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Effects of whole-body vibration exercise on the endocrine system of healthy men

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ABSTRACT. Whole-body vibration is reported to increase muscle performance, bone mineral density and stimulate the secretion of lipolytic and protein anabolic hormones, such as GH and testosterone, that might be used for the treatment of obesity. To date, as no controlled trial has examined the effects of vibration exercise on the human endocrine system, we performed a randomized controlled study, to establish whether the circulating concentrations of glucose and hormones (insulin, glucagon, cortisol, epinephrine, norepinephrine, GH, IGF-1, free and total testosterone) are affected by vibration in 10 healthy men [age 39±3, body mass index (BMI) of 23.5±0.5 kg/m^2, mean±SEM]. Volunteers were studied on two occasions before and after standing for 25 min on a ground plate in the absence (control) or in the presence (vibration) of 30 Hz whole body vibration. Vibration slightly reduced plasma glucose (30 min: vibration 4.59±0.21, control 4.74±0.22 mM, *p*=0.049) and increased plasma norepinephrine concentrations (60 min: vibration 1.29±0.18, control 1.01±0.07 nM, *p*=0.038), but did not change the circulating concentrations of other hormones. These results demonstrate that vibration exercise transiently reduces plasma glucose, possibly by increasing glucose utilization by contracting muscles. Since hormonal responses, with the exception of norepinephrine, are not affected by acute vibration exposure, this type of exercise is not expected to reduce fat mass in obese subjects.

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INTRODUCTION

Muscle contraction induced by low amplitude, high frequency mechanical stimulation is reported to increase muscle strength and performance (1-4), as well as bone density (5-7). Whole body mechanical vibration has a tonic excitatory influence on muscles eliciting a response named "tonic vibration reflex" (4). This reflex involves activation of muscle spindles, mediation of the neural signals by 1a afferents, and activation of the muscle fibers via large α-motor neurones (4). Potentially, repeated muscle contractions might exert endocrine and/or metabolic effects. Vibration has been reported to affect the endocrine system augmenting the circulating concentrations of GH and testosterone and reducing those of cortisol (8). At present, use of whole-body vibration is confined to the training regimens of athletes. As far as the potential clinical applications of the technique are concerned, the few controlled studies published in literature focus on its beneficial effects on osteoporosis (5-7). However, the paper by Bosco et al. (8) in showing that whole-body vibration increases serum GH and testosterone and reduces cortisol concentrations, suggests a potential use of vibration exercise for obesity treatment. Visceral obesity is associated with deficient GH and testosterone (9-12) and probably also with excessive cortisol secretion (13), so that hypercortisolism and hyposomatotropism might both contribute to visceral fat deposition (9, 13). Furthermore, lipolysis of visceral obese men is particularly sensitive to treatment with very low doses of recombinant human GH (14). Thus, the concomitant stimulation of two protein anabolic hormones, such as GH and testosterone (15), and the inhibition of cortisol secretion should reduce fat and augment lean body mass in obese subjects. Vibration exercise might be a safe, low-cost way of

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inducing these hormonal changes with the advantage of being more easily accepted by overweight individuals than conventional physical exercise.
To date, as no controlled trial has examined the acute effects of whole-body vibration on the human endocrine system, we performed a randomized controlled study to establish whether circulating concentrations of glucose and several hormones (insulin, glucagon, cortisol, epinephrine, norepinephrine, GH, IGF-1, and testosterone) are affected by vibration exercise in healthy men, using the vibration protocol published by Bosco et al. (8).

MATERIALS AND METHODS

Subjects

After the study was approved by the Local Ethical Committee, informed written consent was obtained from 10 adult men in good health as determined by medical history, physical examination and laboratory evaluation. Their age (mean±SEM) was 39±3 yr (range 25-50 yr) and their body mass index (BMI) was 23.5±0.5 (range 21-26 kg/m^2).

Design of the study

All subjects were studied, in random order, on two different occasions: vibration or control at 2- to 4-day intervals. On each occasion, volunteers were admitted to the Clinical Research Center of our Department at ~ 07:30 h, after an overnight fast. An antecubital vein was cannulated with a 21-gauge plastic catheter needle and kept patent by 0.9% NaCl infusion. The volunteers relaxed in the sitting position and at ~ 08:00 h 15 ml of blood were drawn for measurements of basal circulating concentrations of glucose and hormones (insulin, glucagon, GH, IGF-1, cortisol, epinephrine, norepinephrine and free and total testosterone). After the basal blood sampling, in the control study, subjects stood with the knees slightly bent (~ 70°) for 25 min on the ground platform of the vibration device (NEMES 30 L, KB Ergotest, Mikkeli, Finland). Their hands were placed on the rigid lever arms. In the vibration study, volunteers in the same position on the vibration device, were exposed to 10 vibration series of 1 min duration with 1 min rest between each treatment and with 5 min rest after the first 5 series (total 25 min). The frequency of the vibrations was set at 30 Hz (displacement±4 mm; acceleration 17 g); all subjects wore thin-soled gymnastic-type shoes. In both studies, after 25 min standing on the platform the subjects sat down and 15 ml of blood were withdrawn for measurements of glucose and hormones 5 min after standing (i.e. at 30 min from baseline) and again 30 min later (i.e. at 60 min from baseline).

Analytical methods

Plasma concentrations of glucose were determined using a Beckman glucose analyzer (Beckman Instruments, Palo Alto, CA). Serum concentrations of insulin (Technogenetics, Milan, Italy), GH (Biodata, Ares Serono, Norwell, MA), IGF-1 (acid alcohol extraction, Nichols Institute Diagnostics, S. Juan Capistrano, CA), free testosterone (Biochem Immuno System, Bologna, Italy) and the plasma concentrations of glucagon (DRG International Inc., USA) were measured using commercial immunoradiometric assays. Serum concentrations of cortisol and total testosterone were determined by enhanced chemiluminescence using Ortho-Clinical Diagnostics kits (Johnson & Johnson, New Brunswick, NJ). The plasma concentrations of catecholamines were measured by high performance liquid chromatography (HPLC) (16).

Statistical analysis

Statistical analyses were performed using repeated measure analysis of variance with treatment (vibration vs no vibration) and time as within factors and corrections for non-sphericity according to Huynh-Feldt epsilon. Where significant differences in mean responses were found, Fisher's LSD Multiple-Comparison Test was applied. Data are presented as mean±SEM, $p<0.05$ was considered statistically significant. All analyses were run using Statistica 4.5 (StatSoft, Inc. 1993, OK).

RESULTS

The results are reported in Table 1. In the vibration and control studies, plasma glucose concentration was similar at baseline. In the vibration study, it decreased at 30 min ($p=0.049$ vs control) and returned to normal values at 60 min. The reduction in plasma glucose concentration occurred in the absence of significant changes in the circulating concentrations of serum insulin and plasma glucagon.
During both the control and the vibration studies, serum cortisol concentration significantly decreased ($p<0.05$) at 30 and 60 min compared with baseline, without differences between the two studies. In both control and vibration studies, plasma norepinephrine concentration significantly increased at 30 min ($p<0.05$ vs baseline). In the vibration study, plasma concentration of norepinephrine at 60 min was higher than the 60 min control level ($p=0.038$). Vibration had no significant effect on serum concentrations of GH, IGF-1, free testosterone, total testosterone and plasma epinephrine. Although at 30 min circulating serum GH concentrations showed a trend to increase more in the vibration (7.4±3.6 μU/ml) than in the control study (5.2±2.5 μU/ml), these changes did not reach statistical significance ($p=0.216$).

DISCUSSION

The results of this study demonstrate that acute exposure to whole-body vibration in healthy men induced transient changes in plasma glucose and norepinephrine concentrations, but did not activate the pituitary-adrenal-gonadal axis.
As serum insulin concentrations were not affected by vibration exercise, hepatic glucose production appeared to remain unchanged. The transient drop in plasma glucose concentration at the end of the vibration session was probably due to increased uptake of circulating glucose by contracting muscles. Our hypothesis is supported by several studies