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BRIEF ARTICLE

Acute effects of stochastic resonance whole body vibration

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Abstract

AIM: To investigate the acute effects of stochastic resonance whole body vibration (SR-WBV) training to identify possible explanations for preventive effects against musculoskeletal disorders.

METHODS: Twenty-three healthy, female students participated in this quasi-experimental pilot study. Acute physiological and psychological effects of SR-WBV training were examined using electromyography of descending trapezius (TD) muscle, heart rate variability (HRV), different skin parameters (temperature, redness and blood flow) and self-report questionnaires. All subjects conducted a sham SR-WBV training at a low intensity (2 Hz with noise level 0) and a verum SR-WBV training at a higher intensity (6 Hz with noise level 4). They were tested before, during and after the training. Conclusions were drawn on the basis of analysis of variance.

RESULTS: Twenty-three healthy, female students participated in this study (age = 22.4 ± 2.1 years; body mass index = 21.6 ± 2.2 kg/m^2). Muscular activity of the TD and energy expenditure rose during verum SR-WBV compared to baseline and sham SR-WBV (all $P < 0.05$). Muscular relaxation after verum SR-WBV was higher than at baseline and after sham SR-WBV (all $P < 0.05$). During verum SR-WBV the levels of HRV were similar to those observed during sham SR-WBV. The same applies for most of the skin characteristics, while microcirculation of the skin of the middle back was higher during verum compared to sham SR-WBV ($P < 0.001$). Skin redness showed significant changes over the three measurement points only in the middle back area ($P = 0.022$). There was a significant rise from baseline to verum SR-WBV (0.86 ± 0.25 perfusion units; $P = 0.008$). The self-reported chronic pain grade indicators of pain, stiffness, well-being, and muscle relaxation showed a mixed pattern across conditions. Muscle and joint stiffness ($P = 0.018$) and muscular relaxation did significantly change from baseline to different conditions of SR-WBV ($P < 0.001$). Moreover, muscle relaxation after verum SR-WBV was higher than after sham SR-WBV ($P < 0.05$).

CONCLUSION: Verum SR-WBV stimulated musculoskeletal activity in young healthy individuals while cardiovascular activation was low. Training of musculoskeletal capacity and immediate increase in musculoskeletal relaxation are potential mediators of pain reduction in preventive trials.

Key words: Musculoskeletal system; Electromyography; Quasi-experimental study; Prevention; Relaxation

Core tip: Musculoskeletal function improves after application of stochastic whole body vibration (SR-WBV). The pathway of the beneficial effect, however, is unclear. This study shows SR-WBV to increase muscle activity of descending trapezius muscle, the muscle that is often associated with reported pain in computer work. Participants report improved muscular relaxation after SR-WBV while the cardiovascular activation was very low. In addition to ergonomic interventions SR-WBV may help to prevent trapezius muscle related pain at work.

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INTRODUCTION

Stochastic resonance whole body vibration training (SR-WBV) is still rather new and to date, only few studies have been conducted with this kind of vibration[1,2]. Nevertheless, there is increasing evidence that SR-WBV improves musculoskeletal function in patients with neurodegenerative disorders[3-5] and paraplegia[6]. The application of SR-WBV in stroke patients has been approved and found to not be physically demanding[7]. SR-WBV is a practical and well-accepted method to prevent musculoskeletal disorders (*e.g.*, neck, shoulder or low back pain)[8] while the exact physiological working mechanisms are still unclear[9]. Bosco *et al*[10] found metabolic changes after sinusoidal WBV, although these findings could not be reproduced by other researchers[9]. By using electromyography (EMG) an enhancement of the muscle activity was shown after sinusoidal WBV[11]. Studies on the activity of back muscles are still lacking. Therefore, the aim of this study was to assess the immediate effects of SR-WBV on back muscles, especially the descending trapezius muscle. A recent study showed that sustained trapezius muscle activity is associated with neck and shoulder pain in young adults[12]. It was hypothesized that SR-WBV would increase muscle activity during SR-WBV while the expected cardiovascular activation would remain low. In addition increased muscle relaxation is expected after SR-WBV.

MATERIALS AND METHODS

Ethics

All participants gave informed consent prior to study inclusion. The study was performed in accordance with the requirements defined by the Swiss Society of Psychology. Every participant was able exit the study at any time. The study has been approved by the Ethical Committee of the Faculty of Human Sciences of the University of Bern.

Subjects

Healthy participants between 18 and 30 years with a body mass index (BMI) between 17 and 26 kg/m^2 being able to cope physically with the load of a SR-WBV training were included in the study. Potential participants with any kind of metallic or synthetic implants such as a cardiac pacemaker were excluded. Due to gender specific variations in heart rate variability (HRV)[13] male participants were excluded as well. In addition, athletes and individuals performing more than three training units per week were also excluded. All of these restrictions assured homogeneity of the fitness level and the age range within the sample as they could possibly interfere with the measurements[14] and hence, confound the outcome data.

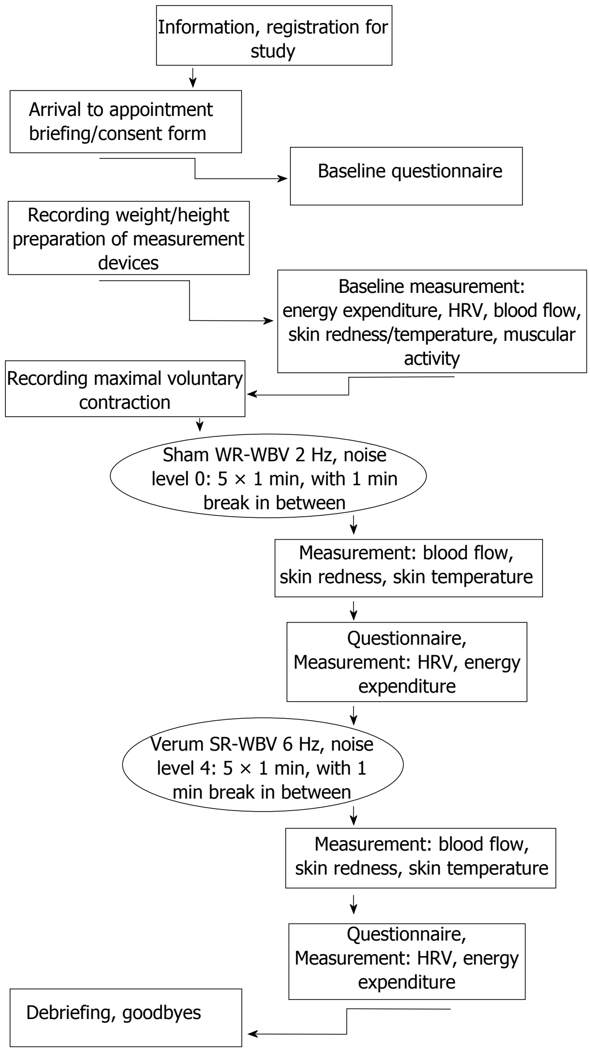

Figure 1 Flow chart of the study procedure. HRV: Heart rate variability; SR-WBV: Stochastic resonance whole body vibration.

Design

The present study can be considered as a quasi-experimental pilot study using repeated measurements. The participants performed two training sessions: a sham SR-WBV at a frequency where no effects were expected[1] followed by training at a vibration frequency high enough to expect effects (Figure 1). Thus, changes from sham SR-WBV to verum SR-WBV levels were considered as acute training effects.

SR-WBV

Ward *et al*[15] defined stochastic resonance as "a nonlinear cooperative effect wherein the addition of a random process, or 'noise' to a weak signal, or stimulus results in improved detectability or enhanced information content in some response". SR-WBV is a whole body vibration training based on stochastic oscillation with the benefit that the sensorimotor system does not adapt to the stimulus and therefore reacts continuously[3]. SR-WBV training in this study lasted for one minute. SR-WBV training was followed by a break of one minute where the person on the device was able to rest. For SR-WBV the srt Zeptor® medical plus noise device (FreiSwiss AG, Zurich, Switzerland)[1] was used.

For the sham SR-WBV a frequency of 2 Hz with noise level 0 was used as no increased muscle activity effects can be expected under such conditions[1]. For the verum SR-WBV intervention a 6 Hz frequency with noise level 4 was used as this condition is applied most often when subjects have a free choice. Moreover, these SR-WBV training characteristics have been shown to activate muscles[8,16].

Muscle activity

The activity of the descending trapezius (TD) muscle was measured by EMG following the application recommendations of SENIAM (Seniam project)[17] and Perreto[18]. EMG signals were taken by single-use surface electrodes (Nicolet Disposable Center Snap Rectangular Silver/Silver Chloride Electrode, REF: 019-767700, Warwick, United Kingdom). All myoelectric signals were filtered by a pre-amplifier (Input impedance > 100 MOhm, common mode rejection ratio > 100 dB, Base gain = 500, Bandpass 10-500 Hz), then transferred to a transmitter (TeleMyo™ 2400T G2 Transmitter, Noraxon Inc. United States, Velamed medical technics and biomedical concepts GmbH, Cologne, Germany) and finally transduced to a receiver (TeleMyo™ 2400T G2 Receiver, Noraxon Inc. United States, Velamed medical technics and biomedical concepts GmbH, Cologne, Germany). The EMG signals were sampled with a frequency of 2 kHz. Obtained data were displayed and analyzed with the "Analog Signal Caption and Analysis" software (ADS, uklabs, Kempen, Germany). The root-mean-square (RMS) values of the EMG-signal parts of maximal voluntary contraction (MVC) and SR-WBV were calculated and all SR-WBV signals normalized to the RMS values of the MVC signal part (%MVC).

Energy expenditure

Total energy expenditure (EE) during one training session was assessed using a SenseWear Armband (SWA) motion sensor (HealthWear Bodymedia, Pittsburgh, Penn., United States) placed on the back of the upper right arm just above the triceps muscle. The SWA measures heat flux, galvanic skin response, skin temperature and near-body temperature including also a 2-axis accelerometer[19,20]. Based on additional personal data such as gender, age, body height and weight, EE was calculated by the SWA system[21]. Validity and reliability of the SWA has been shown for different situations, activities and populations[22].

Heart rate variability

Heart rate variability (HRV) was assessed following the guidelines of the Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996) (furthermore referred as the task force). According to this task force, a power spectral analysis is especially suitable for short-term measurements. As such, the square root of the mean of the sum of the squares of the differences (RMSSD) between adjacent intervals was analyzed[23]. The RMSSD reacts sensitively to fast variations of the HRV and can be seen as a marker for parasympathetic activity[13]. Therefore, RMSSD can be used as a proxy for the degree of body relaxation. For HRV measurements the telemetric Polar RSX 800 system (Polar Electro Europe BV, Zug, Switzerland) was used. This procedure has been shown to be accurate for short-term measurements[24].

Skin measurements

The skin microperfusion was measured using the Periflux laser-Doppler device (Periflux 4001, perimed AB, Järfälla, Sweden). The Periflux device "counts" by laser technology the movement of blood cells at the moment of measurement and provides an average value of the blood flow in arbitrary perfusion units (AU). The reliability of the instrument has been demonstrated in previous studies[25].

Skin redness was measured using the Chroma Meter CR-300 Camera (Minolta Camera Co., Ltd., Osaka, Japan). This device is specially designed to analyze reflecting colors of surfaces and can therefore be used to analyze the degree of redness of the skin surface (Minolta, n.d). This technique is based on pulsed xenon light illuminating the surface and feedback systems recording the incident and reflected light and thus calculating the color of the surface. The device is often used in medical studies and its reliability has been approved by Van den Kerckhove *et al*[26]. In addition, skin temperature was measured using an infrared thermometer (ScanTemp 380, TFA Dostmann, Wertheim-Reicholzheim, Germay). Several skin characteristics were measured at standardized anatomical landmarks on the upper, middle and lower back as proposed by Perreto[18].

Questionnaire assessment

Muscular well-being and relaxation were assessed by a short version of the Burger *et al*[8] self-administered questionnaire and completed before and after the sham SR-WBV and after the verum SR-WBV.

This questionnaire was based on items of the chronic pain grade questionnaire (CPG)[27], but has some changes due to time specification. Four items being relevant for the study question were used. The first item assessed pain in muscle and joints, the second muscle and joints stiffness while the third and fourth item assessed muscular and joint well-being, as well as muscular relaxation. The participants were asked to rate themselves on a 10-point Likert scale. In its original version the CPG showed a high internal consistency and reliability (Cronbach alpha > 0.9)[28]. Other studies showed good correlations between the CPG and other pain related proxies[29].

Procedure

University students were the main recruitment source.

Eligible participants were contacted and informed about this study and their potential participation in early February 2012. The participants could apply *via* email or telephone, then received further information about the procedure of the study and were asked to inform the authors prior to the appointment about any acute health issues such as a major flu, headaches, feeling unwell, back or muscle pains. In such a case, the potential participants were ineligible and excluded from the study. All measurements were conducted at the Movement Laboratory of the Bern University of Applied Sciences. After their arrival at the laboratory, participants were informed about the procedure and signed the consent form. Then, the self-administered baseline questionnaires were completed. Body weight and height were recorded. Skin of the participant was prepared, the EMG device as well as the polar belt and the SWA were placed. The anatomical landmarks were palpated and electrodes then attached by the same trained research assistant at all times. The resistance of the electrodes was tested and a resistance beneath 10 κΩ was accepted[17]. If the resistance was higher the electrodes were removed and the preparation procedure of the skin repeated. The cables connecting the electrodes with the EMG device were attached to the body of the participants to avoid motion artifacts. The participants were then given a large T-shirt to wear over these instruments.

The EMG, EE, HRV and skin characteristics baseline data were measured while standing still. To normalize the EMG data, measurement of the maximal voluntary muscles force (maximal voluntary contractions, MVC) were taken by the same trained research assistant at all times. To compare muscle activities of different subjects, an isometric MVC had to be performed prior to the test trials for data normalization (%MVC). MVC testings (3-5 s per muscle, break of 15 s between two series) were based on muscle tests[30].

Once the participants had been prepared, the training started. For the first intervention, the sham SR-WBV was chosen. The subjects were barefoot and asked to stand still during 15 s on the srt Zeptor® medical vibration platform with loose-hanging arms at their sides and slightly bent knees looking at a fixed point on the wall as a preparation before the vibration of one minute took place, which was followed by a recovery of 60 s where the participants could relax and move on the platform. This procedure was repeated 5 times. The participants completed the intervention training on the srt Zeptor® medical with the verum SR-WBV. Hence, both SR-WBV training sessions were very similar varying only in vibration frequency and noise level. Skin characteristics were measured immediately after the SR-WBV training. Five minutes after the training the participants were asked to sit down to complete the questionnaire. In the meantime the HRV and the SWA measurements were taken.

Statistical analysis

The HRV data, initially recorded by the Polar System, were exported to the Kubios HRV Version 2.0 software (University of Kuopio, Biosignal Analysis and medical Imaging Group, Kuopio, Finland) to calculate the RMSSD for the specific time intercepts. These time intercepts used for the RMSSD calculations were the 5 times 1 min of vibration training (for the HRV). In addition, the minimal RMSSD reached as well as the average RMSSD over the whole training were taken into account for HRV analysis. Further RMSSD for the baseline (T0), after the sham SR-WBV (T1) and the verum SR-WBV (T2) were calculated. The RMSSD for these measurement points were calculated for 1 min each.

The mean muscle activation of the 1 min vibration blocks in each of the two SR-WBV conditions was calculated based on the EMG data and presented as percent of the (%MVC). For all statistical analyses the SPSS software (version 19, SPSS, IBM Inc., United States) was used and the level of significance was set at $P < 0.05$. Pearson's product-moment correlations between study variables at each time point were calculated. Repeated measures analyses of variance were calculated to test differences between sham and verum SR-WBV. Post hoc tests using the Bonferroni correction were applied. If the assumption of sphericity was violated the degrees of freedom were corrected by the Greenhouse-Geisser correction as proposed by Field[31]. The effect sizes were calculated by the partial eta-squared (η^2).

RESULTS

Twenty-three healthy, female students participated in this study (age = 22.4 ± 2.1 years; BMI = 21.6 ± 2.2 kg/m^2). Table 1 depicts the descriptive study results while the repeated measures analysis of variance results for all measurements are shown in Table 2. Analyses indicated that the activity of the back muscles differed between time points of measurement. Post hoc tests with Bonferroni correction showed that muscle activity increased significantly during sham SR-WBV (2.24 ± 0.48 %MVC) and during verum SR-WBV (5.71 ± 1.14 %MVC) (both $P < 0.0005$). The observed muscle activity increased between sham and verum SR-WBV training condition (3.47 ± 0.97 %MVC) and also reached statistical significance ($P = 0.006$). The effect size for muscle activity change was large ($\eta^2 = 0.50$).

Further analyses showed that HRV dropped during sham and verum SR-WBV training compared to baseline when mean HRV was analyzed and also when minimal HRV reached during SR-WBV was considered (all $P \leqslant 0.0005$). EE rose significantly under verum SR-WBV conditions ($P < 0.0005$). Post hoc tests showed, that increased EE was significant for sham and verum training (4.86 ± 0.81 calories and 21.81 ± 1.36 calories, respectively) as well as the difference between sham and verum training (16.95 ± 1.19 calories) (all $P < 0.0005$). Effect size of change in EE was $\eta^2 = 0.91$.

Among the indicators of microperfusion of the skin, only the flow of the middle back regions showed a significant rise over the three measurement time points (P

Table 1 Descriptive study results (mean ± SD)

	Baseline	Sham SR-WBV (2 Hz, noise level 0)	Verum SR-WBV (6 Hz, noise level 4)
EMG TD (%MVC)	3.43 ± 2.08	5.68 ± 2.78	9.14 ± 5.81
HRV (mean RMSSD, ms)	38.28 ± 19.76	28.07 ± 26.81	26.14 ± 17.38
Energy expenditure (kcal)	13.67 ± 3.41	18.52 ± 2.96	35.48 ± 5.69
Blood flow (perfusion units)			
Neck	27.83 ± 9.22	27.86 ± 11.05	30.81 ± 20.62
Middle back	22.25 ± 6.04	26.33 ± 7.82	27.13 ± 12.45
Lower back	15.40 ± 5.15	14.92 ± 6.22	15.87 ± 6.04
Skin temp (℃)			
Neck	34.48 ± 0.85	35.27 ± 1.04	35.65 ± 0.81
Middle back	33.95 ± 0.99	34.85 ± 1.30	35.19 ± 0.91
Lower back	33.90 ± 1.34	34.19 ± 1.35	34.25 ± 1.32
Skin redness (colour unit)			
Neck	8.56 ± 2.37	8.83 ± 2.75	8.91 ± 2.58
Middle back	6.39 ± 1.63	7.20 ± 2.03	7.25 ± 2.27
Lower back	6.55 ± 1.74	6.34 ± 1.61	6.41 ± 1.94
CPG pain	1.52 ± 0.75	1.33 ± 0.58	1.33 ± 0.91
Stiffness	2.52 ± 2.16	1.95 ± 1.72	1.76 ± 1.67
Well-being	8.10 ± 1.34	8.24 ± 1.04	8.14 ± 1.71
Muscle relaxation	6.67 ± 1.74	7.24 ± 1.95	8.38 ± 0.97

EMG: Electromyography, activation expressed as percentage of activation measured at maximal voluntary contraction (%MVC) of the decending part of the trapezius muscle (TD); RMSSD: Root of the mean of the sum of the squares of the differences; HRV: Heart rate variability; CPG: Chronic pain grade; SR-WBV: Stochastic resonance whole body vibration.

< 0.0005; η^2 = 0.49) with significant changes between baseline and verum SR-WBV (7.33 ± 1.58 AU, $P < 0.0005$) and sham and verum SR-WBV noise 4 (11.41 ± 2.11 AU, $P < 0.0005$). Skin temperature of neck and middle back differed significantly between baseline and follow-up ($P \leqslant 0.0005$). On average the overall skin temperature raised from baseline to sham SR-WBV by 0.66 ± 0.12℃ ($P \leqslant 0.0005$) and between baseline and verum SR-WBV with 0.92 ± 0.13℃ ($P \leqslant 0.0005$).

Skin redness showed significant changes over the three measurement points only in the middle back area ($P = 0.022$). There was a significant rise from baseline to verum SR-WBV (0.86 ± 0.25 AU, $P = 0.008$).

The self-reported CPG indicators of pain, stiffness, well-being and muscle relaxation showed a mixed pattern across conditions. Muscle and joint stiffness ($P = 0.018$) and muscular relaxation did significantly change from baseline to different conditions of SR-WBV ($P < 0.001$). Moreover, muscle relaxation after verum SR-WBV was higher than after sham SR-WBV ($P < 0.05$).

DISCUSSION

Stochastic whole body vibration training activates the musculoskeletal system[9] while the metabolic and cardiovascular strain is low[7]. The EMG, HRV and EE data of the present study showed significant differences over the different SR-WBV modalities, suggesting SR-WBV related acute psychological and physiological effects[1]. As hypothesized, verum SR-WBV training effect showed a pattern of enhanced muscle activity, decreased HRV and increased EE. With this observed substantial increase of EE and muscle activity, this verum SR-WBV training at a frequency of 6 Hz and noise level 4 fulfills the requirements of a physical activity or an exercise to prevent diseases according to the definition by the United Sates Surgeon General's Report[32]. The latter defined physical activity as "bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure" and exercise as "planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness".

However, the 9.14 %MVC muscle activity during verum SR-WBV remains fairly limited compared to more classic strength training such as push-up or press-up exercises which increase the trapezius muscle activity between 22 and 33 %MVC[33]. Similarly, the effects on EE during verum SR-WBV were low to moderate compared to classic resistance exercise. The EE during classical resistance training varies widely[34] from 2.2 to 35 calories per minute adding up to 22 to 350 calories for a 10-min session. Hence, the mean energy consumption of 35.5 calories per 10 min is low but in line with other findings on resistance training related EE[35]. These results support previous findings concerning the moderately increased oxygen absorption during WBV training[3]. Furthermore, these findings suggest that verum SR-WBV training may be an effective prevention tool for musculoskeletal diseases in work environments. SR-WBV training sessions can easily be done before, during or after work without having to change clothes or take a shower afterwards.

HRV measurements during training showed that both sham and verum SR-WBV training conditions may have similar effects on the parasympathetic system. No differences between sham and verum training conditions were found. Thus, cardiovascular training demands in verum SR-WBV are low. The effects of verum SR-WBV on the musculoskeletal system and proxies of microperfusion of the skin (blood flow, temperature and redness) could explain the self-reported musculoskeletal well-being experiences of the participants. The measurements of skin characteristics showed an unusual pattern over all performed analyses. Though the measurements of temperature and skin redness of the three different anatomical locations of the back were correlated with each other only the middle back showed significant differences throughout the means of elicitation. This study demonstrated that there is only a significant rise of blood flow, skin temperature and redness of the skin under verum training conditions, while these changes do not occur under sham training conditions. These findings corroborate those of Elfering *et al*[1] who did not find any significant long-term effects on the prevention of musculoskeletal diseases at very low vibration frequencies. Musculoskeletal relaxation rose significantly after verum SR-WBV training ($P < 0.001$) but not after sham training ($P = 0.657$) while well-being and pain did not show any significant differences after verum SR-WBV. As a healthy young sample was addressed a possible explanation could be a floor effect.

Table 2 Results of repeated measurement analyses of variance

	df^1	F	P	η^2	BL *vs* Sham		BL *vs* Verum		Sham *vs* Verum	
						P^3		P^3		P^3
EMG TD (%MVC)	1.26	20.19	< 0.001	0.50	2.24 ± 0.48	< 0.001	5.71 ± 1.14	< 0.001	3.37 ± 0.97	0.006
HRV (mean RMSSD, msec)	1.54	6.73	< 0.001	0.25	-10.21 ± 4.41	0.094	12.14 ± 3.25	0.004	1.93 ± 2.83	1.000
Energy expenditure (kcal)	1.56	199.90	< 0.001	0.91	4.86 ± 0.81	< 0.001	21.81 ± 1.30	< 0.001	16.95 ± 1.19	< 0.001
Blood flow (AU)	1.42	0.42	0.591	0.02	0.03 ± 2.31	1.000	2.98 ± 4.04	1.000	2.95 ± 4.48	1.000
Middle back	2.00	18.93	< 0.001	0.49	-4.08 ± 1.91	0.136	7.33 ± 1.58	< 0.001	11.41 ± 2.11	< 0.001
Lower back	1.56	0.35	0.655	0.02	-0.48 ± 0.92	1.000	0.48 ± 1.04	1.000	0.95 ± 1.41	1.000
Skin temperature (℃)	2.00	23.79	< 0.001	0.54	0.79 ± 0.18	< 0.001	1.17 ± 0.18	< 0.001	0.38 ± 0.16	0.075
Middle back	1.36	27.98	< 0.001	0.58	0.90 ± 0.19	< 0.001	1.24 ± 0.10	< 0.001	0.34 ± 0.21	0.348
Lower back	1.55	1.74	0.197	0.08	0.29 ± 0.18	0.390	0.35 ± 0.25	0.515	0.07 ± 0.16	1.000
Skin redness (colour unit)	2.00	0.58	0.565	0.03	0.27 ± 0.30	1.000	0.35 ± 0.32	0.889	0.08 ± 0.38	1.000
Middle back	2.00	4.19	0.022	0.17	0.81 ± 0.38	0.130	0.86 ± 0.25	0.008	0.05 ± 0.36	1.000
Lower back	2.00	0.93	0.404	0.04	-0.20 ± 0.11	0.257	-0.14 ± 0.17	1.000	0.07 ± 0.16	1.000
CPG pain	1.55	1.49	0.240	0.07	0.19 ± 0.09	0.127	0.19 ± 0.15	0.641	0.00 ± 0.14	1.000
CPG stiffness	1.33	5.65	0.018	0.22	0.57 ± 0.29	0.187	0.76 ± 0.30	0.023	0.19 ± 0.13	1.000
CPG well-being	1.31	0.09	0.828	0.01	0.14 ± 0.19	1.000	0.05 ± 0.41	1.000	0.10 ± 0.42	1.000
CPG muscle relaxation	2.00	10.32	< 0.001	0.34	0.57 ± 0.45	0.657	1.71 ± 0.33	< 0.001	1.14 ± 0.36	0.014

[1]If the sphericity is not given the Greenhouse-Geisser correction was applied; [3]Bonferroni correction applied for *post hoc* tests. EMG: Electromyography, activation expressed as percentage of activation measured at maximal voluntary contraction ± %MVC) of the decending part of the trapezius muscle ± TD); HRV: Heart rate variability; CPG: Chronic pain grade; RMSSD: The square root of the mean of the sum of the squares of the differences.

The significant rise of mean skin temperature has to be viewed critically. It could be hypothesized that SR-WBV leads to the release of vaso-active substances from connective tissue cells, increasing the local blood flow and the microperfusion of the skin. However, it cannot be excluded that the observed change in skin temperature is related to the procedure of the experiment. For example, baseline values were assessed shortly after the electrodes had been placed, hence, after the participants had spent some time without clothes. This could have caused a cool down of the skin temperature at baseline. Significant changes of the skin measurements were found only in the middle back region. In addition, verum SR-WBV increased musculoskeletal relaxation. The middle back includes the trapezius muscle and according to Blangsted *et al*[36] office workers often report muscle problems of this region. Therefore, the observed increase in blood flow and activity of the trapezius muscles can lead to musculoskeletal relaxation. Relaxation is deeper after muscles have been forced. Many relaxation techniques include this technique, *e.g.*, progressive relaxation technique after Jacobson[37] So, to improve muscle relaxation in clerical workers with excessive stable tension in low back and upper limb musculature SR-WBV appears to be a promising technique that induces relaxation after activation. Also more appropriate postures and better office furniture should be addressed to avoid excessive muscle tension during work.

Limitations

This pilot study had a quasi-experimental design and thus has to face criticism[36]. There are confounders which are difficult to control in quasi-experimental designs and as such they jeopardize the internal validity[38] with respect to alternative explanations of effects that cannot be ruled out. Because of the convenience sampling method, aimed at recruiting healthy, young and physically active participants external validity of the study may be questioned. Potential selection bias has been attempted to control with the limitation of women exercising not more three times a week. With an average activity level of 2.4 training units per week the study participants are comparable to the activity level in the Swiss population[39]. A blinding of the primary investigator was not possible but the blinding of participants was guaranteed by sham training sessions. The participants were told in the beginning that they would go through two identical training programmes and that they would have to complete questionnaires afterwards. The participants stood on the vibration device with their back to the remote control where the vibration frequency was set and the setting-screen was additionally covered by a piece of paper so that the participants never knew the exact vibration frequency. Griffin[40] wrote in his Handbook of Human Vibration: "The shaking of the human body - a complex, active, intelligent, dynamic structure - should not be expected to have a single, simple or easily predictable consequence." This may apply as well to SR-WBV training. As difficult as it is to predict the effects of SR-WBV so complicated it is to show all training effects that contribute to SR-WBV effectiveness in prevention. Nevertheless, this study sheds some light on this complex matter.

Verum SR-WBV induced acute changes in the musculoskeletal system that are eligible to cause the known positive effects on back pain[1,8]. These findings make a contribution to the explanation of back pain prevention through SR-WBV. Verum SR-WBV stimulated musculoskeletal activity in young healthy females while the cardiovascular activation was low. Therefore, verum SR-WBV served as short, specific exercise stimulus (likely followed by muscle relaxation), but was not a stressful, constant load, *e.g.*, like sitting in front of a computer. So, to improve muscle relaxation in office workers with excessive stable tension in the lower back and upper limb musculature SR-WBV appears to be a promising technique.

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COMMENTS

Background

Musculoskeletal pain is common and so far no tests of acute musculoskeletal and cardiovascular changes due to stochastic resonance whole-body vibration training (SR-WBV) as intervention have been reported.

Research frontiers

There is need for research on short, economic, and effective training interventions. In this pilot study SR-WBV is shown to specifically activate back muscles while cardiovascular demands are low.

Innovations and breakthroughs

The study demonstrates acute SR-WBV training effects in physiological and self-perceived musculoskeletal function.

Applications

SR-WBV at work appears to be a promising tool in the prevention of occupational musculoskeletal problems.

Terminology

SR-WBV constantly challenges the neuro-musculoskeletal coordination to adapt to unforeseeable changes.

Peer review

The present manuscript investigated the influence of a technique termed SR-WBV on various physiological and psychological parameters. Young healthy participants underwent a “sham” (2 Hz with noise level 0) then a “verum” (6 Hz with noise level 4) SR-WBV training. Main results showed that electromyography activity of descending trapezius and energy expenditure were both larger during verum training as compared to baseline and sham training. This study is globally interesting, the experiments well-conducted and the topic chosen by the authors.

REFERENCES

1 **Elfering A,** Thomann J, Schade V, Radlinger L. Stochastic resonance whole body vibration reduces musculoskeletal pain: A randomized controlled trial. *World J Orthop* 2011; **2**: 116-120 [PMID: 22474630 DOI: 10.5312/wjo.v2.i12.116]

2 **Pang MY.** Whole body vibration therapy in fracture prevention among adults with chronic disease. *World J Orthop* 2010; **1**: 20-25 [PMID: 22474623 DOI: 10.5312/wjo.v1.i1.20]

3 **Haas CT,** Turbanski S, Kessler K, Schmidtbleicher D. The effects of random whole-body-vibration on motor symptoms in Parkinson's disease. *NeuroRehabilitation* 2006; **21**: 29-36 [PMID: 16720935]

4 **Schuhfried O,** Mittermaier C, Jovanovic T, Pieber K, Paternostro-Sluga T. Effects of whole-body vibration in patients with multiple sclerosis: a pilot study. *Clin Rehabil* 2005; **19**: 834-842 [PMID: 16323382 DOI: 10.1191/0269215505cr919oa]

5 **Ebersbach G,** Edler D, Kaufhold O, Wissel J. Whole body vibration versus conventional physiotherapy to improve balance and gait in Parkinson's disease. *Arch Phys Med Rehabil* 2008; **89**: 399-403 [PMID: 18295614 DOI: 10.1016/j.apmr.2007.09.031]

6 **Haas CT,** Schulze-Cleven K, Turbanski S, Schmidtbleicher D. Interactions of coordinative and proprioceptive performances. *Deutsche Zeitschrift für Sportmedizin* 2007; **58**: 19-24 Available from: URL: http://www.zeitschrift-sportmedizin.de/fileadmin/externe_websites/ext.dzsm/content/archiv2007/heft01/19-24.pdf

7 **Herren K,** Hotz Hängärtner C, Oberli A, Radlinger L. Cardiovascular and metabolic strain during stochastic resonance therapy in stroke patients. *Physioscience* 2009; **5**: 13-17 [DOI: 10.1055/s-0028-1109140]

8 **Burger C,** Schade V, Lindner C, Radlinger L, Elfering A. Stochastic resonance training reduces musculoskeletal symptoms in metal manufacturing workers: a controlled preventive intervention study. *Work* 2012; **42**: 269-278 [PMID: 22699194 DOI: 10.3233/WOR-2012-1350]

9 **Cochrane DJ.** Vibration exercise: the potential benefits. *Int J Sports Med* 2011; **32**: 75-99 [PMID: 21165804 DOI: 10.1055/s-0030-1268010]

10 **Bosco C,** Iacovelli M, Tsarpela O, Cardinale M, Bonifazi M, Tihanyi J, Viru M, De Lorenzo A, Viru A. Hormonal responses to whole-body vibration in men. *Eur J Appl Physiol* 2000; **81**: 449-454 [PMID: 10774867]

11 **Torvinen S,** Kannu P, Sievänen H, Järvinen TA, Pasanen M, Kontulainen S, Järvinen TL, Järvinen M, Oja P, Vuori I. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. *Clin Physiol Funct Imaging* 2002; **22**: 145-152 [PMID: 12005157 DOI: 10.1046/j.1365-2281.2002.00410.x]

12 **Hanvold TN,** Wærsted M, Mengshoel AM, Bjertness E, Stigum H, Twisk J, Veiersted KB. The effect of work-related sustained trapezius muscle activity on the development of neck and shoulder pain among young adults. *Scand J Work Environ Health* 2013; **39**: 390-400 [PMID: 23494255 DOI: 10.5271/sjweh.3357]

13 **Sztajzel J.** Heart rate variability: a noninvasive electrocardiographic method to measure the autonomic nervous system. *Swiss Med Wkly* 2004; **134**: 514-522 [PMID: 15517504]

14 **Rauch F,** Sievanen H, Boonen S, Cardinale M, Degens H, Felsenberg D, Roth J, Schoenau E, Verschueren S, Rittweger J. Reporting whole-body vibration intervention studies: recommendations of the International Society of Musculoskeletal and Neuronal Interactions. *J Musculoskelet Neuronal Interact* 2010; **10**: 193-198 [PMID: 20811143]

15 **Ward LM,** Neiman A, Moss F. Stochastic resonance in psychophysics and in animal behavior. *Biol Cybern* 2002; **87**: 91-101 [PMID: 12181585 DOI: 10.1007/s00422-002-0328-z]

16 **Lauper M,** Kuhn A, Gerber R, Luginbühl H, Radlinger L. Pelvic floor stimulation: what are the good vibrations? *Neurourol Urodyn* 2009; **28**: 405-410 [PMID: 19283866 DOI: 10.1002/nau.20669]

17 SENIAM project (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles) (n.d.). Retrieved Feb 11th, 2013, Available from: URL: http: //www.seniam.org/

18 **Perotto AO.** Anatomical Guide for the electromyographer.4th ed Springfield (IL): Charles C Thomas, 2005:1-345

19 **Elfering A,** Grebner S. Ambulatory assessment of skin conductivity during first thesis presentation: lower self-confidence predicts prolonged stress response. *Appl Psychophysiol Biofeedback* 2011; **36**: 93-99 [PMID: 21533677 DOI: 10.1007/s10484-011-9152-3]

20 **Pereira D,** Meier LL, Elfering A. Short-term Effects of Social Exclusion at Work and Worries on Sleep. *Stress Health* 2013; **29**: 240-252 [PMID: 23027673 DOI: 10.1002/smi.2461]

21 **Wadsworth DD,** Howard T, Hallam JS, Blunt G. A validation study of a continuous bodymonitoring device: Assessing energy expenditure at rest and during exercise. *Med Sci Sports Exercise* 2005; **37** Suppl: S24

22 **Drenowatz C,** Eisenmann JC. Validation of the SenseWear Armband at high intensity exercise. *Eur J Appl Physiol* 2011; **111**: 883-887 [PMID: 20972880 DOI: 10.1007/s00421-010-1695-0]

23 Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation* 1996; **93**: 1043-1065 [PMID: 8598068 DOI: 10.1161/01.CIR.93.5.1043]

24 **Nunan D,** Jakovljevic DG, Donovan G, Hodges LD, Sand-

ercock GR, Brodie DA. Levels of agreement for RR intervals and short-term heart rate variability obtained from the Polar S810 and an alternative system. *Eur J Appl Physiol* 2008; **103**: 529-537 [PMID: 18427831 DOI: 10.1007/s00421-008-0742-6]
25 **Røe C,** Knardahl S. Muscle activity and blood flux during standardised data-terminal work. *Int J Ind Erg* 2002; **30**: 251–264 [DOI: 10.1016/S0169-8141(02)00129-4]
26 **Van den Kerckhove E,** Staes F, Flour M, Stappaerts K, Boeckx W. Reproducibility of repeated measurements on healthy skin with Minolta Chromameter CR-300. *Skin Res Technol* 2001; **7**: 56-59 [PMID: 11301642 DOI: 10.1034/j.1600-0846.2001.007001056]
27 **Von Korff M,** Ormel J, Keefe FJ, Dworkin SF. Grading the severity of chronic pain. *Pain* 1992; **50**: 133-149 [PMID: 1408309 DOI: 10.1016/0304-3959(92)90154-4]
28 **Smith BH,** Penny KI, Purves AM, Munro C, Wilson B, Grimshaw J, Chambers WA, Smith WC. The Chronic Pain Grade questionnaire: validation and reliability in postal research. *Pain* 1997; **71**: 141-147 [PMID: 9211475 DOI: 10.1016/S0304-3959(97)03347-2]
29 **Haefeli M,** Elfering A. Pain assessment. *Eur Spine J* 2006; **15** Suppl 1: S17-S24 [PMID: 16320034 DOI: 10.1007/s00586005-1044-x]
30 **Wieben K,** Falkenberg B. Muscle function. Testing and clinical significance. 6th ed. Stuttgart: Georg Thieme, 2012: 1-376
31 **Field A.** Discovering Statistic using SPSS. London: Sage Publications, 2010: 1-856
32 **US Department of Health and Human Services.** Physical activity and health Atlanta GA: Department of Health and Human Services Centre for Disease Control and Prevention National Centre for Chronic Disease Prevention and Health Promotion, 1996. Available from: URL: http://www.cdc.gov/nccdphp/sgr/pdf/sgrfull.pdf
33 **Andersen CH,** Zebis MK, Saervoll C, Sundstrup E, Jakobsen MD, Sjøgaard G, Andersen LL. Scapular muscle activity from selected strengthening exercises performed at low and high intensities. *J Strength Cond Res* 2012; **26**: 2408-2416 [PMID: 22076101 DOI: 10.1519/JSC.0b013e31823f8d24]
34 **Meirelles CD,** M Sergio P, Gomes C. Acute effects of resistance exercise on energy expenditure: revisiting the impact of the training variables. *Revista Brasileira De Medicina* 2004; **10**: 131-38
35 **Beckham SG,** Earnest CP. Metabolic cost of free weight circuit weight training. *J Sports Med Phys Fitness* 2000; **40**: 118-125 [PMID: 11034431]
36 **Blangsted AK,** Søgaard K, Hansen EA, Hannerz H, Sjøgaard G. One-year randomized controlled trial with different physical-activity programs to reduce musculoskeletal symptoms in the neck and shoulders among office workers. *Scand J Work Environ Health* 2008; **34**: 55-65 [PMID: 18427699 DOI: 10.5271/sjweh.1192]
37 **Jacobson E.** Progressive relaxation (2nd ed.). Chicago (IL): University of Chicago Press, 1938:1-494
38 **Grimshaw J,** Campbell M, Eccles M, Steen N. Experimental and quasi-experimental designs for evaluating guideline implementation strategies. *Fam Pract* 2000; **17** Suppl 1: S11-S16 [PMID: 10735262 DOI: 10.1093/fampra/17.suppl_1.S11]
39 **Lamprecht M,** Fischer A, Stamm HP. Sport Schweiz 2008: Das Sportverhalten der Schweizer Bevölkerung (Sport in Switzerland: Population data). Magglingen: Bundesamt für Sport BASPO, 2008
40 **Griffin MJ.** Handbook of human vibration. San Diego: Academic Press, 1996: 1-998

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