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Improved insulin sensitivity following a short-term whole body vibration intervention

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Abstract: *Background and Objective:* Despite being recommended for reducing the risk of type 2 diabetes (T2D) the majority of the population do not partake in the advised amount of regular exercise. While high intensity type training has been shown to produce improvements in insulin sensitivity its uptake in high risk populations has been questioned. Contrastingly, whole body vibration training (WBVT) is reported to benefit a range of outcomes in a variety of populations. Limited data exists regarding this training modality on insulin sensitivity. Current study assessed the effect of WBVT on oral glucose tolerance response. *Method:* Following institutional ethics approval, five young healthy sedentary individuals undertook oral glucose tolerance test (OGTT) prior to and on completion of 5-week progressive WBVT. *Result:* There were no changes in fasting plasma glucose concentrations before and after the 6 weeks of WBVT. Both pre- and post-training OGTT revealed no significant changes in plasma glucose concentrations over time. There was a 9% reduction in plasma glucose area under the curve (AUC) post training. The Homeostasis Model Assessment of Insulin Resistance (HOMA-IR) decreased by 21% and Cederholm index of insulin sensitivity was increased by 18% following WBVT. *Conclusion:* Results suggest WBVT is associated with improved insulin sensitivity and could produce clinically relevant effects on fat metabolism in sedentary young people. Large-scale studies are now necessary to assess the effectiveness of WBVT in diabetic populations.

Keywords: Exercise, Glucose, Diabetes, Vibration, Sedentary

Introduction

Exercise is a powerful therapy for the treatment and prevention of type 2 diabetes (T2D) and other chronic conditions such as cardiovascular disease [1]. It has been shown that physical activity alone, or in combination with dietary changes, reduces the risk of developing T2D in populations with impaired glucose tolerance by >50% [2-4]. Despite the acknowledged health benefits of exercise [5], only 43% of men and 32% of women in the UK achieve the recommended 30 minutes of moderate intensity exercise on 5 days of the week according to the Health and Social Care Information Centre [6]. Lack of time to exercise, because of work or family commitments, is the most common reason given for not participating [7-9].

It has been demonstrated previously that a high intensity training protocol can produce rapid improvements in insulin sensitivity with just 15 minutes of exercise per week [10]. However, motivation for strenuous exercise in overweight and sedentary individuals is low due to feelings of discomfort [8] and this type of intervention, according to Hawley & Gibala [11], is unlikely to make a substantial impact in high risk populations. Therefore, an exercise intervention for the general population needs to be as time and intensity efficient as possible (i.e. has a low time requirement with a low-to-moderate intensity).

Whole body vibration training (WBVT) has been reported to improve neuromuscular performance and mechanical strength [12-15], prevent and treat the age related loss of muscle and bone mass [16-17], and combat associated decrements in performance [18]. The main reasons for such effects have been ascribed to high neuromuscular activity arising from the vibratory stimulation [19-20]

as well as marked responses in bone tissue [21-22]. It has also been reported that 12 weeks of WBVT can improve blood glucose control compared to traditional resistance exercise when undergoing a carbohydrate challenge; in addition to a trend for a reduction in long-term glucose control as measured by glycosylated haemoglobin [23]. As the time commitment associated with WBVT is significantly less than traditional resistance training [24-25], with lower levels of perceived exertion [26], physical discomfort [13], and strain on the cardiovascular system [26-27], the potential for WBVT to represent a viable non-pharmacologic alternative for affecting insulin sensitivity is promising. Therefore, the current feasibility study aimed to assess the effectiveness of a WBVT paradigm on insulin sensitivity in a sedentary population.

Material and Methods

Following institutional ethics approval and in accordance with the latest rendition of the Helsinki Declaration [28], five young healthy sedentary individuals (2 male and 3 female; age: 19 ± 2 y; BMI: 24 ± 2 $kg.m^{-2}$) were recruited to participate in the current study. All participants self-reported that they were not engaged in any structured exercise training. Participants were informed of the experimental protocol both verbally and in writing before giving informed consent. Furthermore, all participants were informed about how potential life-style changes could affect the results of the study, and were requested to maintain their normal diet and levels of physical activity throughout the duration of the study.

Experimental Procedures:

Baseline Oral glucose tolerance test (OGTT). Participants refrained from performing any strenuous physical activity for 2 days prior to the OGTT, and attended the laboratory at 9am having fasted overnight. Venous blood samples were collected by venepuncture before, 60mins and 120mins after ingestion of 75 g glucose (Fisher Scientific, Loughborough, UK) dissolved in 100 ml of water. Plasma was separated by centrifugation (10 min at 1600 g) and stored at -20ºC until glucose, insulin and non-esterified fatty acid (NEFA) concentrations were analysed. Plasma glucose concentrations were measured using an automatic analyzer (YSI Stat2300, Yellow Spring Instruments, Yellow Spring, OH). Plasma insulin concentration was determined by ELISA (Invitrogen, UK). Plasma NEFA concentrations were determined by a colorimetric assay (Wako Chemicals, Germany). All concentrations were analysed in accordance with Babraj *et al.* [10].

Whole Body Vibration Training:

The vibration training involved holding a static squat (90^{o}) on a vibration platform (NEMES–LC, Nemes: Italy, produced in 2002; synchronous vibration; amplitude 2mm [peak-to-peak displacement 4mm]). The sinusoidal behaviour of the platform, as well as the vibratory parameters, were quantified in a previous pilot study and were stable up to a frequency of 40Hz and with a load on the platform up to 110kg with the procedures recommended by Rauch *et al*. [29]. For this reason, we recruited participants below a body mass of 110Kg and designed a training progression up to a frequency of 40Hz. Participants exercised with their socks on but no shoes to avoid any effect of footwear on damping the vibratory stimulation, as reported by Marin *et al* [30].

Participants were required to put their hands on the handlebars of the machine to ensure balance was maintained. Each participant completed three training sessions each week for six weeks; completing eighteen sessions in total. The intensity of vibration increased each week in accordance with the overload principle as described by Ingham [31] (see Table 1). For the purpose of compliance and standardisation, all sessions were supervised and a rate of perceived exertion (RPE) was obtained after sessions 1,4,7,10,13 and 16 using the Borg Scale [32].

Post-training assessment: A second OGTT was performed 72 hrs after completion of the last training session in accordance with recommendations regarding recovery from resistance training [33-34]. This second OGTT followed the same protocol as the original test and was conducted at a similar time of day (± 1 hr.) as the baseline assessment to avoid the confounding influence of circadian variation [35-36].

Table-1: The 6-week training protocol showing change in intensity of whole body vibration								
Sessions	**Reps/ Set**	**Time/ Rep (Secs)**	**Frequency (Hz)**	**Peak-to-peak displacement (mm)**	**Peak acceleration (g) (1g=9.81m·s^{-2})**	**Rest/ Rep (Secs)**	**Rest/ Set (Mins)**	**RPE (mean ± SD)**
1-3	5	30	30	4	7.2	60	3	7 ± 2
4-6	5	60	30	4	7.2	60	3	9 ± 2
7-9	10	60	30	4	7.2	60	3	10 ± 2
10-12	10	60	35	4	9.9	60	3	10 ± 2
13-15	10	60	40	4	12.9	60	3	11 ± 2
16-18	10	60	40	4	12.9	30	3	10 ± 2

Calculations and statistical analysis: Area under the [plasma] curve (AUC), described by Sowunmi *et al* [37] as a frequently used clinical method of estimating the plot of plasma versus time, was calculated using the conventional trapezoid rule. Plasma glucose, insulin, and NEFA responses to the baseline and post-intervention OGTTs were analysed using 2 factor repeated measures ANOVA with *post hoc* Student Newman-Keuls tests. Given the small sample size used in the current study conventional inferential statistics were not the most appropriate method to make an inference about the true effect of the intervention and, accordingly, an approach recommended by Hopkins [38] was utilised. Pre-post t-tests were carried out for each AUC and insulin sensitivity measure. The resulting P-values and mean change were used to calculate 90% confidence intervals and clinical inferences. For all measures a 10% change was deemed clinically meaningful. All data are presented as mean ± standard error of the mean (SEM).

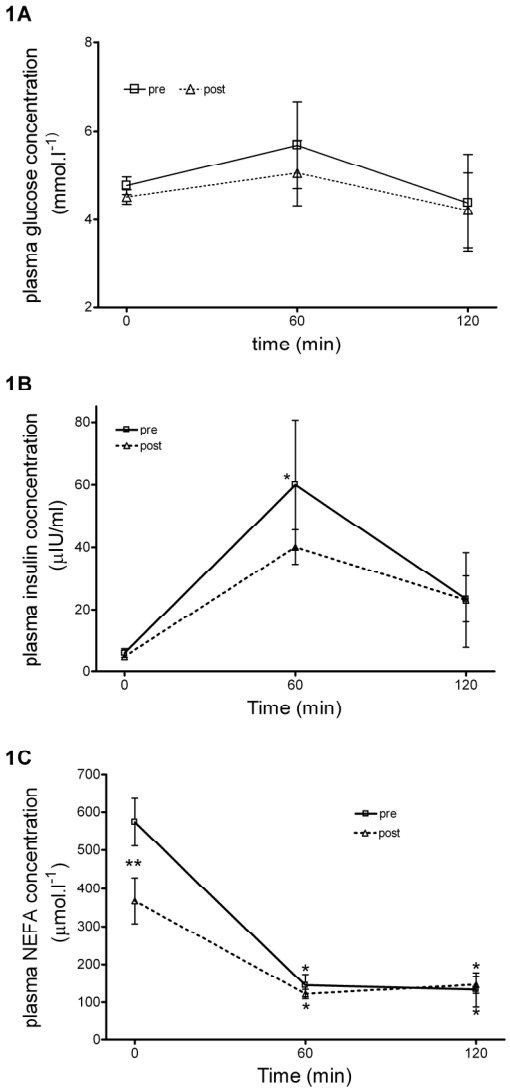
Results

Glucose Responses: There were no changes in fasting plasma glucose concentrations before (4.77 ± 0.09 mmol.l^{-1}) and after (4.52 ± 0.07 mmol.l^{-1}) the 6 weeks of WBVT (Figure 1a). In both pre- and post-training OGTT, there were no significant changes in the plasma glucose concentrations over time (Figure 1a). There was a 9% reduction in plasma glucose area under the curve (AUC) post training (Table 2).

Table-2: Qualitative outcomes for area under the curve (AUC) and insulin sensitivity. [1] Qualitative outcomes reflect the chance that change in each measure is likely to be beneficial, trivial or harmful to participants. For this study a change of 10% for each measure was deemed to be clinically meaningful							
	Pre mean	**Post mean**	**Change**	**90% Confidence limit of change**	**Qualitative Outcome[1] Percentage change that the change is clinically meaningful**		
					Substantially beneficial	**Negligible or trivial**	**Substantially harmful**
Glucose AUG (mmol.min.l^{-1})	550 ± 69	501 ± 65	49	8 - 88	46% possibly	54% possibly	0.2% most unlikely
Insulin AUC (μIU.Ml^{-1}.min^{-1})	3264 ± 1361	2448 ± 788	816	-584 - 2216	78% likely	13% unlikely	9% unlikely
NEFA AUC (μmol.l^{-1}.min^{-1})	32780 ± 5072	23139 ± 2682	9641	2084 - 17198	95% very likely	4% very unlikely	1% very unlikely
HOMA-IR	1.3 ± 0.3	1.0 ± 0.1	0.27	-0.7 - 1.2	63% possibly	13 unlikely	23% unlikely
Cederholm Index (mg-l^{2}- mmol^{-1}.mU^{-1}.min^{-1})	106 ± 18	125 ± 19	19	-14 - 52	70% possibly	24% unlikely	7% unlikely

Insulin Responses: There were no changes in fasting plasma insulin concentrations before (6.0 ± 1.5mmol.l^{-1}) and after (5.0 ± 0.7 µIU.ml^{-1}) the 6 weeks of WBVT (Figure 1b). In the pre training OGTT, plasma insulin concentration was significantly elevated 60 minutes after the 75g glucose load (Figure 1b; 0 min: 6.0 ± 1.5 v 60min: 60.1 ± 20.6 µIU.ml^{-1}, P < 0.05) but not in the post training OGTT (Figure 1b; 0min (n = 5): 5.0 ± 0.7 v 60min 40.1 ± 5.5 µIU.ml^{-1}). There was a 25% reduction in plasma insulin AUC post WBVT (Table 2).

Figure-1: Changes in blood concentration over time A: blood glucose; B: blood insulin; C: blood NEFA. * P<0.05 compared to 0 min time point; ** P<0.05 pre training compared to post training.



NEFA responses: There was a decrease in baseline plasma NEFA levels after 6 weeks of WBVT (Figure 1c; Pre-training:574 ± 140.2 v post-training: 368 ± 135.9µmol·l^{-1}: P<0.05). Plasma NEFA levels were decreased significantly at 60 min and also 120 minutes compared to baseline in the pre and post-training OGTT (Figure 1c; pre- 0 min: 574 ± 140.2 v 60min: 143 ± 66.1; P<0.05 v 120min: 133 ± 100.6µmol·l^{-1}; P<0.05; post- 0 min: 368 ± 135.9 v 60 min: 121 ± 24.7; v 120 min: 146 ± 45.1 µmol·l^{-1}; P<0.05). There was a 30% reduction in the plasma NEFA AUC post WBVT (Table 2).

Insulin sensitivity: The Homeostasis Model Assessment of Insulin Resistance (HOMA-IR), as described by Gayoso-Diz [39], decreased by 21% following training (Table 2) and Cederholm index of insulin sensitivity was increased by 18% (Table 2) following training.

Discussion

The current study provides novel information regarding the usefulness of WBVT in treating metabolic disease. The 6 week WBVT programme produced a lower glucose response (9% reduction in AUC suggesting a possible positive effect), insulin (25% reduction in AUC suggesting a likely positive effect), and NEFA (36% reduction in AUC suggesting a very likely positive effect) to a 75g glucose load in young sedentary individuals. The decrease in glucose AUC was similar to that seen by Baum *et al* [23] in patients with type 2 diabetes. There was also a decrease in insulin resistance as measured by HOMA-IR (21% suggesting a possible positive effect) and an increase in insulin sensitivity (18% suggesting a possible positive effect) following WBVT.

Insulin sensitivity has been shown, in part, to be regulated by plasma NEFA concentration. In older adults fasting NEFA concentrations are elevated in those with impaired post carbohydrate challenge with a loss of suppression of lipolysis in response to insulin [40]. In lean and obese non-diabetic middle aged subjects decreasing plasma NEFA levels improved oral glucose tolerance with both

decreased plasma glucose and insulin AUC [41]. Conversely, elevating plasma NEFA concentration through lipid infusion lowers the glucose infusion rate during peripheral insulinemia-euglycemia in young men [42].

The most interesting finding of the current feasibility study was that WBVT was associated with a 36% decrease in fasting plasma NEFA concentration without a concomitant change in fasting insulin, as well as a 29% reduction in NEFA AUC following WBVT despite a 25% reduction in the plasma insulin AUC. This is in contrast with studies in which 10 weeks of aerobic training failed to affect fasting plasma NEFA concentration [43], and only elicited a small effect on plasma NEFA AUC (2%) and plasma insulin AUC (5%) following a glucose load in young healthy participants [44].

This suggests that insulin was able to inhibit lipolysis to a greater extent following WBVT than is seen with traditional exercise modalities. The results of the current study suggest that WBVT is associated with improved insulin sensitivity and could produce clinically relevant effects on fat metabolism in sedentary young people. Unlike traditional exercise modalities WBVT has a low rate of perceived exertion, which suggests it may be a suitable exercise paradigm in people with type 2 diabetes. Additionally, due to the lower perceived exertion levels, discomfort and strain placed on the heart, WBVT could be a useful training tool for people with cardiovascular disease or secondary complications associated with type 2 diabetes; factors which often limit participation in more traditional forms of exercise. More large-scale studies are now necessary to assess the effectiveness of WBVT in diabetic populations as well as define the safest and most effective training protocol.

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