV exercise ($P = 0.017$) and CTRL ($P < 0.001$) at 2 h. The RER immediately post-NoV exercise was also lower ($P < 0.001$) versus CTRL at 2 h. No other time points reached statistical significance

24-h total oxygen consumption

Total VO_2 over 24 h was increased ($P = 0.01$) by 10% for WBV (518.9 ± 61.2 L O_2) versus NoV (471.1 ± 43.7 L O_2) and by 25% ($P < 0.001$) versus CTRL (415.2 ± 51.6 L O_2; Fig. 5b). NoV was 14% greater than CTRL ($P = 0.003$).

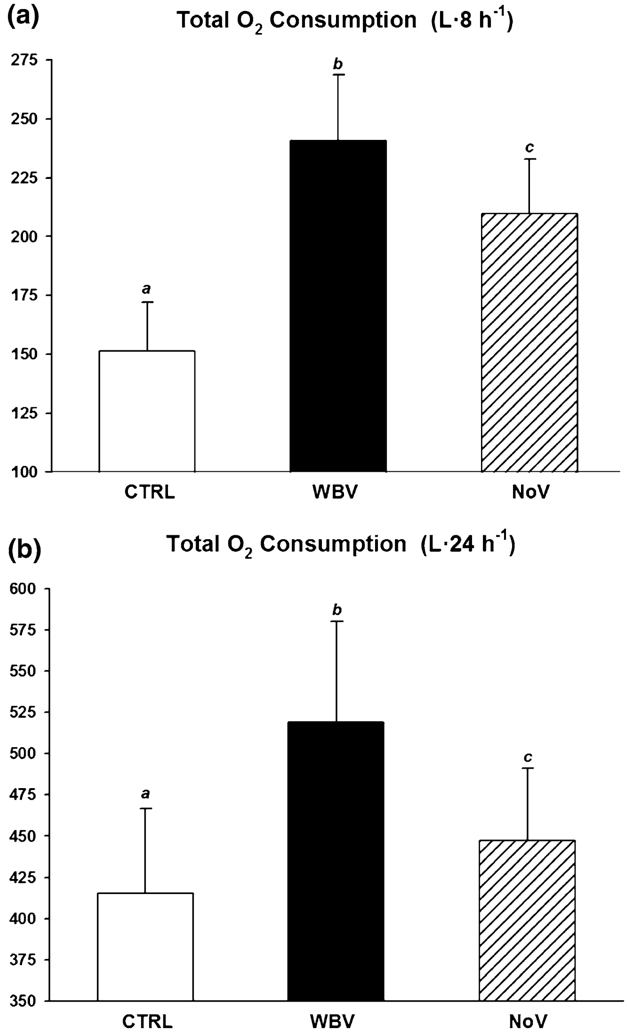

Fig. 5 **a** Total oxygen consumed (L) over 8 h for CTRL, WBV, and NoV. The total VO_2 was greater with WBV exercise versus NoV exercise (by 31 L; $P = 0.004$) and CTRL (by 89 L; $P < 0.001$) while NoV was also greater than CTRL (by 58 L; $P < 0.001$). *Unlike letters* indicate within time point treatment differences. **b** Total oxygen consumed (L) over 24 h for CTRL, WBV, and NoV. The total VO_2 was greater with WBV exercise versus NoV exercise (by 48 L; $P = 0.010$) and CTRL (104 L; $P < 0.001$) while NoV was greater than CTRL (by 56 L; $P = 0.003$). *Unlike letters* indicate within time point treatment differences

Discussion

The purpose of this study was to quantify VO_2 during and following (24 h) a WBV exercise session compared to the same session without vibration (NoV) in order to evaluate the potential of chronic WBV exercise with body mass as the resistance as a body fat loss treatment. The WBV exercise session resulted in a significantly greater VO_2 during and following exercise (8 and 24 h) versus both NoV exercise and control. Although previous studies have demonstrated that exposure to WBV during both static and dynamic movements results in VO_2 increases compared to the same exercises without vibration, these investigations used single exercises (or sets of a single exercise) and the increases observed were modest (~20–190 kJ; Da Silva et al. 2007; Rittweger et al. 2000, 2001, 2002). Further, no one has studied upper body exercise or made prolonged recovery measures so previous data are likely underestimates because much of any anaerobic contribution would have been missed. Our study was designed to extend these findings by examining a more complete whole body exercise session (multiple sets of both upper and lower body exercises) and to incorporate prolonged (24 h) recovery measures to more completely assess the potential of this type of exercise as a method to alter body composition.

Our exercise session was also more strenuous than those used in previous studies as indicated by both HR and RER responses during the WBV (~71% predicted HR_{max}; 0.99 ± 0.05) and NoV (~65% predicted HR_{max}; 0.95 ± 0.03) exercise sessions. Total oxygen consumed during the WBV exercise session was increased by 23% versus NoV. This increase in VO_2 amounted to ~12 L more oxygen (~265 kJ) than NoV.

Although only statistically significant at the immediate post-exercise measure (0945–1015 h), VO_2 appeared to be greater throughout the remainder of the day following WBV exercise versus NoV exercise. When totalled over 8 h, VO_2 with WBV was increased significantly compared to both NoV and control by 15 and 59%, respectively. These significant increases in VO_2 totalled 31 L (~550 kJ) versus NoV and 89 L (~1,690 kJ) versus control. As the subjects remained in the laboratory, this entire time and food intake was controlled these data suggest that acute WBV exercise causes a significant increase in metabolic rate that continues for some time into recovery. Over 24 h, total VO_2 was also increased with WBV treatment versus both NoV (by 10%) and control (by 25%). These significant increases in VO_2 totalled 48 L (~970 kJ) and 104 L (~1,960 kJ) over NoV and control, respectively. Further, because the treatment differences were smaller at 24 h than at 8 h and because we extrapolated linearly from 8 to 24 h it is possible that differences following the 8-h time point were actually underestimated over this 16-h time period. Consequently, the 24 h differences in energy expenditure reported here represent a conservative estimate of the difference among WBV, NoV, and control.

Relative to body composition changes, these acute observations could be important. For example, assuming constant energy intake and similar expenditure differences with a 4 sessions week^{-1}, 16-week training program one would expect an ~4 kg fat loss with WBV versus an ~2 kg fat loss with NoV. Unfortunately, to date, only a few studies have examined the effect of chronic WBV exercise and fat mass loss and the results are equivocal. In untrained young women, 24 weeks (3 sessions week^{-1}) of WBV training (squat, lunges, biceps curls) resulted in no changes in body composition (Roelants et al. 2004), while 24 weeks (3 sessions week^{-1}) of WBV training (squats and lunges) in postmenopausal women caused a significant 0.6 kg decrease in fat mass (Verschueren et al. 2004). Supplementing conventional strength training with three WBV exercises (squats on the platform, sitting on the platform performing shoulder extension/flexion with straps attached to the platform, standing on the ground performing wrist curls with straps attached to the platform) to strength training over 32 weeks (3 sessions week^{-1}) in postmenopausal women resulted in a 0.7 kg greater fat loss versus strength training alone (Fjeldstad et al. 2009). In contrast, adding three WBV exercises (heel rise, one-legged squat, leg abduction) to a combined endurance and strength training over 72 weeks (2 sessions week^{-1}) demonstrated no effect on body composition (von Stengel et al. 2010). Consequently, while the current study demonstrates that moderate intensity WBV exercise could enhance body composition in young adults, low intensity WBV exercise is likely unable to do so. Importantly, in all these training studies diet was not controlled (and in some cases insufficient description of the exercise program was provided) so, although our acute results are promising, a definitive conclusion regarding the effects of chronic WBV exercise on body composition change must await future studies that document carefully both the food intake and the exercise program used.

WBV could increase VO_2 in part by inducing increased postural control (Abercromby et al. 2007) but at least some of the increased VO_2 during the WBV exercise session is due to the increased exercise intensity resulting from the WBV-induced increase in skeletal muscle activity (Abercromby et al. 2007; Cardinale and Lim 2003; Hazell et al. 2007, 2010; Marin et al. 2009; Ritzmann et al. 2010; Roelants et al. 2006). Our data demonstrating a greater VO_2 and HR during the WBV exercise session compared to NoV are consistent with this suggestion. While the specific mechanisms responsible for the prolonged increases in VO_2, i.e. cost of glycogen resynthesis, oxidation of lactate, hormone and/or catecholamine-induced increases in metabolism and lipolysis, thermic effect of exercise and food, increased muscle protein turnover (muscle damage/repair), etc. were not measured in this study, all have been documented previously to play a role (see comprehensive reviews, Borsheim and Bahr 2003; LaForgia et al. 2006). Specifically, increases in temperature (Cochrane et al. 2008; Hazell et al. 2008) and lactate formation (Rittweger et al. 2000) have been shown with WBV exercise.

Recently in animals, chronic, daily exposure to vibration reduced fat accumulation (Luu et al. 2009; Maddalozzo et al. 2008) perhaps by reducing the differentiation of precursor cells to adipocytes (Rubin et al. 2007). If so, chronic vibration exercise could produce even greater fat losses than estimated from our acute metabolic measures.

The significantly lower RER immediately after both exercise sessions compared to control is also interesting and likely indicative of CO_2 retention in response to the intensity of the exercise completed (perhaps to replenish bicarbonate stores reduced by the exercise; Laforgia et al. 1997). Although lactate produced was not measured in our study, the WBV exercise was more strenuous than the NoV and the lower observed immediate post-exercise RER is consistent with the need to buffer hydrogen ions. However, with no other RER differences between treatments over the rest of the 24-h period it appears unlikely that either exercise session resulted in any prolonged change in fuel utilization.

As mentioned, it was necessary to replace three of our subjects for the during exercise measures because the original subjects could not be rescheduled. Although this substitution could limit our results, we consider any error introduced to be minimal because not only did we match the subjects to those who could not return for the during exercise measures but also because the VO_2 for the five subjects that completed both the during exercise and the recovery measures was increased significantly versus the NoV (WBV: 544.0 ± 59.5 vs. NoV 490.5 ± 37.7 L O_2; $P < 0.05$). In fact, this increase was greater than the data of all eight subjects (the estimated fat loss of a 16-week program over NoV for these five subjects would be 2.3 versus 2 kg calculated for all 8 subjects). Consequently, we feel that replacing the three subjects did not affect the key measure in the study, oxygen consumption.

From a practical standpoint, it is interesting to note that many participants seem to prefer vibration workouts relative to more traditional exercise. Although this might reflect the novelty of this form of exercise, a recent review paper compiled data from nine WBV training studies and reported that only 1 of 266 subjects dropped out (Wilcock et al. 2009). While the reason(s) for this unusually high adherence rate is (are) unclear, the potential effectiveness of WBV exercise to promote fat loss combined with a very low dropout rate suggests that this training modality has considerable fat loss potential. Finally, careful monitoring with chronic WBV exercise would be prudent to ensure this modality does not cause health problems but, as alluded to earlier, it should not be assumed that WBV exercise induces similar harmful effects as vibration in industrial settings because WBV exercise involves a much greater frequency for substantially shorter durations and is administered intermittently rather than continuously.

Summary/conclusion

The present study demonstrates a significant increase in VO_2 both during and following an acute WBV exercise session compared to the same exercise session without vibration. Although previous WBV data indicate little effect on fat loss with training those studies used a more limited exercise session, lower exercise intensity, and did not control diet (Fjeldstad et al. 2009; Roelants et al. 2004; Verschueren et al. 2004; von Stengel et al. 2010). Our results illustrate the significant potential of WBV exercise as a component of any program designed to reduce fat mass. However, because any adaptation to WBV exercise is unclear, additional study is needed to verify that these fat losses do occur with training.

Acknowledgments Meals were provided with funds from a Kinesiology Graduate Research Award Grant from The University of Western Ontario awarded to Tom J. Hazell. Whole-body Advanced Vibration Exercise, (WAVE^{TM}; Windsor, Canada) donated the platform for scientific use.

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