

Hormonal responses to a single session of whole-body vibration exercise in older individuals

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ABSTRACT

Objective: Whole-body vibration (WBV) has been recently suggested as an alternative form of exercise. In this study, the acute effects of a single session of WBV exercise on anabolic hormones in aged individuals were analysed.

Design: A randomised cross-over trial design was used. **Settings:** Geriatrics Department, Hospital.

Participants: 20 individuals (9 men and 11 women; median age 70 years (range 66 to 85 years) volunteered in the experiment.

Interventions: Isometric squat on a platform with vibration or no vibration (control) conditions.

Main outcome measurements: Plasma cortisol, testosterone, growth hormone (GH) and insulin-like growth factor 1 (IGF-1) were measured before, immediately after, and 1 and 2 h after the interventions.

Reports: A significant difference between treatments ($p < 0.001$) and a time \times treatment interaction ($p < 0.05$) was found in IGF-1 levels. Cortisol levels were shown not to be significantly different between treatments ($p = 0.43$), but a difference over time ($p < 0.001$) and a time \times treatment interaction ($p < 0.05$) were identified. No significant differences were identified in GH and testosterone levels.

Conclusions: As shown by the results of the study, 5 min of WBV exercise characterised by static squat with a frequency of 30 Hz can be performed by older individuals without apparent signs of stress and/or fatigue. Furthermore, WBV produced an acute increase in the circulating levels IGF-1 and cortisol greater than that observed following the same exercise protocol conducted without vibration.

Human muscle strength has been shown to decrease by approximately 15% per decade after the age of 50 years. The decline in muscle strength is congruent to muscle mass loss, with a total loss of 40% of muscle mass by the age of 80 years compared with the muscle mass at the second decade of life.¹ Muscle mass in humans declines mainly due to two basic reasons: loss of muscle fibres and loss of cross-sectional area of existing fibres.^{2,3} Alterations in motor units and in the central and peripheral nervous systems have also been shown to contribute to the decline in strength observed in ageing humans.⁴⁻⁸

The observed reduction in muscle form and function has been also shown to occur in conjunction with alterations in the hormonal profile of ageing humans. Circulating levels of insulin-like growth factor 1 (IGF-1) decline with age and may also be casually related to loss of muscle mass and strength.⁹ Testosterone and growth hormone (GH) levels are also reduced with age¹⁰⁻¹⁴ and could

contribute to age-related sarcopenia. Exercise, especially strength training, has been shown to be most effective in retarding muscle functional loss.¹⁵⁻¹⁷ Strength training has been shown not only to effectively counteract the loss of muscle mass and strength but also to acutely alter hormonal secretion of IGF-1¹⁸ and GH.^{15,19} Testosterone and cortisol secretion seem to be acutely affected by strength training sessions in young men,²⁰ but there is no consensus on the responses of aged individuals.^{19,21,22}

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It has been recently suggested that vibration transmitted to the whole body by means of specially designed vibrating plates could produce similar adaptive responses to that of conventional strength training (for a review, see Cardinale and Rittweger²³). The acute hormonal responses to whole-body vibration (WBV) have so far shown conflicting results. To date, no study has been conducted on the acute hormonal responses to WBV in older individuals. Therefore, the aim of this study was to analyse the acute effects of a single session of WBV on anabolic hormones in aged individuals. It was hypothesised that a single WBV session would be feasible for this age group, be well accepted and produce an acute increase in circulating anabolic hormones.

METHODS

Participants

To meet inclusion criteria, volunteers had to be aged 65 years or older, in good health, able to give informed consent, and demonstrate an ability to rise from sitting on a chair without using their upper limbs and stand with flexed knees for at least 2 min. Potential volunteers were excluded if they were participating in a strength training programme or had ischaemic heart disease, heart failure, a cardiac pacemaker, recent (in the last 12 months) lower limb fracture, severe osteoporosis, cancer or any metallic plates in the bones or any acute medical problem. The study was approved by the Grampian Local Research Ethics Committee (Ref 05/S/0802/107).

Twenty individuals (9 men and 11 women; median age 70 years (range 66 to 85 years); height 168 (9) cm; body mass 78 (22) kg) meeting the inclusion criteria volunteered to participate in this study.

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Design

A randomised single-blind, controlled, cross-over trial design was used. The volunteers underwent two interventions at least 2 weeks apart (vibration and control (no vibration)).

Both interventions consisted of standing on a vibration plate (FitVibe Medical, GymnaUniphy, Bilzen, Belgium) with slight knee flexion for five 1-min sessions separated by 1-min rest periods. During the vibration intervention, the plate vibrated at a frequency of 30 Hz with 4-mm peak-to-peak displacement. The plate oscillated with a linear movement upwards and downwards of the whole plate. During the control intervention, the participants were asked to maintain the same position, with the only difference being that the plate did not vibrate. The individuals, therefore, acted as their own control.

Volunteers were told the study compared the effects of "high" vibration (the intervention) with a lower frequency "natural" vibration that would normally be imperceptible (the control), effectively "blinding" the participants. All data generated were coded so that the individual analysing the data did not know the order of intervention of each participant.

Experimental procedures

Participants were asked to attend the experimental session after 24 h of complete rest from any physical activity. During the familiarisation trials, age, sex, height, body mass, together with heart rate and blood pressure were recorded.

4 Blood samples were performed at each experimental session (vibration and control) before, immediately after, and 1 and 2 h after the end of each intervention. The baseline sample was collected at 09:00, after a minimum of 8 h of fasting. The participants were not allowed to consume food during the treatments.

Volunteers fasted for a minimum of 8 h before each intervention. An intravenous cannula was inserted in an antecubital vein or a superficial vein in the back of the hand. Baseline blood samples (5 ml) were collected at rest before treatment (to determine basal circulating hormonal concentrations), with further blood samples drawn immediately after the end of the treatment, and after 1 h and 2 h from the end of the treatment. The measurements were all performed in the morning and repeated in both conditions at the same time.

5 The intravenous catheter was kept patent by flushing with sterile 0.9% sodium chloride to allow blood collection at further time points during the session. Blood samples were dispensed into potassium EDTA tubes and stored on ice. After 20 min of mixing (Spiramix-10, Denley Instruments, Sussex, UK), haemoglobin concentration (in duplicate by the cyanmethaemoglobin method) and packed cell volume (in triplicate by spun haematocrit) were measured to allow calculation of changes in plasma volume relative to the volume at baseline. Each blood sample was then centrifuged at $\sim 17\,000$ g for 2 min, and the plasma was subsequently stored at -30°C until it was analysed.

Plasma hormone concentrations were measured using commercially available ELISA kits (DRG Instruments, Marburg/Lahn, Germany). Plasma testosterone concentration was determined using kit EIA-1559, with an intra-assay coefficient of variation (CV) of 3.34% to 4.16%. Plasma cortisol concentration was determined using kit EIA-1887, with an intra-assay CV of 3.2% to 8.1%. Plasma IGF-I concentration was determined using kit EIA-4140, with an intra-assay CV of 4.72% to 6.62%. Plasma human GH concentration was determined using kit EIA-3552, with an intra-assay CV of 2.2% to 9.8%. Assays were carried out in accordance with the manufacturer's instructions. Optical densities were measured at the required wavelength with reference filter subtraction using a microplate reader (HT3; Anthos Labtech Instruments, Wals, Austria) with automated logistic function curve fitting that facilitated data processing. All samples collected from the participants were analysed in the

same assay to obviate any inter-assay variation. Commercially available standards and quality control samples were used for all assays (ALPCO Diagnostics, Windham, New Hampshire, USA). Immediately after each intervention, heart rate and blood pressure were recorded and volunteers were asked to rate the acceptability of the intervention on a Likert scale from 1 (totally unacceptable) to 10 (perfectly acceptable). Each intervention was supervised by a doctor and senior physiotherapist.

Statistical analysis

The hormonal data and calculated changes in plasma volume were first analysed for normality. GH data were not normally distributed; therefore, non-parametric statistical procedures were applied in this case. Friedman test was used to identify differences between treatments (vibration vs control), time, and treatments \times time (time of blood collection) interactions. The Kruskal-Wallis test and Mann-Whitney U test were used to identify the significant difference when a significant interaction was found; α was set at $p < 0.05$ level. All other hormonal data, calculated changes in plasma volume and Likert scores were analysed with a two-way ANOVA (2×4). Data are reported as average (SE).

RESULTS

All volunteers completed both interventions with median acceptability scores of 9 (range 6 to 10) for vibration and 10 (range 9 to 10) for control. There were no significant changes in pulse rate or blood pressure with either intervention. Haemoglobin levels were similar ($p = 0.49$) before the start of both interventions (vibration treatment 146 (16) and control treatment 142 (15) g/l). Spun haematocrit volumes were also similar ($p = 0.68$) before the vibration treatment (43.5 (4.5) l/l) and control treatment (43.0 (4.5) l/l). There were no significant differences ($p = 0.89$) in percentage changes in plasma from baseline between treatments; the overall median value was 3.3 (-7.7% to 23%) on the vibration treatment and 4.1 (-7.7% to 17.6%) on the control treatment.

A significant difference between treatments (vibration vs control; $p < 0.001$) and a time \times treatment interaction ($p < 0.05$) was found in IGF-1 levels. Post hoc analyses revealed a significant difference between conditions in IGF-1 levels at the end of the experimental treatments and 1 and 2 h post-treatment. In particular, IGF-1 levels after vibration treatment were shown to increase and remain higher than the control condition for up to 2 h after the exercise treatment (fig 1).

Cortisol levels were shown not to be significantly different between treatments ($p = 0.43$), but a difference over time ($p < 0.001$) and a time \times treatment interaction ($p < 0.05$) were identified. Both treatments were shown to significantly alter cortisol levels over time ($p < 0.001$). Cortisol increased significantly at the end of both treatments; however, the increase was greater after vibration exposure compared with the control condition ($p < 0.05$). Cortisol levels then decreased below pre-exercise values and remained lower for up to 2 h after the exercise bouts (fig 2).

No significant differences were identified in GH levels between treatments (fig 3; $p = 0.40$). Testosterone data were analysed separately for men and women. In both groups, no significant difference was identified (fig 4).

IGF-1 to cortisol ratio and testosterone to cortisol ratio were also calculated to establish the ratio between anabolic/catabolic hormones. Statistical analysis revealed a significant main effect on time and treatment \times time interaction in the IGF1/cortisol

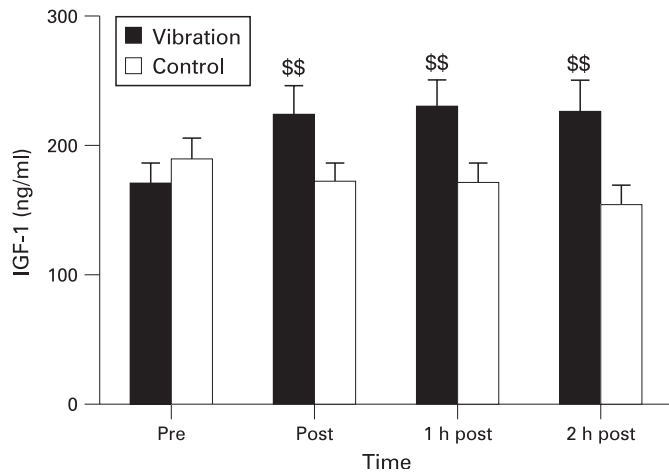


Figure 1 Plasma IGF-1 measured before, immediately after, and 1 and 2 h after the treatments (vibration and control). Data are expressed as average (SE). * $p < 0.005$; statistically different from control.

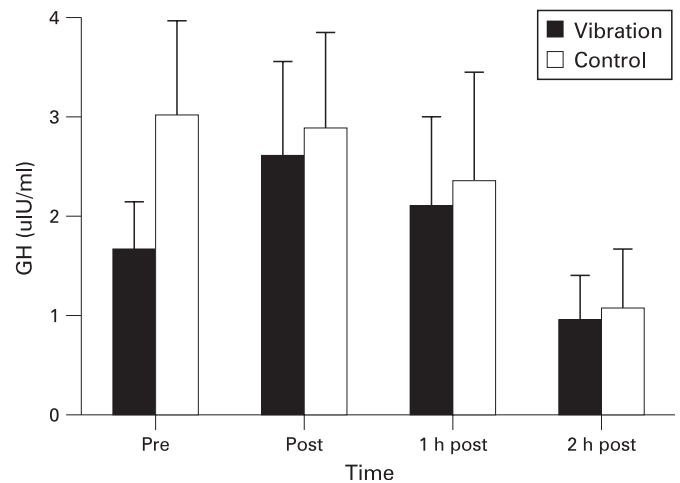


Figure 3 Plasma growth hormone measured before, immediately after, and 1 and 2 h after the treatments (vibration and control). Data are expressed as average (SE).

ratio only ($p < 0.001$). In particular, a significant increase was seen in both treatments at 1 and 2 h post treatment compared with the respective baseline. However, a bigger increase was observed in the vibration treatment 2 h after the bout when compared with the control ($p < 0.05$; fig 5).

DISCUSSION

The study showed that a single 5 min session of WBV vibration exercise was well tolerated by all the participants recruited into this study. The study exercise mode elicited an acute increase in IGF-1 levels, higher than the control condition, which lasted for up to 2 h after the vibration exercise. Furthermore, cortisol levels were shown to increase acutely and then decrease to levels lower than the baseline value with a larger increase observed in vibration condition. Plasma levels of GH and testosterone were shown not to change after either treatment.

Previous studies conducted on the acute hormonal responses to WBV exercise have so far been equivocal. Bosco *et al*²⁴ showed an acute increase in GH and testosterone and an acute decrease in cortisol in healthy young men after 10 min of WBV exercise

performed in a similar manner to that used in the present study. More recent, better controlled studies²⁵⁻²⁷ showed no acute alterations in serum or salivary hormones in healthy young men

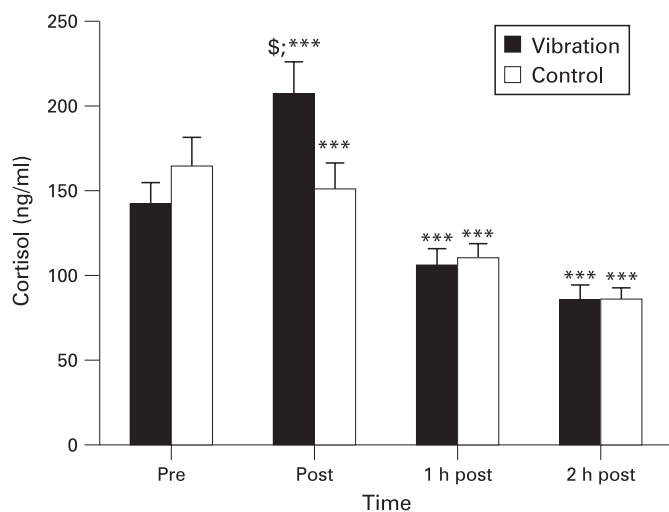


Figure 2 Plasma cortisol measured before, immediately after, and 1 and 2 h after the treatments (vibration and control). Data are expressed as average (SE). * $p < 0.05$ statistically different from control; *** $p < 0.001$ statistically different from the corresponding baseline value.

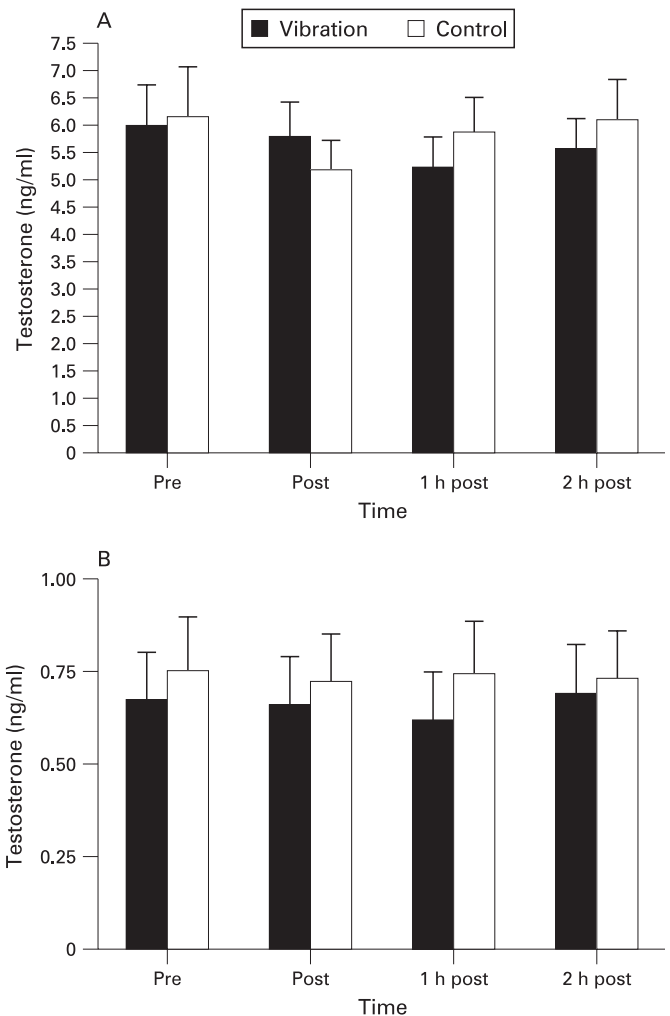


Figure 4 Plasma testosterone measured before, immediately after, and 1 and 2 h after the treatments (vibration and control; (A) men; (B) women). Data are expressed as average (SE).

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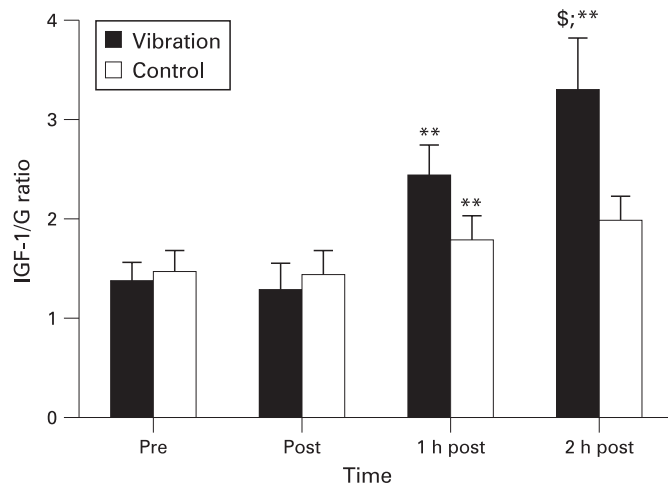


Figure 5 IGF-1 to cortisol ratio measured before, immediately after, and 1 and 2 h after the treatments (vibration and control). Data are expressed as average (SE). * $p < 0.05$ statistically different from control; ** $p < 0.05$ statistically different from corresponding baseline value.

performing static WBV exercise. Anabolic hormones and cortisol have been suggested as the most important modulators in the adaptations to strengthening exercises (for a review see²⁸).

Acute elevations of testosterone have been shown in young,^{29–31} middle aged²⁹ and older men³² after a training session characterised by resistance exercise. The results of these studies clearly suggest that in order to transiently increase testosterone levels, large muscle masses need to be exercised, for a relatively prolonged period at high intensity (mainly lifting heavy loads close to one repetition maximum or maximal voluntary contraction). The lack of a change in circulating levels of testosterone observed in our older volunteers (both men and women) could be explained by the possibility that five sets of 1 min of WBV did not represent a sufficiently intense training stimulus. Previous studies have shown that low intensity resistance training had no influence on testosterone in older individuals.³³ The lack of changes observed in GH response is in line with previous observations in healthy young men performing WBV exercise.^{25, 26} This limited acute GH response has been already observed with resistance exercise protocols.^{33–35} In particular, low volume exercise sessions seem to be unable to elicit an acute increase in GH in older individuals.³⁶ Furthermore, Kraemer²⁸ suggested that maximal effort may be required to optimise the exercise-induced secretion of GH. Therefore, as with the absence of an exercise-induced testosterone response, it is possible that 5 min of WBV in static squat with the frequency and amplitudes used in our study did not require a maximal effort from the participants. It is worth mentioning that considering the large variability in GH response observed in the current study and the effectiveness of locally applied vibration in increasing bioassayable GH,³⁷ further investigation is required to ascertain the influence of WBV exercise on immunoassayable and bioassayable GH release.

The significantly greater increase in cortisol levels observed at the end of the vibration exercise compared with the control condition in the present study is opposite to that found by Bosco *et al*²⁴ who reported an acute decrease in circulating cortisol concentrations after WBV. Various studies have shown significant acute elevations in cortisol and adrenocorticotropic hormone during a resistance exercise training session (for a review see²⁸). In particular, serum cortisol has been shown to be elevated in young and older men up to 30 min after the end of a

What is already known on this topic

WBV exercise has been previously shown to produce acute hormonal responses similar to other forms of exercise such as strength training in healthy young individuals.

What this study adds

WBV exercise characterised by five sets of 1 min each with a 30-Hz frequency can be performed safely by older people, and it could represent an effective stimulation for the neuroendocrine system.

resistance exercise session characterised by four sets of 10 repetition maximum squats.³⁴ Previous studies have shown that cortisol is a good indicator of acceleration stress.³⁸ The WBV protocol employed in our study was characterised by a vibration magnitude of 3.5 g (where 1 g = 9.81 m/s²) transmitted to the body. The acceleration load was most likely the cause of the transient increase in cortisol levels observed in the vibration treatment compared with the control condition. The acute response observed characterised by the reduction to levels lower than the pre-exercise values within 1 h of the exposure paired with a significant increase in the IGF-1/cortisol ratio, suggest that this is a typical exercise response that should not represent an indication of catabolic activities and/or negative effects on brain function.

IGF-1 levels increased immediately after WBV exercise and remained elevated for up to 2 h after the end of the exercise bout. A similar post-exercise response has been observed in older individuals performing low-volume resistance exercise.³⁶ No clear-cut relationship was identified between GH and IGF-1 response suggesting that the IGF-1 response to WBV exercise was not GH mediated. Acute IGF-1 responses to resistance exercise have so far been shown to be equivocal.²⁸ At this stage, it is not possible to discuss the likely mechanisms involved in the increased IGF-1 secretion elicited by the WBV exercise; further studies are required to understand the dynamic regulation of specific IGF-binding proteins induced by vibration exercise in order to assess the possible biological influence of acute increases in IGF-1 levels. IGF-1 is part of the IGF family of growth factors and plays a vital role in the regulation of somatic growth and cellular proliferation. The IGF-1 receptor is present in many cell types, and its interactions with circulating levels of IGF-1 are the main determinants of IGF-1 actions on specific tissues. IGF-1 levels have been shown to decline with age and this decline has been identified as one of the main determinants of sarcopenia. Because of the observed beneficial effects of IGF-1 in mediating the effects of physical activity in the brain in animal models³⁹ and the potential of IGF-1 to reduce the ageing effects on brain function,^{40–44} the observed acute response after WBV could represent an alternative non-pharmacological intervention that would benefit not only skeletal muscles but also brain function. To our knowledge, this is the first study conducted to analyse IGF-1 responses to WBV protocols in older individuals. More studies are needed to understand how to manipulate WBV training parameters to obtain similar responses in various populations and also what could be the biological effects of the observed acute increases.

The WBV exercise protocol used in the present study was well accepted by our aged participants. Their reported subjective feeling suggest that the vibration exercise was only slightly less comfortable than was the control condition. Similarly, the WBV produced little physical stress as shown by a minimal increase in pulse rate immediately after exercise and no real change in systolic or diastolic blood pressure, or in changes in blood volume.

In conclusion, the results of our study suggest that five sets of 1 min of WBV exercise characterised by static squat with a frequency of 30 Hz can be performed by older individuals without apparent signs of fatigue. Furthermore, the results of the study showed that WBV produced an acute increase in the circulating levels of IGF-1 and cortisol greater than that observed following the same exercise protocol conducted without vibration. Future studies should be aimed at understanding how different WBV exercise protocols affect the neuroendocrine system of elderly individuals and the mechanisms responsible for the acute alterations in hormonal levels.

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Competing interests: None.

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