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Hormonal responses to whole body vibration exercise

Hormonal responses to a single session of whole body vibration exercise in elderly individuals.

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Short Title: Hormonal responses to whole body vibration exercise

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ABSTRACT

OBJECTIVE: Whole body vibration has been recently suggested as an alternative form of exercise. The aim of the study was to analyse the acute effects of a single session of whole body vibration exercise on anabolic hormones in aged individuals. **DESIGN:** A Randomised cross-over trial design was used. **SETTINGS:** Geriatrics department, Hospital. **PARTICIPANTS:** Twenty subjects (9 males and 11 females; median age 70 years (range 66 to 85 years) volunteered in the experiment. **INTERVENTIONS:** isometric squat on a platform with vibration (V) or no vibration (C) conditions. **MAIN OUTCOME MEASUREMENTS:** Plasma Cortisol, Testosterone, Growth Hormone, **and** IGF-1 were measured before, after, 1h and 2h after the interventions. **REPORTS:** A significant difference between treatments ($P<.001$) and a time by treatment interaction ($P<.05$) 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 ($P<.001$) and a time x treatment interaction ($P<.05$) were identified. No significant differences were identified in GH and Testosterone levels. **CONCLUSIONS:** the results of our study suggest that 5 minutes of WBV exercise characterised by static squat with a frequency of 30Hz can be performed by elderly individuals without apparent signs of stress and/or fatigue. Furthermore, the results of the study showed that 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.

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INTRODUCTION

Human muscle strength has been shown to decrease by approximately 15% per decade after the age of 50. 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 compared with the muscle mass of 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 system 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 age [10-14] 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-1 [18] 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]

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 [23]). The acute hormonal responses to WBV have so far shown conflicting results. To date, no study has been conducted on the acute hormonal responses to WBV in the elderly. 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, would be well accepted, and would produce an acute increase in circulating anabolic hormones.

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Methods

Subjects

To meet inclusion criteria volunteers had to be aged 65 years or over, 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 to stand with flexed knees for at least two minutes. 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 last 12 months) lower limb fracture, severe osteoporosis, cancer, 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). 20 subjects (9 males and 11 females; 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.

Design

A randomised single-blind, controlled, cross-over trial design was used. The volunteers underwent two interventions at least two weeks apart (Vibration [V] and Control [C]).

Both interventions consisted of standing on a vibration plate (FitVibe Medical, GymnaUniphy N.V., Belgium) with slight knee flexion for five one-minute sessions separated by one-minute rest periods. During the V intervention the plate vibrated at a frequency of 30 Hz with 4mm peak-to-peak displacement. The plate oscillated with a linear movement upwards and downwards of the whole plate. During the C intervention, the participants were asked to maintain the same position with the only difference being that the plate did not vibrate. The subjects 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

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

Blood samples were performed at each experimental session (V and C) before, after, 1h and 2h after the end of each intervention. The baseline sample was collected at 9 am in the morning after a minimum of 8 hours of fasting. The subjects were not allowed to consume food during the treatments.

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

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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. Following 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 ~17 000 g for 2 min and the plasma subsequently stored at -30 °C until it was analysed.

Plasma hormone concentrations were measured using commercially available ELISA kits (DRG Instruments GmbH, Germany). Plasma testosterone concentration was determined using kit EIA-1559, with an intra-assay CV of 3.34 – 4.16%. Plasma cortisol concentration was determined using kit EIA-1887, with an intra-assay CV of 3.2-8.1%. Plasma IGF-I concentration was determined using kit EIA-4140, with an intra-assay CV of 4.72-6.62%. Plasma hGH concentration was determined using kit EIA-3552, with an intra-assay CV of 2.2-9.8%. 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 subjects 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, NH, 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 plasma volume were first analysed for normality. Growth Hormone 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 x time (time of blood collection) interactions. The Kruskal-Wallis test and Mann-Whitney test were used to identify the significant difference when a significant interaction was found. Alpha was set at P <.05 level. All other hormonal data, calculated changes in plasma volume and Likert scores were analysed with a two-way ANOVA (2 x 4). Data are reported as average \pm standard error.

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Results

All volunteers completed both interventions with median acceptability scores of 9 (range 6 to 10) for V and 10 (range 9 to 10) for C. 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 (V treatment 146 (16) and C treatment 142 (15) g/l). Spun haematocrit volumes were also similar ($P=0.68$) before the V treatment (43.5 (4.5) l/l) and C 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 V treatment and 4.1 (-7.7 to 17.6%) on the C treatment.

A significant difference between treatments (Vibration vs. Control; $P<0.001$) and a time by 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 1h and 2h post treatment. In particular, IGF-1 levels following V treatment were shown to increase and remain higher than the C condition for up to two hours following the exercise treatment (Figure 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 x 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 following V exposure as compared with C condition ($P<0.05$). Cortisol levels then decreased below pre-exercise values and remained lower for up to two hours after the exercise bouts (Figure 2).

No significant differences were identified in GH levels between treatments (Figure 3; $P=0.40$). Testosterone data were analysed separately for males and females subjects. In both groups, no significant difference was identified (Figure 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 x time interaction in the IGF1/Cortisol ratio only ($P<0.001$). In particular a significant increase was seen in both treatments at 1h and 2h post as compared to the respective baseline. However a bigger increase was observed in the vibration treatment 2h after the bout when compared to control ($P<0.05$; see Figure 5).

Discussion

The study showed that a single 5 minute session of WBV vibration exercise was well tolerated by all the subjects 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 two hours following 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 V condition. Plasma levels of GH and testosterone were shown not to change following 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 males after 10 minutes of WBV exercise performed in a similar manner to that used in the present study. More recent, better controlled studies [25-27] showed no acute alterations in serum or salivary

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hormones in healthy young men 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 see [28]).

Acute elevations of testosterone have been shown in young [29-31], middle aged [29] and older men [32] following 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 1 repetition maximum or maximal voluntary contraction). The lack of a change in circulating levels of testosterone observed in our elderly volunteers (both males and females) could be explained by the possibility that 5 sets of 1 minute 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 elderly subjects. [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 elderly individuals. [36] Furthermore, Kraemer [28] 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 minutes 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 growth hormone, [37] further investigation is required to ascertain the influence of WBV exercise on immunoassayable and bioassayable growth hormone 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 following WBV. Various studies have shown significant acute elevations in cortisol and adrenocorticotrophic hormone during a resistance exercise training session (for a review see [28]). In particular, serum cortisol has been shown to be elevated in young and old men up to 30 minutes after the end of a 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 $1g=9.81 \text{ m/s}^2$) transmitted to the body. The acceleration load was most likely the cause of the transient increase in cortisol levels observed in the V treatment as compared with the C condition. The acute response observed characterised by the reduction to levels lower than the pre-exercise values within 1 hour 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 two hours after the end of the exercise bout. A similar post-exercise response has been observed in older subjects performing low-volume resistance exercise. [36] No clear-cut relationship was identified between GH and IGF-1 response suggesting that

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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 determinant 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 models [39] and the potential of IGF-1 to reduce the ageing effects on brain function, [40-44] the observed acute response following 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 the elderly. 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 subjects. 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 **5 sets of 1 min** of WBV exercise characterised by static squat with a frequency of 30Hz can be performed by elderly individuals without apparent signs of fatigue. Furthermore, the results of the study showed that 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. 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.

Information Box

What is already known on this topic

Whole body vibration 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

Whole body vibration exercise characterised by 5 sets of 1 min each with a 30Hz frequency can be performed safely by older people and it could represent an effective stimulation for the neuroendocrine system.

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I and my co-authors declare no competing interests with regards to this manuscript. This manuscript does not constitute endorsement of the equipment used in the study.

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Figure Legends

Figure 1. Plasma IGF-1 measured before, immediately after, 1h and 2h after the treatments (vibration and control). Data are expressed as average \pm standard error. (\$\$ = P<.005; statistically different from control).

Figure 2. Plasma cortisol measured before, immediately after, 1h and 2h after the treatments (vibration and control). Data are expressed as average \pm standard error. (\$= P<.05 statistically different from control; ***=P<.001 statistically different from the corresponding baseline value).

Figure 3. Plasma Growth Hormone measured before, immediately after, 1h and 2h after the treatments (vibration and control). Data are expressed as average \pm standard error.

Figure 4. Plasma testosterone measured before, immediately after, 1h and 2h after the treatments (vibration and control; a) Males; b) Females). Data are expressed as average \pm standard error.

Figure 5. IGF-1 to Cortisol ratio measured before, immediately after, 1h and 2h after the treatments (vibration and control). Data are expressed as average \pm standard error. (\$=P<.05 statistically different from control; * = P<.05 statistically different from corresponding baseline value).

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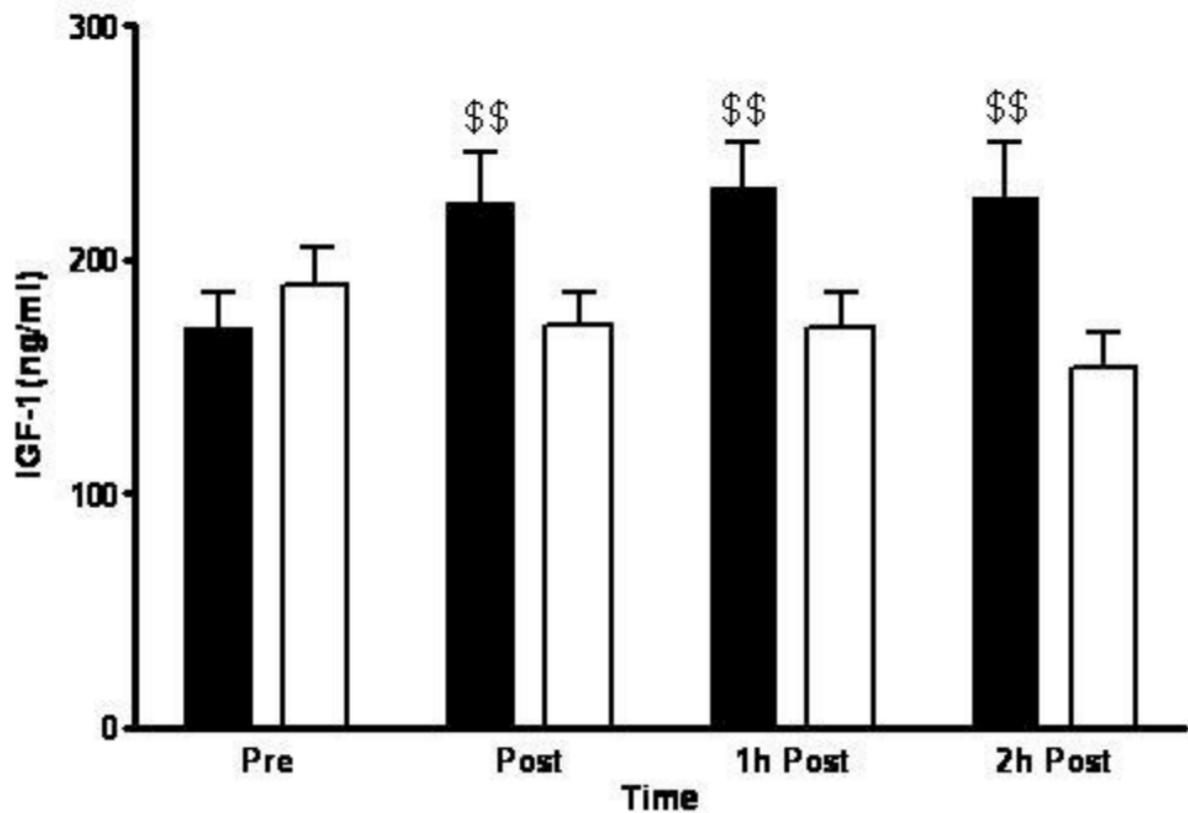
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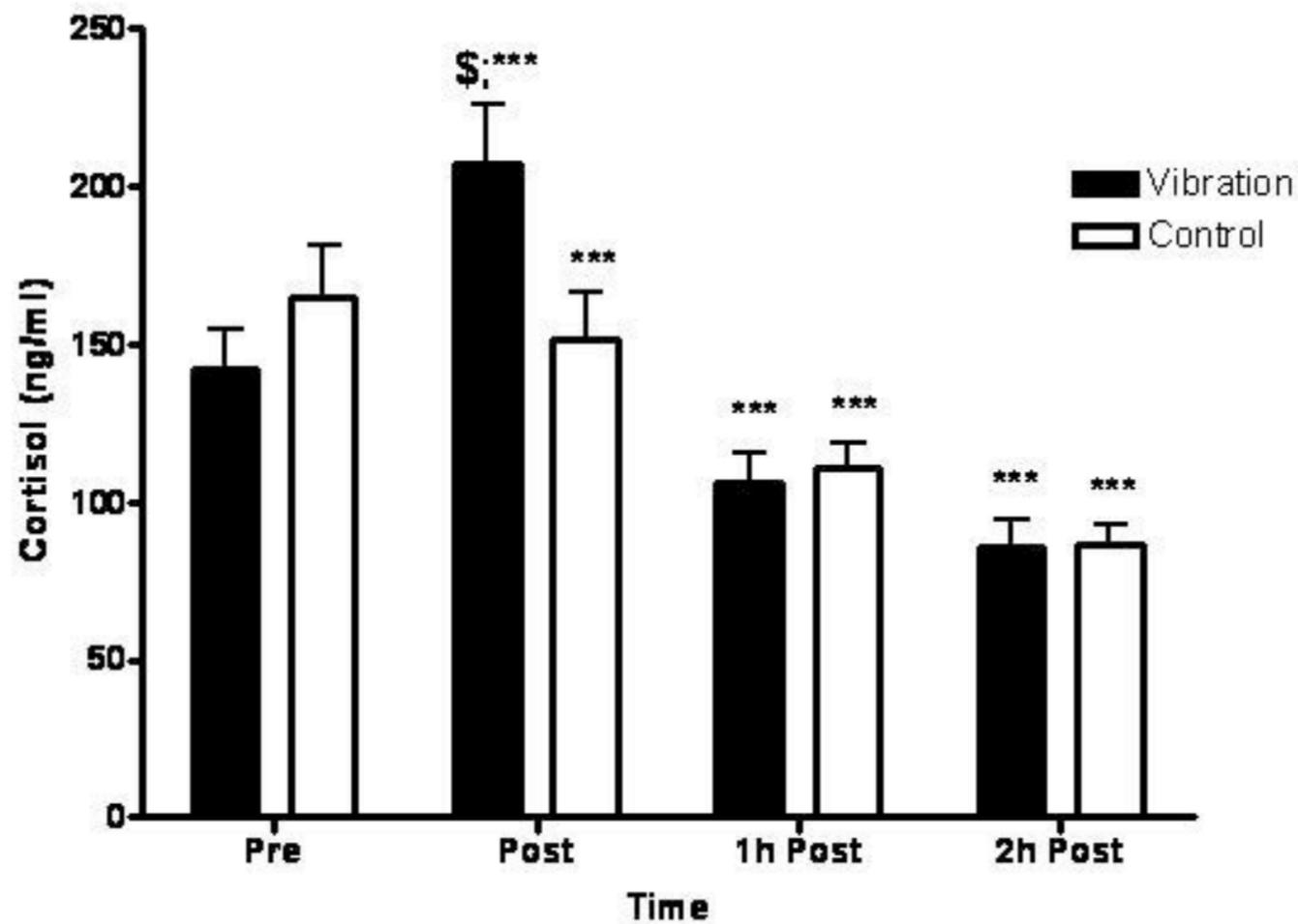
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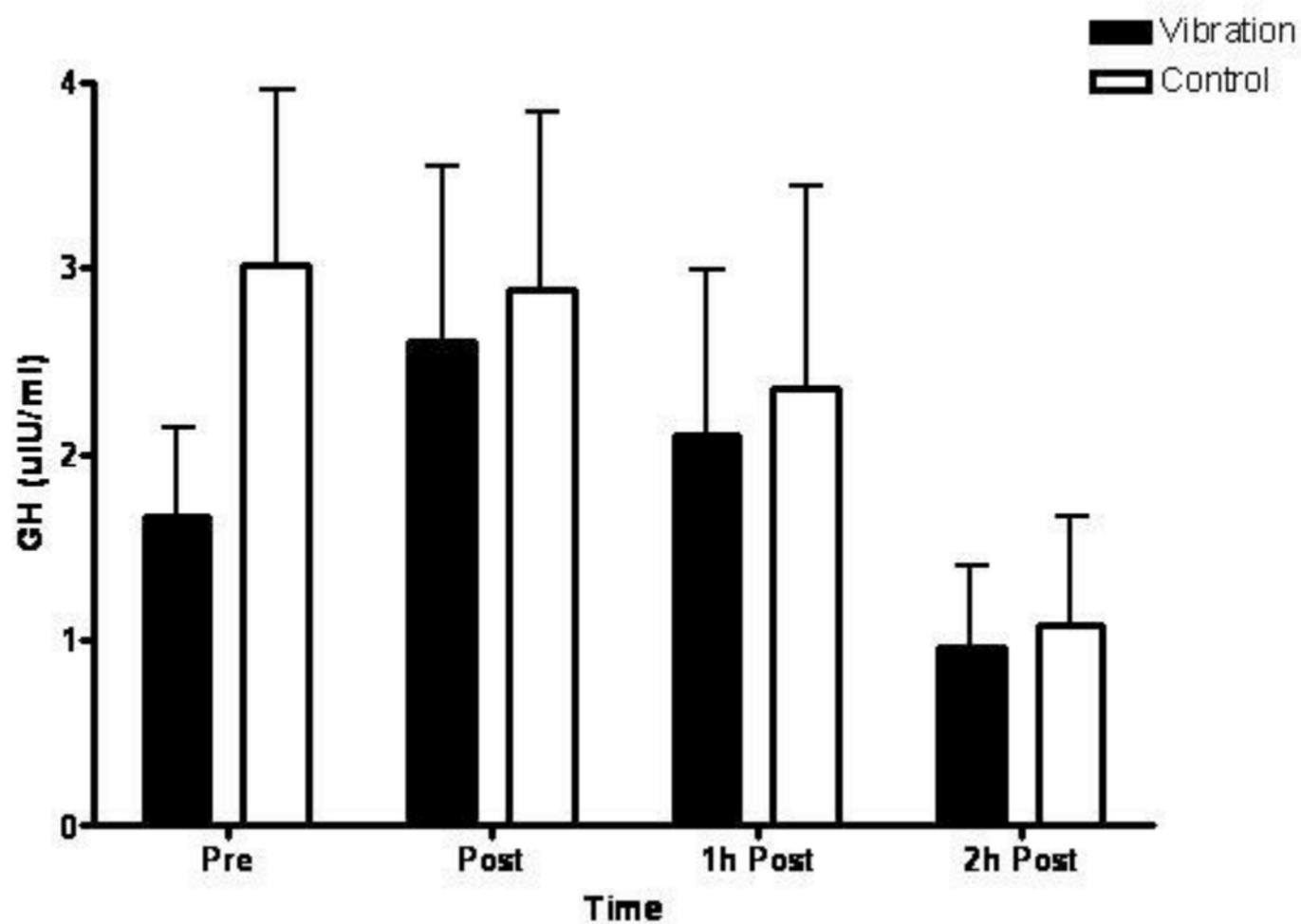
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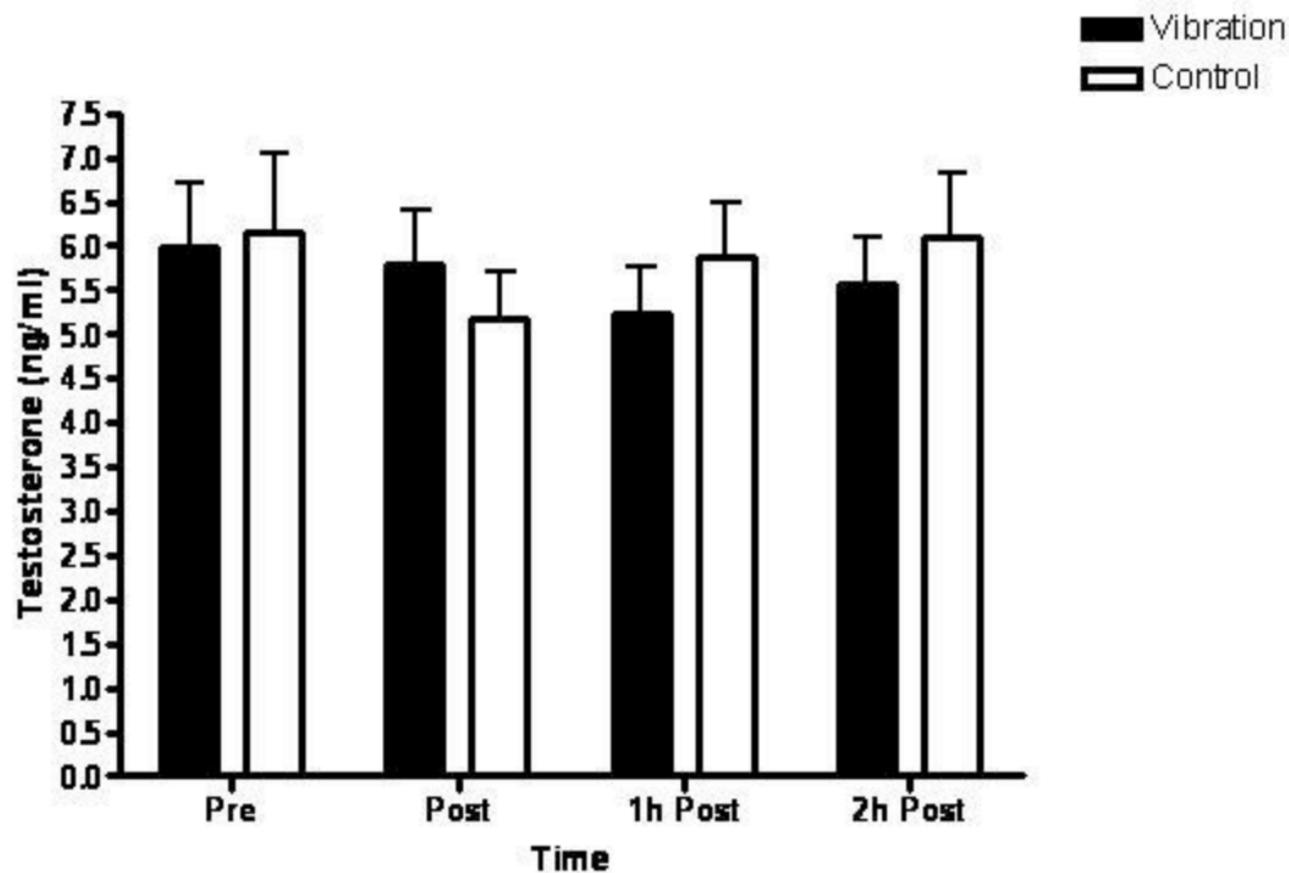
■ Vibration
□ Control







a)



b)

