Original Research

Acute Effects of Whole-Body Vibration and Resistance Exercise on Cortisol Concentrations in Young Men

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ABSTRACT

International Journal of Exercise Science 8(1) : 11-20, 2015. Few studies have focused on the acute hormone responses to whole-body vibration (WBV) combined with resistance exercise. The purpose of this study was to compare the cortisol response to a single bout of WBV combined with resistance exercise (WBV + RE) and resistance exercise only (RE) in young men (n=9). This study used a cross-over repeated measures design. 1-RM testing was performed for four lower body and two upper body isotonic resistance exercises. Subjects performed the RE condition (80% 1-RM, three sets, 10 reps) and the WBV+RE condition (20 Hz, five one-minute bouts, one- minute rest between bouts) followed by RE in random order separated by two weeks to avoid a last bout effect. Fasting morning blood samples were obtained at baseline (PRE), immediately after exercise (IP), and 30 minutes after exercise (30P) to assess cortisol and lactate concentrations. The WBV + RE condition included a blood draw immediately after the vibration exposure (POSTVIB). There were no significant time, group, or interaction effects for cortisol concentrations. Also, there were no significant differences between conditions for absolute changes in cortisol. Cortisol did not change at POSTVIB. Blood lactate significantly ($p<0.01$) increased at IP for both conditions, but there was no difference between conditions. Lactate significantly ($p<0.05$) increased at POSTVIB (PRE 1.03 ± 0.15; POSTVIB 1.38 ± 0.15 mmol/L). In conclusion, acute cortisol responses were similar for whole-body vibration plus resistance exercise and resistance exercise only conditions. There was large variability in the cortisol responses to both exercise protocols.

KEY WORDS: Whole-body vibration, lactate, cortisol, resistance exercise

INTRODUCTION

Whole-body vibration (WBV) is a recently developed exercise modality that has been shown to have effects on a wide range of physiological systems, including musculoskeletal, endocrine, and metabolic systems (19). This type of mechanical loading involves oscillations, where energy is transferred from the vibration device to the whole human body (19). The intensity of the vibration stimulus is determined by the frequency (f) and peak-to-peak displacement (D) of the oscillations. The gravitational forces (g) imposed on the body can be calculated as [2 × π2 × f2 × D] in side alternating vibration devices (18). Many studies have reported that WBV enhances neuromuscular performance (2, 4, 23, 25). A possible mechanism for this effect

is that vibration stimulates neural responses, such as the stretch reflex and antagonist co-contraction, which enhance muscle contraction (19). In addition, WBV has been reported to enhance bone density and bone strength (5, 19) both indirectly, by increasing the force of muscle contractions that exert greater stress on the bone, and directly, by stimulating the bone cells to increase bone formation (13).

Cortisol is a glucocorticoid hormone that is released by the adrenal gland in response to different types of stress, including exercise. Its secretion is regulated by the hypothalamic-pituitary-adrenal (HPA) axis and negative feedback mechanisms (11). Cortisol has multiple regulatory functions in the body, such as maintaining blood glucose homeostasis, stimulating the release of amino acids from skeletal muscle, inhibiting the release of cytokines associated with the inflammatory response (11), and increasing bone resorption (16). Many studies have examined cortisol responses to resistance training because of its catabolic role in skeletal muscle remodeling (7, 12, 14). Generally, acute bouts of resistance exercise (RE) stimulate increases in cortisol, whereas chronic resistance training lowers resting cortisol concentrations. Also, the ratio of testosterone: cortisol resting concentrations has been used to indicate the anabolic/catabolic status of skeletal muscle (7, 14).

Whole-body vibration protocols, both without weight (2, 4, 8, 9) and in conjunction with weight lifting exercises (10, 15), have been shown to elicit changes in circulating hormones. However, cortisol responses to WBV protocols are inconsistent as cortisol concentrations have been reported to significantly increase (4) and decrease after acute WBV (2, 8, 10). The variable patterns in cortisol may be due to biological factors, such as circadian rhythms, or to differences in WBV protocols, including amplitude, frequency, duration, type of vibration device, and the inclusion of resistance exercise in the protocol.

Most of the previous studies have focused on WBV performed without weights or with dynamic weight loaded exercises performed while standing on the vibration platform (2, 4, 8, 9, 10, 15). However, performing the WBV exposures immediately before resistance exercise may be potentiate physiological responses to the exercise stimulus; for example, improving muscle performance via a warm-up effect (19). Therefore, the purpose of this study was to compare cortisol responses of an acute bout of WBV followed by RE to RE only in young untrained males. We hypothesized that the addition of the WBV stimulus immediately prior to resistance exercise would enhance cortisol responses compared to RE alone.

METHODS

Participants

Nine healthy untrained male volunteers, ages 20 to 30 years, completed this study. The study was approved by the University of Oklahoma Institutional Review Board and written informed consent was obtained from subjects prior to participation. Subjects were screened for study enrollment based on their answers to a Health Status Questionnaire, Physical Activity Readiness Questionnaire (PAR-Q), and Bone-Specific Physical Activity

Questionnaire (BPAQ). The BPAQ asked the subjects to list their regularly participated physical activities in the past 12 months so that their physical activity status could be determined. According to their BPAQ responses, sedentary or recreationally active subjects were defined as men who performed resistance or aerobic training less than 3 times/week in the past 12 months. Inclusion criteria were: 1) male, age 20-30 years old; 2) involved in resistance training less than 3 times/week in the past 12 months. Exclusion criteria were: 1) current smoker; 2) aerobic exercise more than 2 hours per week or more than 2 times/week in the past 6 months; 3) a"Yes" answer on the PAR-Q; 4) body weight greater than the weight limit of the scanner table (300 lbs); 5) having contraindications to WBV exposure, such as epilepsy, fresh bone fractures, knee or hip implants, gallstones, kidney stones, and bone cancers; and 6) taking medications known to affect muscle or bone metabolism.

Protocol

We utilized a repeated measures randomized crossover design for this study that required subjects to perform two resistance exercise (RE) protocols: 1) WBV followed by RE (WBV + RE); and 2) RE only. Subjects came to the Bone Density Laboratory for a total of four visits. In the first visit, subjects signed the written informed consent form and completed the PAR-Q, health status questionnaire, and BPAQ. Subjects then underwent body composition testing and familiarization with the resistance exercise techniques at a low intensity. Muscular strength of four lower body and two upper body resistance exercises was assessed in visit 2; after one week, subjects were randomly assigned to perform either the RE or WBV+RE protocols, separated by two weeks, during visits 3 and 4. The timeline of the protocol was shown in figure 1.

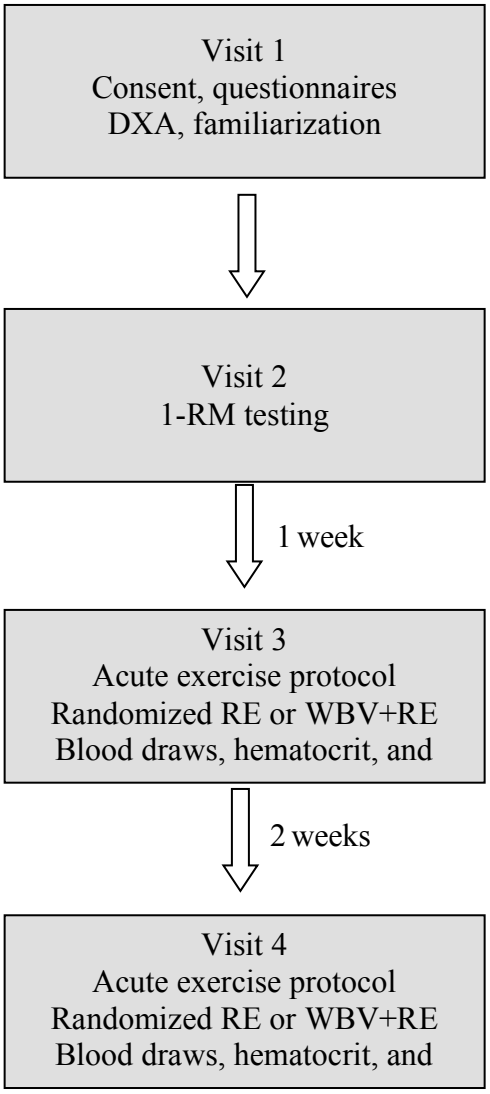

Figure 1. Timeline of study protocol.

Body composition was assessed by a total body scan using dual energy x-ray absorptiometry (DXA) (GE Lunar Prodigy, Madison, MI). Height was measured by a wall stadiometer (Novel Products, Rockton, IL) and body weight was measured using a digital electric scale (Tanita Corporation of America, Inc., Arlington Heights, IL). Hydration status was assessed prior to the DXA scans by measuring urine specific

gravity with a refractometer (VEE GEE Scientific, Inc., Kirkland, WA) to confirm subjects were normally hydrated. The total body scan required subjects to lie in a supine position on the DXA table with knees and ankles secured by Velcro straps. The trunkal thickness of the subject was determined by the DXA software to further determine the scan mode (standard = 13-25 cm; thin < 13 cm; thick > 25 cm). Scans were analyzed using the enCORE 2010 software, version 13.31.016 (GE Healthcare, Madison, WI) by the same qualified DXA technician. In this laboratory, the coefficients of variation (CV%) for the body composition variables are as follows: 2.5% for percent fat; 2.74% for fat mass; and 1.39% for bone free lean body mass (BFLBM).

Maximal muscular strength for leg press, hip extension, hip abduction, hip adduction, shoulder press, and seated row resistance exercises was tested by standardized one-repetition maximum (1-RM) procedures using isotonic resistance exercise machines (Cybex International, Inc., Medway, MA). Following a five-minute warm up of cycling, subjects were instructed to perform a set of 10 repetitions at low intensity (~ 50% of estimated 1-RM). After two minutes rest, subjects performed one repetition at about 80% of estimated 1-RM through the full range of motion. The weight was progressively increased after each successful lift until a failed lift occurred. Two minutes rest was given between lifts, and their 1-RM for each exercise was obtained within 5 attempts. If a subject was able to lift the entire weight stack on the machine, then a multiple repetition maximum was used to estimate the 1-RM using the following equations 1-RM = Weight ÷ (1.0278 – (0.0278 × number of repetitions)) (3). This muscular strength testing procedure has been found to be reliable (intraclass correlation coefficient >0.91) in our laboratory (21).

Subjects completed two exercise protocols in the early morning (07:00 h) following an overnight fast, in random order, and separated by two weeks. They were instructed to be well hydrated and to eat a good meal with about 400-600 grams of carbohydrate at about 18:00 h and a snack about 20:00 h the night before testing via email. The RE protocol consisted of three sets of 10 repetitions of each exercise at 80% 1-RM. Two minutes rest was given between sets. The WBV+RE protocol included the RE protocol described above, but subjects performed five, one-minute bouts of WBV at 20 Hz, 3.38 mm peak to peak displacement (2.7 g) using a Vibraflex Vibration Platform (Orthometrix Inc., Naples, FL) immediately before RE. Vibration exposures were separated by one-minute rest intervals. Subjects stood bare foot on the vibration platform with the second toe lined up with the dot between foot positions 1 and 2. The knees were bent to a 30 degree angle, measured by a goniometer, to minimize the transmission of the vibration to the neck and head (19).

Blood samples were obtained in the morning after an 8 hour overnight fast, with both protocols starting at 07:00 h and ending about 10:00 h. Venipuncture blood draws were performed by a registered nurse before (PRE), immediately post (IP), and 30 minutes post (30P) each exercise condition using butterfly needles and 7 ml serum separator tubes. An additional blood draw was obtained immediately post vibration (POSTVIB) in the WBV+RE protocol. Lactate concentrations (mmol/L) at PRE, POSTVIB, and IP time points were

determined by a Lactate Plus analyzer (Nova Biomedical, Waltham, MA). During exercise, there is an acute decline in plasma volume depends on the exercise intensity (26). Therefore, it is important to determine whether the change in hormone concentration is because of increased release of hormone or reduction in plasma volume (1). Hematocrit was measured by CritSpin Hematocrit Centrifuge (StatSpin, Inc., Norwood, MA) at PRE, POSTVIB, IP and 30P to estimate plasma volume changes. Plasma volume changes and corrected cortisol concentrations were calculated by the following equations: %ΔPV = (100/(100 - Hct Pre) * 100((Hct Pre – Hct Post)/Hct Post); Corrected Cortisol Concentration = Uncorrected value * ((100 + %ΔPV) (11).

Blood samples were allowed to clot then centrifuged to separate the serum from the red blood cells. Serum was collected, transferred into microtubes, and stored in a –84° C freezer until the assays were performed. Serum cortisol concentrations were determined in duplicate using a commercial ELISA kit (DRG International Inc., Springfield, NJ). In this study, intra assay CV% for controls were 0.3% to 12.5% and inter assay CV% ranged from 7% to 8.2%.

Statistical Analysis

All descriptive data were reported in mean ± standard error (SE). Statistical analysis was performed by PASW (SPSS Inc., Chicago, IL), version 19.0. Normality of data was determined by the Kolmogorov-Smirnov test and all dependent variables were determined to be normally distributed. Paired t-tests were used to compare total workloads and baseline cortisol concentrations for the two conditions. Two-way repeated measures ANOVA (condition × time) was used to examine lactate, hematocrit, and cortisol responses to exercise. Pearson correlation coefficients were computed to examine the relationship between baseline cortisol concentrations and cortisol responses and total workload and cortisol responses. The level of significance was set at $p \leq 0.05$.

RESULTS

Tables 1 and 2 show the physical characteristics and muscular strength data, respectively. There was no significant difference in total workload performed between the two exercise sessions.

Table 1. Subject characteristics (n=9).

Variables	Mean ± SE
Age (yr)	23.3 ± 0.6
Height (cm)	179.5 ± 3.3
Weight (kg)	77.4 ± 5.6
BFLBM (kg)	58.8 ± 3.4
Fat Mass (kg)	16.3 ± 2.8
% Body Fat	19.9 ± 2.3

BFLBM: Bone Free Lean Body Mass

Table 2. Muscular strength and total workload (n=9).

1-RM (kg)	Mean ± SE
Leg Press	203.7 ± 23.9
Seated Row	59.2 ± 3.3
Shoulder Press	64.5 ± 8.2
Hip Extension	106.0 ± 6.1
Hip Abduction	60.0 ± 2.9
Hip Adduction	70.9 ± 7.2
Total Workload (RE)	18,962.7 ± 1083.9
Total Workload (WBV+RE)	19,334.8 ± 1039.9

RE: resistance exercise; WBV: whole-body vibration; Workload (kg): weight (kg) x reps x sets; Total Workload: sum up of the workload of all the 6 exercises that one individual completed in each condition.

Table 3 shows the lactate and hematocrit responses for the two exercise conditions. Blood lactate concentrations significantly

(p<0.001) increased at IP for both conditions, but there were no significant condition or time × condition interaction effects. In addition, blood lactate significantly increased (p<0.05) immediately after the vibration exposure (POSTVIB) for WBV + RE. There was no significant condition or time x condition effects for hematocrit concentrations. Hematocrit significantly increased PRE to IP (p<0.01), then decreased (p<0.01) from IP to 30P for RE. A similar pattern was observed for WBV + RE as there was a trend for an increase in hematocrit (p=0.059) from PRE to POSTVIB, followed by a significant decrease (p<0.05) from IP to 30P. Plasma volume decreased immediately post exercise (IP) by -11.6 ± 2.3% and -11.0 ± 5.1% for RE and WBV + RE, respectively. The greatest change in plasma volume (-14.4 ± 6.5%) for WBV + RE occurred immediately after the vibration exposures (POSTVIB).

Table 3. Lactate and hematocrit responses (n=9, Mean ± SE).

Variables	WBV+RE	RE
Lactate (mmol/L)		
PRE	1.03 ± 0.15	1.59 ± 0.45
POSTVIB	1.38 ± 0.15*	------
IP	9.22 ± 0.99***	9.02 ± 0.65***
Hematocrit (%)		
PRE	46.6 ± 1.6	47.7 ± 0.8
POSTVIB	50.2 ± 2.1	------
IP	49.6 ± 1.5*	50.9 ± 1.3*
30P	47.4 ± 1.3**	46.6 ± 0.7**

RE: resistance exercise; WBV: whole-body vibration; PRE: pre-exercise; POSTVIB: immediately post vibration; IP: immediately post exercise; 30P: 30 minutes post exercise; *: p<0.05 vs. PRE; ***: p<0.001 vs. PRE; **: p<0.01 vs. IP.

Table 4 shows the cortisol concentrations for the two conditions, both uncorrected and corrected for plasma volume shifts. Cortisol responses showed large inter-individual variability. There were no significant time, condition, or time x condition interaction effects for cortisol (p>0.05). Correcting for plasma volume changes did not alter the cortisol results, although there was a trend (p=0.066) for cortisol to be higher in the WBV + RE session compared to RE.

Table 4. Cortisol responses (n=9, Mean ± SE).

Variables (ng/mL)		WBV+RE	RE
PRE	Uncorrected	141.35 ± 12.27	123.54 ± 6.38
POSTVIB	Uncorrected	150.62 ± 17.29	------
	Corrected[a]	117.31 ± 6.45	------
IP	Uncorrected	149.65 ± 30.43	124.08 ± 23.56
	Corrected[a]	135.25 ± 30.04	103.46 ± 22.30
30P	Uncorrected	157.57 ± 35.77	118.81 ± 17.05
	Corrected[a]	156.09 ± 37.49	119.11 ± 18.65

RE: resistance exercise; WBV: whole-body vibration; PRE: pre-exercise; POSTVIB: immediately post vibration; IP: immediately post exercise; 30P: 30 minutes post exercise; [a]Corrected for plasma volume shifts

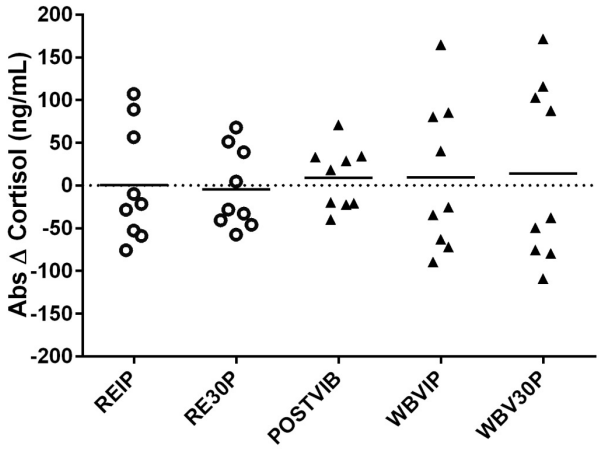

Figure 2. Mean and individual (n=9) absolute changes in uncorrected cortisol concentrations from pre-exercise (PRE). RE: resistance exercise; WBV: whole-body vibration; PRE: pre-exercise; POSTVIB: immediately post vibration; IP: immediately post exercise; 30P: 30 minutes post exercise

Figure 2 depicts absolute changes in cortisol from PRE for the two conditions for each subject. There were no significant

condition, time, or condition × time effects for absolute changes in cortisol. The large variability in responses is evident, as three subjects had large increases, but six subjects had decreases in cortisol immediately post (IP) RE. For the WBV + RE condition, the number of subjects with positive and negative cortisol responses was more evenly distributed as about 50% of subjects had positive changes (increase), whereas the other 50% of subjects had negative changes. In the RE condition, correlations between the absolute changes in cortisol and total workload were 0.457 (IP to PRE) and 0.483 (30P to PRE). In the WBV + RE condition, correlations between the absolute changes in cortisol and total workload were -0.201 (IP to PRE) and -0.162 (30P to PRE). Therefore, absolute changes in cortisol were not significantly correlated with total workload (r = -0.201 to 0.483) performed for either condition. Similarly, absolute changes in cortisol were not significantly correlated with PRE cortisol concentrations (r = -0.127 to 0.049) in either condition.

DISCUSSION

Our cortisol response patterns confirm a growing number of studies documenting no acute elevation of cortisol concentrations in response to WBV (2, 8, 9) or to RE (15, 17, 22). Also, there was large variability in the cortisol responses in our study. Bosco et al. (2) reported that acute bouts of WBV (10 one-minute bouts, 26 Hz, one-minute rest) significantly decreased cortisol concentrations compared to baseline. Kvorning et al. (15) compared acute hormone responses to three protocols: weight loaded squat only (S), WBV only (WBV), and WBV combined with weight loaded squat (S+WBV) in young men. They found that cortisol concentrations significantly increased after the acute S+WBV condition, but decreased after the WBV condition. Giunta et al. (10) used a similar research design in women as Kvorning et al. (15), but also included unloaded dynamic squat with and without WBV conditions. In their study, cortisol significantly increased only in response to the weight loaded squat WBV protocol and decreased for the unloaded squat WBV, unloaded squat only and weight loaded squat protocols. It is possible that the lack of cortisol responses in some of our subjects was caused by insufficient stimulation of central motor command and neural feedback from the skeletal muscles; however, the lack of correlation between total workload and absolute cortisol changes does not support this explanation. The frequency used in the WBV protocols, which varies from 18 Hz (6) to 35 Hz (10), may affect cortisol. Elmantaser et al. (9) found that cortisol responses to WBV depended on the frequency of the vibration stimulus, as cortisol significantly decreased at the 18 Hz frequency, while showing a more variable, less robust response at 22 Hz. Our WBV protocol (20 Hz) also resulted in variable cortisol responses similar to the 22 Hz protocol of Elmantaser et al (9). For example, five subjects in our study exhibited increases and four had decreases in cortisol immediately post the vibration exposures (POSTVIB).

Circadian rhythm and dietary status are critically important biological variables that influence cortisol concentrations. Circadian rhythm is regulated by the endogenous pacemaker in the anterior hypothalamus. Cortisol reaches peak concentrations in the early morning (about 06:00 h) and lowest concentrations in the evening and

overnight (12). Di Loreto et al. (8) compared a single bout of 25 min of no vibration and vibration exercise in two groups, and found that serum cortisol concentrations were significantly decreased at 30 and 60 min compared to the baseline for both protocols. Thus, they concluded that the changes of cortisol concentrations were mainly due to diurnal rhythm. In order to minimize the influence of circadian rhythm and diet, we scheduled the two exercise conditions to start at the same time in the morning (07:00 h) with subjects in a fasting state.

Lactate is measured during resistance exercise protocols as an indicator of metabolic load (14). We found that the blood lactate concentrations significantly increased immediately post the WBV stimulus suggesting a change in the balance of lactate production and removal caused by the vibration stimulus. However, the post resistance exercise lactate concentrations were similar for both protocols, thus, WBV did not have an additive effect on the metabolic load of the resistance exercises. The pattern of hematocrit changes also was similar for the WBV+RE and RE conditions.

This study has several limitations. First, the small sample size, although typical of hormone studies, resulted in small effect sizes for the cortisol responses (effect size of absolute cortisol changes were 0.12 (IP), 0.23(30P)). Another limitation was that we did not have a control condition, which would be useful for discerning between a time of day effect and a true response to the exercise stimulus. Additionally, we were able to measure only cortisol responses due to limited resources. We recommend that future studies measure other hormones, such as testosterone and IGF-1, and glucose to help better understand the implications of the cortisol responses. Although not resistance trained, subjects' exercise participation ranged from sedentary to recreationally active. In the end, the inexperience with RE in some subjects may have caused more psychologically stress than in others, thus contributing to the large variability in the cortisol responses.

In terms of practical applications, it may be better to perform the vibration simultaneously with resistance exercise in order to enhance cortisol responses (10, 15). Also, there is a need to investigate the dose-response relationship between the vibration stimulus and hormone responses.

In conclusion, acute cortisol responses to whole body vibration combined with resistance exercise were similar to resistance exercise only condition. There was large variability in the cortisol responses to both exercise conditions. Previous WBV studies have used a wide variety of frequencies and amplitudes for the vibration stimulus, thus, more research is needed directly comparing the effects of different frequencies and intensities of WBV on hormone responses.

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