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Journal of Sport and Health Science 3 (2014) 284–292
www.jshs.org.cn

Original article

Effects of small-volume soccer and vibration training on body composition, aerobic fitness, and muscular PCr kinetics for inactive women aged 20–45

Luke J. Connolly [a], Suzanne Scott [a], Magni Mohr [a,b,c], Giorgos Ermidis [a,d], Ross Julian [a,e], Jens Bangsbo [f], Sarah R. Jackman [a], Joanna L. Bowtell [a], Rosemary C. Davies [a], Susan J. Hopkins [g], Richard Seymour [g], Karen M. Knapp [g], Peter Krustrup [a,f], Jonathan Fulford [h,*]

[a] *Sport and Health Sciences, College of Life and Environmental Sciences, St Luke's Campus, University of Exeter, Exeter EX1 2LU, UK*
[b] *Faculty of Natural and Health Sciences, University of the Faroe Islands, Torshavn 100, Faroe Islands*
[c] *Department of Food and Nutrition, and Sport Science, University of Gothenburg, Gothenburg 40530, Sweden*
[d] *Department of Physical Education and Sport Science, Democritus University of Thrace, Komotini 69100, Greece*
[e] *Institute of Sports and Preventive Medicine, University of Saarland, Saarbrücken 66123, Germany*
[f] *Copenhagen Centre for Team Sport and Health, Department of Nutrition, Exercise and Sports, University of Copenhagen, Copenhagen 2200, Denmark*
[g] *College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QF, UK*
[h] *NIHR Exeter Clinical Research Facility, University of Exeter Medical School, Exeter EX2 5DW, UK*

Received 21 February 2014; revised 19 May 2014; accepted 3 July 2014
Available online 7 August 2014

Abstract

Purpose: The present study investigated the effects of 16 weeks of small-volume, small-sided soccer training soccer group (SG, $n = 13$) and oscillating whole-body vibration training vibration group (VG, $n = 17$) on body composition, aerobic fitness, and muscle PCr kinetics in healthy inactive premenopausal women in comparison with an inactive control group (CO, $n = 14$).
Methods: Training for SG and VG consisted of twice-weekly 15-min sessions with average heart rates (HRs) of ∼155 and 90 bpm respectively. Pre- and post-measurements of body composition (DXA), phosphocreatine (PCr) on- and off-kinetics, and HR measurements during standardised submaximal exercise were performed.
Results: After 16 weeks of training in SG, fat percentage was lowered ($p = 0.03$) by 1.7% ± 2.4% from 37.5% ± 6.9% to 35.8% ± 6.2% and the PCr decrease in the quadriceps during knee-extension ramp exercise was attenuated (4% ± 8%, $p = 0.04$), with no changes in VG or CO (time-group effect: $p = 0.03$ and $p = 0.03$). Submaximal exercise HR was also reduced in SG after 16 weeks of training (6% ± 5% of HR_{max}, $p = 0.01$).
Conclusion: Short duration soccer training for 16 weeks appears to be sufficient to induce favourable changes in body composition and indicators of aerobic fitness and muscle oxidative capacity in untrained premenopausal women.

Keywords: Fat percentage; Heart rate; MRS; PCr kinetics; Small-sided soccer

1. Introduction

It is well documented that physical activity (PA) can improve the cardiorespiratory fitness and health profile and may lower the risk for several cardiovascular and metabolic diseases.[1] However, inactive behavior has continued to

* Corresponding author.
E-mail address: j.fulford@exeter.ac.uk (J. Fulford)
Peer review under responsibility of Shanghai University of Sport.

http://dx.doi.org/10.1016/j.jshs.2014.07.003

increase over the past few decades,[2,3] with lack of time commonly cited as an issue preventing women from meeting PA recommendations.[4] Focus should therefore be placed on developing PA interventions for inactive women for which high compliance rates can be achieved while obtaining the positive health benefits of exercising.

As soccer is one of the most popular sports in the world, with over 29 million registered women players globally,[5] it may serve as an appealing, inexpensive PA for inactive women. Soccer is a motivational and social activity[6,7] and, most importantly, participation in small-sided recreational soccer games has been shown to be an effective health-promoting activity for both untrained men[8−11] and women.[12−18] In untrained premenopausal women, Krustrup et al.[17] and Andersen et al.[18] found that participating in twice-weekly 1-h sessions of small-sided recreational soccer or outdoor continuous running for 16 weeks produced a number of positive health benefits. Maximal oxygen uptake, lean mass, and heart function were increased and fat mass and systolic blood pressure (BP) were reduced for both groups. In addition, a decrease in diastolic BP and low-density/high density lipoprotein cholesterol ratio was evident for the soccer group only, and the cardiac adaptations induced by the training were considered to be more consistent when compared to continuous running.[18] Similar health benefits have been observed after 12 weeks of soccer, 2−3 × 1 h per week, organised as a workplace intervention outside working hours.[14] Although these interventions produced positive health benefits, they required participants to exercise for 1 h per session, a length of time not necessarily easy to accommodate within peoples' daily routine. However, it is not known whether the same health benefits can be achieved with a reduction in training session duration.

Whole-body vibration (WBV) training is an alternative exercise modality that is becoming increasingly popular in gyms and may address time constraints and compliance issues in inactive populations[19] due to the short duration of sessions. However, rather than a cardiovascular focus, much of the research within this area has examined muscle strength[20] and power,[21,22] postural control in the elderly[23] and bone mineral density in postmenopausal women.[24] Acute responses to WBV training (vertical and oscillating), in combination with upper- and lower-body exercises, have shown that oxygen consumption increases linearly as load, frequency (f), and amplitude (A) rise.[25,26] However, only a small number of studies have examined the effects of WBV training as an intervention to improve the cardiovascular risk profile in inactive populations. Song et al.[27] revealed a significant decrease in weight, waist circumference and BMI after 8 weeks of oscillating WBV training, 10 min twice a week, in obese postmenopausal women, although this was not accompanied by changes in body fat percentage. Likewise, 18 months of WBV training in postmenopausal women performed twice a week (60 min/session) was associated with reductions in body fat percentage and abdominal fat mass and an increase in lean body mass.[28] However, these changes were not significantly different from other training modes (e.g., aerobic dance). Thus, to date it is unclear whether oscillating WBV training provides sufficient cardiovascular stimulation to improve the health profile of inactive premenopausal women after a short intervention period.

As such we aimed to investigate some of the potential differences in health benefits that may arise between two very different exercise modalities, thereby possibly informing the decision process of individuals when selecting an exercise regime to fit into the limited time available to them. Hence, the goal of the present study was to undertake a pilot study to examine the feasibility of measuring cardiovascular and metabolic adaptations in inactive middle-aged premenopausal women in response to participation in 16 weeks of small-sided soccer training and WBV training. The main focus was to assess whether measureable changes could still be detected with short exercise durations, when examining similar group sizes to those that have shown beneficial health effects with longer duration exercise intervention[9−11,16] and to assess the differences in responses between exercise modalities. We hypothesised that low-volume small-sided soccer training would reduce fat mass, resting heart rate (HR) and HR during submaximal tasks, and would improve muscle PCr kinetics. In contrast, it was hypothesised that WBV training would not provide a sufficient cardiovascular and metabolic challenge to induce equivalent adaptations.

2. Methods

2.1. Participants

Participants were recruited through advertisements in the local newspaper, community venues, and local radio stations. No financial or other inducements were offered to participants. All participants completed a questionnaire prior to the training intervention to confirm that they were premenopausal and that none of them were smokers, pregnant, or on medication. Participants also confirmed there were no known medical conditions that would exclude them from undertaking in an exercise program. None of the participants had been taking part in regular PA for at least 2 years. This was established via questionnaire at baseline requiring participants to detail time spent weekly undertaking activities likely to cause significant increases in cardiovascular output. Activities listed included jogging, cycling, swimming, gym sessions, fitness classes, and sporting events. In addition, the participants had no previous experience of participating in competitive or professional level sport and had little or no experience of playing soccer or using WBV equipment. Although not directly monitored, the participants were encouraged not to change their dietary intake for the duration of the study and, apart from the intervention, were requested to maintain their normal lifestyle. All the participants gave their written informed consent after they were fully informed of the potential benefits, possible risks, and discomforts associated with the study. The study was approved by the National Research Ethics Service (NRES) (12/SW/0045) and the institutional research ethics committee (NHS 2012/329).

The participants were randomly assigned to a soccer group (SG, $n = 21$), a WBV group (VG, $n = 21$), or a control group who performed no physical training (CO, $n = 24$). Switching between groups was generally not possible. However, two participants who had initially been assigned to SG were reassigned to VG prior to any training sessions taking place, as it was impossible for them to attend any of the soccer training sessions due to work commitments at those times. Eight, four, and 10 participants in SG, VG, and CG, respectively withdrew from the study due to pregnancy, personal problems, minor injuries, or low compliance with the training.

2.2. Study design

Of the 44 participants of Caucasian ($n = 42$) and Southeast Asian ($n = 2$) origin who completed the study; i.e., SG ($n = 13$), VG ($n = 17$), and CO ($n = 14$), those in SG and VG trained for 16 weeks, while CO continued their normal daily lives. The participants were assessed before and after the intervention period with continuous recordings of HR throughout the training sessions.

2.3. Training intervention

The soccer training was organised as small-sided games made up of two teams with no goalkeepers and the aim of the game was to score in the opposition's goal. The sessions took place twice a week for 13.5 min on various playing surfaces, including outdoor natural grass, artificial turf and, during bad weather, an indoor court. All surfaces were 15–25 m wide and 20–40 m long. Each participant was supplied with relevant soccer footwear for indoor and outdoor facilities. Three to four morning and evening training sessions were organised every week in order to ensure that each participant could attend two of them, with a recommended gap of at least 48 h between sessions and a minimum gap of at least 24 h between sessions. All sessions were fully supervised by an instructor who had previous experience of playing soccer and could act as an extra participant when teams were unequal. Due to the variation in session participants, the small-sided games were played as 2 v 2, 3 v 3 or 4 v 4. Each training session was preceded by a standardised 2-min warm-up consisting of the first six 20-m shuttle runs of the Yo-Yo intermittent endurance level 1 test (YYIE1).[29] After each 40-m run, the participants had a 5-s active recovery period during which they walked 2×2.5 m.

The 13.5-min WBV training was also administered twice a week on a WBV plate (Galileo Sport, Novotec Medical GmbH, Pforzheim, Germany) with at least a 24-h gap between sessions. The participants were instructed to remove their shoes, stand on the plate with slightly bent knees and heels touching the board and bring their weight over the forefoot. The protocol consisted of a 3-min warm-up at a frequency of 6 Hz with amplitude of 2 mm. After the warm-up, the participants completed 1-min bouts of 1) static squats (at 30° knee flexion), 2) dynamic squats (between 30° and 90° knee flexion), 3) pelvic floor muscle loading, 4) alternating "hump back, swallow back", 5) static squats (at 30° knee flexion), 6) dynamic squats (between 30° and 90° knee flexion), and 7) pelvic floor muscle loading. Each 1-min bout was followed by 1 min of recovery. For the duration of the study, the first four exercises were completed at a frequency of 12 Hz. For the first 4 weeks, the final three exercises were also completed at 12 Hz and increased to 18 Hz for weeks 5–7 and 27 Hz for the remaining 9 weeks. Vibrational amplitude increased from 1 mm in the first week to 1.5 mm in weeks 2–3, 2 mm in weeks 4–5, 2.5 mm in week 6, 3 mm in weeks 7–9, 3.5 mm in week 10, and 4 mm in weeks 11–16. A load of 4, 6, and 8 kg was also applied in weeks 14, 15, and 16 for exercises 1, 2, 5, and 6. All WBV sessions were organised on a one-to-one basis with a trained supervisor to ensure safety and guidance in the required exercises.

Compliance for both training groups was monitored, with attendance records controlled by the supervisors.

2.4. Pre- and post-exercise intervention testing procedures

The subjects were familiarised with all testing procedures on at least one occasion before baseline testing and no PA was performed 2 days prior to testing. All measures were performed at baseline and were subsequently repeated within 1 week of the completion of the 16-week training intervention.

Height (Seca stadiometer SEC-225; Seca, Hamburg, Germany), resting HR and BP were obtained after at least 10 min of rest with the participant in a seated position. A minimum of five measurements were performed using an automatic upper-arm BP monitor (M7; OMRON, Lake Forest, IL, USA) with an average value calculated.

In order to examine body composition, a total body DXA scan was performed (GE Lunar Prodigy, GE Healthcare, Bedford, UK), and fat and lean tissue were compartmentalised using standard regions of interest.

To examine muscle phosphorus metabolite concentrations at rest and during two different exercise protocols, the participants were positioned in the bore of a 1.5 T superconducting magnet (Intera; Philips, Amsterdam, the Netherlands) at the University of Exeter Magnetic Resonance Research Centre. Prior to the exercise bouts, baseline measurements were taken. On completion, two different exercise regimes were carried out to examine different facets of muscle function. In the first, PCr recovery kinetics was examined by undertaking short bouts of continuous exercise. Subsequently, after a recovery period, a ramp exercise protocol was undertaken in which the workload was continually increased until the point of participant failure.

The participants were positioned in the scanner head first in a prone position such that the subject's right quadriceps muscle was centred directly over a 6-cm ^{31}P transmit/receive surface coil. They were subsequently secured to the scanner bed using Velcro straps at the thigh, buttocks, lower back, and middle back to minimise extraneous movement. In order to undertake exercise testing, a custom-designed nylon ergometer frame fitted onto the bed in alignment with the subject's feet and a base unit was positioned behind the bed. Cuffs with

Velcro straps were secured to the subject's foot and attached to a rope which passed around pulleys housed within the frame to the base unit, where they were attached to non-magnetic weights.

Prior to the beginning of exercise, images were acquired to confirm that the quadriceps muscle was positioned directly above the ^{31}P coil. Subsequently, a pre-exercise baseline spectrum was acquired with long repetition time (TR = 20 s) in which the relative unsaturated peak amplitudes could be determined. Molar concentrations of PCr and ATP were subsequently calculated via the ratio of Pi:PCr and Pi:ATP, assuming a resting concentration of ATP of 8.2 mmol/L.

The exercise protocol consisted of one-legged knee extensions, which resulted in the lifting of weights via the pulley system. The extensions took place at a frequency of 0.67 Hz with the foot moving over a distance of ∼0.22 m, with both visual and audio cues being given to ensure that the rate of contraction was maintained at the desired value. To examine PCr recovery kinetics, two 24-s bouts of exercise were performed, separated by a recovery period of 4 min. In order to obtain a significant PCr depletion (∼40%), thereby maximising the accuracy of the recovery data fitting, exercise was undertaken with weights of mass 1 kg less than the maximum weight each subject achieved during the previous familiarity session. As the rate of PCr recovery has previously been shown to be pH dependent,[30,31] exercise bouts were limited to 24 s as we have previously determined that exercise for that period does not lead to a measurable decrease in pH. The ramp protocol involved the participants continually exercising to volitional fatigue. Initially, exercise was carried out with a weight of 1 kg mass. This was then increased by 0.5 kg every 30 s until exhaustion, the time of which was recorded. During exercise and recovery, ^{31}P data were acquired every 1.5 s and phase cycling with four phase cycles was employed, leading to spectra being acquired every 6.0 s.

2.5. Measurements during training

HR was recorded during WBV training for 10 participants, using Polar T34 belts (Polar Electro Oy, Kempele, Finland) and noted each minute during the 13.5-min protocol. The remaining seven participants in VG opted not to have HR recorded during WBV training. HR was recorded during soccer warm-ups and training sessions using Polar T34 belts and a portable 15-Hz global positioning system (GPS; SPI Pro X, GPSports, Canberra, Australia). Data were subsequently downloaded using Team AMS v.1.5 (GPSports) where average and peak HR was automatically generated following a user-defined time split for the session duration. Individual HR_{peak} was determined as the highest HR reached within a single soccer session across the length of the study. HR was also analysed for the last 15 s of each YYIE1 warm-up to determine any change in HR over time for the same given work rate. Using GPS measurements, only those who covered a distance of ≥150 m for the YYIE1 in the given time were included in the analyses.

2.6. Data analysis

The acquired spectra were quantified via peak fitting, assuming prior knowledge, using the jMRUI (version 3) software package employing the AMARES fitting algorithm.[32] Spectra were fitted assuming the presence of the following peaks: P_i, phosphodiester, PCr, α-ATP (2 peaks, amplitude ratio 1:1), γ-ATP (2 peaks, amplitude ratio 1:1), and β-ATP (3 peaks, amplitude ratio 1:2:1). Intracellular pH was calculated using the chemical shift of the P_i spectral peak relative to the PCr peak.[33]

For the PCr values following the 24-s exercise period, PCr recovery was fitted with Prism 5 software (GraphPad Software Inc., La Jolla, CA, USA) by a single exponential of the form:

$$PCr_{(t)} = PCr_{end} + PCr_{(0)}\left(1 - e^{(-t/\tau)}\right)$$

where PCr_{end} is the value at the end of exercise, $PCr_{(0)}$ is the difference between the PCr at end exercise and fully recovered, t is the time from exercise cessation and τ is the time constant for the exponential recovery of PCr. Each 24-s recovery period was fitted individually and the time constants determined for each before being averaged to give the value quoted for the trial.

For the ramp protocol, for each participant the PCr depletion at the end of exercise was determined. In addition, the PCr depletion at the same time point from both visits was determined, with the time selected corresponding to the shorter exercise finish time from the two visits.

2.7. Statistics

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, v.20, SPSS Inc., Chicago, IL, USA). Before analysis, data were checked for normality using a Shapiro–Wilk test. Non-normally distributed data were assessed using the Kruskal–Wallis test. Homogeneity of variance was determined using Levene's *F*-test. Repeated measures analysis of variance (ANOVA) were used to evaluate data for 0, 8 (YYIE1 warm-up only), and 16 weeks of the intervention with group as between-subjects factor and time as the repeated factor. Effect sizes (partial η^2) were also reported for interpretative purposes with 0.01, 0.06, and 0.14 regarded as a small, moderate, and large effect.[34] Due to the mean age (40 ± 5 years) and age range (29–46 years) of the participants, repeated measures analysis of covariance (ANCOVA) with age as a covariate were also used. However, as the covariate did not have a significant ($p > 0.05$) relationship to any of the outcome variables, only ANOVA data are reported. When a significant *F*-value was detected, data were subsequently analysed using *post hoc t* tests with a Bonferroni correction. Between-group differences in baseline characteristics as well as intervention-induced changes were evaluated by a one-way ANOVA. Significance was selected at the level of $p < 0.05$. All statistical analyses were presented as mean ± SD unless otherwise stated.

Table 1
Baseline characteristics and (absolute change) in fat mass and lean mass following 16 weeks of training for the soccer (SG), vibration (VG), and control (CO) group (mean ± SD).

Baseline characteristics	SG (n = 13)	VG (n = 17)	CO (n = 14)	ANOVA interaction (p value)	Partial η^2
Age (year)	39 ± 6	40 ± 4	40 ± 5		
Height (m)	1.65 ± 0.05	1.69 ± 0.05	1.66 ± 0.06		
Weight (kg)	67.1 ± 9.8 (−0.67 ± 2.78)	74.0 ± 14.4 (0.26 ± 2.14)	68.8 ± 14.4 (0.04 ± 2.19)		
BMI (kg/m^2)	24.5 ± 3.6	25.9 ± 4.9	25.0 ± 4.9		
Fat					
Arms (kg)	2.22 ± 0.64 (−0.10 ± 0.16)	2.71 ± 1.00 (0.03 ± 0.30)	2.31 ± 0.94 (−0.06 ± 0.53)	0.60	0.02
Legs (kg)	9.79 ± 2.81 (−0.25 ± 1.15)	10.89 ± 3.28 (0.01 ± 1.26)	8.85 ± 3.50 (0.03 ± 0.86)	0.80	0.01
Trunk (kg)	12.65 ± 4.64 (−1.02 ± 1.40)[a,b]	14.50 ± 6.16 (0.33 ± 1.17)	12.96 ± 5.79 (−0.08 ± 1.51)	0.03	0.16
Android (kg)	2.05 ± 0.85 (−0.17 ± 0.27)[a,b]	2.37 ± 1.15 (0.08 ± 0.28)	2.19 ± 1.06 (−0.02 ± 0.20)	0.04	0.15
Gynoid (kg)	5.28 ± 1.31 (−0.18 ± 0.47)	5.76 ± 1.41 (0.03 ± 0.44)	4.84 ± 1.70 (−0.03 ± 0.42)	0.46	0.04
Total (kg)	25.43 ± 7.69 (−1.41 ± 2.59)	28.92 ± 9.99 (0.37 ± 1.92)	24.90 ± 9.90 (−0.17 ± 1.98)	0.09	0.11
Total (%)	37.46 ± 6.94 (−1.69 ± 2.38)[a,b]	38.97 ± 6.93 (0.36 ± 1.81)	35.49 ± 8.28 (−0.23 ± 2.04)	0.03	0.15
Lean					
Arms (kg)	4.02 ± 0.64 (−0.03 ± 0.19)	4.39 ± 0.80 (−0.07 ± 0.19)	4.17 ± 0.67 (−0.19 ± 0.73)	0.62	0.02
Legs (kg)	13.03 ± 1.96 (0.37 ± 0.49)	13.55 ± 2.23 (−0.04 ± 0.60)	12.97 ± 1.95 (0.07 ± 0.83)	0.24	0.07
Trunk (kg)	18.66 ± 2.35 (0.41 ± 0.85)	19.86 ± 3.42 (0.03 ± 1.21)	19.74 ± 1.98 (0.29 ± 2.25)	0.78	0.01
Android (kg)	2.69 ± 0.39 (0.05 ± 0.16)	2.85 ± 0.50 (0.01 ± 0.16)	2.82 ± 0.31 (0.02 ± 0.19)	0.81	0.01
Gynoid (kg)	5.82 ± 0.92 (0.13 ± 0.25)	6.07 ± 0.85 (0.01 ± 0.27)	5.74 ± 0.81 (0.05 ± 0.25)	0.40	0.04
Total (kg)	38.66 ± 4.64 (0.77 ± 1.02)	40.84 ± 6.15 (−0.12 ± 1.37)	40.04 ± 4.43 (0.21 ± 1.17)	0.15	0.09

Abbreviations: ANOVA = analysis of variance; BMI = body mass index.
[a] Significant difference between 0 and 16 weeks ($p < 0.05$).
[b] Delta value significantly different from VG ($p < 0.05$).

3. Results

For the participants who completed the study (SG, $n = 13$; VG, $n = 17$; CO, $n = 14$), no group differences were present for the pre-intervention baseline values (Table 1).

3.1. Fat mass and lean body mass

A significant group × time interaction was found for total fat percentage ($p = 0.03$; partial $\eta^2 = 0.15$). *Post hoc* analysis revealed that in SG, fat percentage significantly decreased by 1.69% ± 2.38% ($p = 0.03$) during the 16-week intervention period, with no changes for VG or CO (Fig. 1). A significant group × time interaction was also evident for fat mass of the trunk ($p = 0.03$; partial $\eta^2 = 0.16$) and android ($p = 0.04$; partial $\eta^2 = 0.15$). *Post hoc* analysis revealed that fat mass of the trunk and android (central fat predictive of body shape) significantly decreased by 1.02 ± 1.40 kg ($p = 0.02$) and 0.17 ± 0.27 kg ($p = 0.04$) respectively in SG over 16 weeks of training, with no changes for VG or CO (Table 1). The changes in fat percentage ($p = 0.03$) for SG was significantly greater than for VG, as was the changes in fat mass of the trunk ($p = 0.03$) and android ($p = 0.03$). Lean mass was not significantly altered in any of the three groups following the 16-week intervention (Table 1).

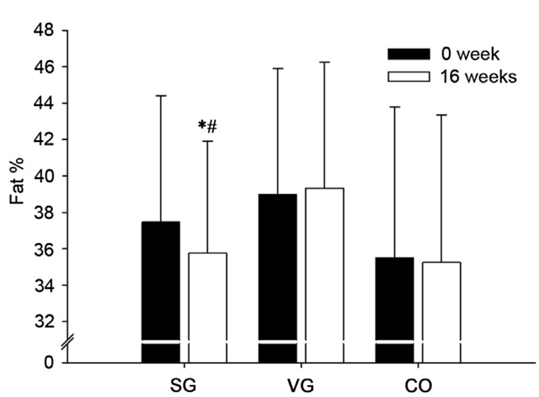

Fig. 1. Fat percentage for inactive premenopausal women after 16 weeks of soccer training (SG), whole-body vibration training (VG), or continuation of a sedentary lifestyle (CO) (mean ± SD). *Significant difference from baseline. #Significant delta value difference from VG following 16 weeks of training.

3.2. Magnetic resonance spectroscopy measurements

During one-legged knee-extensor ramp exercise, a significant group × time interaction was evident ($p = 0.03$; partial $\eta^2 = 0.18$) for PCr depletion at the same time for the pre- and post-tests. In SG, after 16 weeks of training the degree of PCr depletion was less ($p = 0.04$) (PCr content relative to baseline: 54.7% ± 12.5% *vs.* 59.1% ± 12.6% for pre- *vs.* post-training) with no change for VG or CO (Table 2). Data for a representative participant is illustrated in Fig. 2. At the same time-point a significant main effect with time was seen for muscle pH but no significant interaction effects with group (SG: 6.95 ± 0.09 *vs.* 6.98 ± 0.07; VG: 6.95 ± 0.05 *vs.* 6.98 ± 0.06). Following 16 weeks of training, the rate of PCr recovery was not significantly altered after bouts of 24 s constant load exercise (SG; τ: 35.1 ± 8.7 *vs.* 30.7 ± 7.7 s; VG; τ: 32.8 ± 9.3 *vs.* 34.6 ± 9.6 s; CO; τ: 35.5 ± 8.8 *vs.* 32.7 ± 5.9 s, for pre- *vs.* post-training, respectively) in any of the groups.

Table 2
Summary of magnetic resonance spectroscopy measurements prior to and at the end of the ramp exercise test performed before and after the 16-week intervention period in the soccer group (SG), the vibration training group (VG), and the inactive control group (CO) (mean ± SD).

	SG		VG		CO		ANOVA interaction (p value)	Partial η^2
	Week 0	Week 16	Week 0	Week 16	Week 0	Week 16		
Baseline PCr (mmol/L)	32.2 ± 3.5	32.0 ± 3.0	31.3 ± 4.6	31.3 ± 3.3	29.8 ± 4.0	32.6 ± 5.2	0.35	0.06
Baseline PCr:P_i	8.5 ± 1.4	8.5 ± 1.4	9.3 ± 1.7	9.0 ± 1.5	9.2 ± 1.0	8.2 ± 1.4	0.32	0.07
End exercise time (s)	250.8 ± 103.9	282.8 ± 92.8	312.8 ± 46.0	320.0 ± 55.1	293.2 ± 56.2	285.2 ± 59.7	0.50	0.04
End exercise PCr (%)	53.8 ± 57.2	57.2 ± 11.6	51.1 ± 8.2	52.2 ± 9.3	61.8 ± 7.0	59.0 ± 8.0	0.33	0.06
PCr%	54.7 ± 12.5	59.1 ± 12.6[a,b]	52.3 ± 7.8	55.5 ± 8.2	65.1 ± 7.5	60.4 ± 7.8	0.03	0.18

Abbreviations: ANOVA = analysis of variance; PCr% = PCr percentage at the point of volitional exhaustion at 0 week and the equivalent time point at 16 weeks.
[a] Significant difference between 0 and 16 weeks ($p < 0.05$).
[b] Delta value significantly different from CO ($p < 0.05$).

3.3. HR and BP

After 16 weeks, resting HR was not significantly lowered in SG (77 ± 8 *vs*. 73 ± 8 bpm), VG (74 ± 11 *vs*. 72 ± 11 bpm), or CO (77 ± 9 *vs*. 74 ± 6 bpm), respectively. Resting systolic and diastolic BP was also unaltered in all groups following the 16-week intervention (SG: 117 ± 15/75 ± 11 *vs*. 119 ± 13/76 ± 10 mmHg; VG: 121 ± 13/78 ± 9 *vs*. 118 ± 17/77 ± 11 mmHg; CO: 112 ± 16/74 ± 11 *vs*. 113 ± 17/74 ± 10 mmHg, respectively).

The average HR during WBV training conducted in the first and last week of training were 92 ± 14 and 92 ± 17 bpm, respectively. The average and peak HR during the soccer training (n = 13) was 159 ± 8 and 178 ± 6 bpm and 155 ± 7 and 175 ± 6 bpm during the first and last week of training, respectively, which corresponded to 85% ± 5% and 96% ± 4%, and 83% ± 3% and 93% ± 2%, respectively, of peak HR (HR_{peak}).

3.4. Physiological response to the submaximal YYIE1 test

There was a significant time effect on HR ($p < 0.01$; partial $\eta^2 = 0.54$) during the last 15 s of the YYIE1 warm-up for SG. HR during the last 15 s of the YYIE1 warm-up was 160 ± 7, 157 ± 6, and 148 ± 9 bpm after 0, 8, and 16 weeks of the study respectively, corresponding to 85% ± 6%, 84% ± 5%, and 79% ± 5% of HR_{max}. A significant decrease of 6% ± 5% and 5% ± 5% of HR_{max} was evident when comparing 0−16 weeks (p = 0.01) and 8−16 weeks (p = 0.04), respectively.

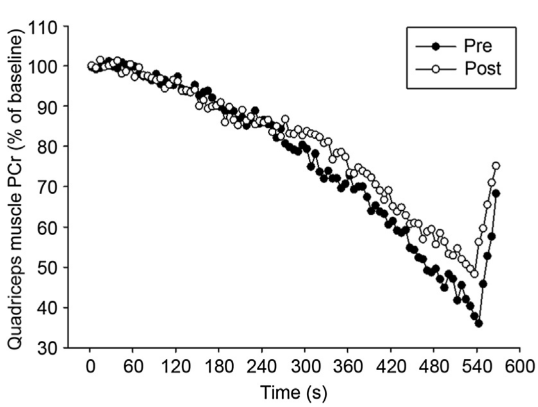

Fig. 2. PCr depletion during a ramp exercise test, pre- and post- the 16-week soccer training intervention for a representative participant.

4. Discussion

The main findings of the present study were that small-volume recreational soccer training resulted in several benefits in body composition and aerobic fitness of inactive premenopausal women relative to either WBV or control participants. Specifically, fat percentage decreased along with reductions in HR during a submaximal running task and positive adaptations in muscle oxidative capacity, as determined by measurements of PCr kinetics.

4.1. Energy expenditure and fat mass

The mean HR for the SG during training sessions was 155 bpm, corresponding to ∼85% of HR_{max}, which is markedly higher than the 90 bpm observed for the WBV training group. The HR during the soccer training was found to be similar to values for 1-h small-sided training sessions for untrained premenopausal females[35] and slightly higher than that observed in untrained and habitually active 25−65-year-old female hospital employees.[14] The high HRs in the soccer group during training illustrates the energy demanding nature of small-sided games, with multiple intense actions such as accelerations, decelerations, rapid changes of direction, and unorthodox movements having been observed to occur as often as every ∼4 s on average.[12,13,35]

A significant finding of the present study is that the fat percentage was reduced markedly (1.7%) in the SG over the 16-week intervention despite the short duration of the twice-weekly training sessions, whereas no changes were observed for the VG and the CO. The decrease in fat percentage was very consistent for the SG participants with as many as 92% of them having a lowered fat percentage after 16 weeks, i.e., all except one, whereas this was only the case for 41% of the VG participants and 43% of the control subjects. Interestingly, the decrease in fat mass for the SG was 1.4 kg which is similar to values reported in previous studies with 12−16 weeks of 1-h twice-weekly recreational soccer training for untrained women[13–17] even though the training volume was only a quarter of that in the other studies (30 *vs*. 120 min/week). The potential clinical significance of reducing abdominal fat has been highlighted by studies such as Rexrode et al.[36] who have reported a higher abdominal adiposity being associated with an increased risk of coronary heart disease in a cohort of 44,702 female registered nurses aged 40–65. The estimated energy consumption over 8 h of soccer training (30 min/week over 16 weeks) at an average HR of 155 bpm for untrained women would be in the area of 4000 kcal, corresponding to about 0.5 kg of fat.[9] It may therefore be speculated that fat oxidation was elevated outside the soccer training, as was found in other studies[17] which demonstrated a positive effect on cardiovascular and metabolic fitness after 12–16 weeks of recreational soccer training, where an increase in the fat oxidation capacity at low to moderate exercise intensities, corresponding to the intensity during everyday life activity, was observed. That no equivalent overall group fat losses were seen following WBV training may well be due to the absence of an equivalent raising of the HR as observed during the soccer training. Other studies using oscillating[27,28] and vertical[37] WBV training have similarly reported no alterations in fat mass. Although WBV training has been reported to stimulate muscular work and to elevate metabolic rate to some extent,[38] the stimulus is probably insufficient to cause any change in fat mass for inactive premenopausal women.

4.2. Aerobic fitness

After 16-week of soccer training, the HR was on average 10 bpm lower in the last phase of a standardised submaximal YYIE1 test. A drop in HR loading during submaximal exercise indicates an increase in aerobic fitness and is in accordance with findings from previous studies using recreational soccer training for premenopausal women. HR was found to decrease by 10–20 bpm during walking and jogging at 6–11 km/h after 16 weeks of twice-weekly 1-h soccer sessions for 20–45-year-old untrained women in conjunction with an increase in maximal oxygen uptake of 15%,[13,17] and HR decreased by 7 bpm during submaximal cycling exercise after 12 weeks of training for twice-weekly 1-h soccer sessions for 25–65-year-old women, who had an increase in maximal oxygen uptake of 5% over the course of training.[14]

The present study also indicated positive effects on muscular aerobic fitness for the SG in comparison to the VG and the CO. The suggestion of an improvement in oxidative metabolism for the SG is reinforced by the recorded decrease in PCr depletion at the end of the ramp test at an equivalent time point, after the training intervention compared with the pre-training value. The changes observed for this parameter indicate that the training was of sufficient intensity to induce adaptive responses within the muscle, either at a mitochondrial level via biogenesis or at a vascular level such that O_2 availability was improved. The fact that the relative PCr sparing is not the result of an increased contribution from glycolytic energy metabolism is confirmed by no differences being recorded for end-exercise muscle pH. Thus, the inference is that a higher proportion of the energy demands during the ramp test were being met by oxidative mechanisms for the participants in the soccer group post-intervention, and hence that a greater oxidative capacity had been developed as a direct result of the training. However, given the inactive nature of the population investigated, vascular changes cannot be ruled out as a potentially contributory factor.

4.3. BP

No changes in BP were observed in any of the groups in the present study. However, decreases in systolic (7–8 mmHg) and diastolic (4–5 mmHg) BP have been previously observed for normotensive premenopausal women and young normotensive men after 12–16 weeks of small-sided soccer played twice weekly for 1 h.[8,17] The lack of change in BP for any of the groups could therefore have been due to the small volume of training, which suggests that a minimum duration and intensity is required to induce a reduction in BP.[18] However, it should also be noted that the SG had baseline systolic pressures of 117 mmHg and diastolic pressures of 75 mmHg, and many participants had values below 115/75 mmHg, where further reductions following exercise interventions have been shown to limit health effects.[39] Further studies are required to elucidate whether small-volume soccer can be used to lower BP for participants with mild to moderate hypertension. In line with some[27] but not all[40] previous studies, no changes were observed in BP after 16 weeks of WBV training. The low HRs and implied lack of cardiovascular challenge may explain why BP did not change in the present intervention. Mechanisms behind the change in BP found in previous studies[40] have not been elucidated and further studies are needed to evaluate whether it was the dynamic nature of the exercises or the heavy load placed on the lower limbs which was associated with the positive impact on BP.

4.4. Limitations

The study has a number of limitations which may impact upon the conclusions subsequently drawn. One aspect was that the net time actually spent exercising was potentially not equal for the SG and VG as soccer is an unpredictable, start-stop exercise modality, in contrast to the carefully regulated vibration protocol. However, one of the central aims of the study was to compare health benefits of different training regimes, which took equivalent times to undertake, and so the time duration was kept constant between modalities rather than trying to ensure equivalent workloads. An additional concern was that the age range of the participants was also quite wide. However, when age was included as a covariate within the analysis it did not affect the results found. A potentially more significant problem were changes in lifestyle that may have occurred over the relatively long intervention period. Although participants were asked to maintain their normal diet and PA, we were not able to directly control it. In particular, for the exercise groups it is not known whether the soccer or vibration training resulted in a reduction in the time spent undertaking other PAs relative to before the beginning of the study, i.e., soccer or vibration training became a replacement activity, rather than an additional one on top of their pre-existing activities.

5. Conclusion

In summary, 16 weeks of small-volume recreational soccer improved body composition, muscle PCr kinetics, and HR during submaximal exercise in inactive premenopausal women with no prior experience of soccer. Specifically, twice-weekly 15-min sessions of soccer were sufficient to reduce fat percentage and fat mass of the trunk and android region. None of the above measures were altered after the WBV training. As such it provides evidence that more aerobically challenging exercise regimes such as small-volume, small-sided soccer training may be a more favourable choice for a training intervention for individuals with time constraints where weight loss and improvements in muscle oxidative capacity are of primary concern.

Acknowledgments

The authors would like to thank the participants for their great efforts. We would also like to thank Rebecca Lear, Don Kim, and Jamie Blackwell for excellent technical support. FIFA-Medical Assessments and Research Centre (F-MARC) and Nordea-fonden supported the study (No. 1-ST-P-$$$-$$$-036-JZ-F1-05858).

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