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Original article

Fitness and health benefits of team handball training for young untrained women—A cross-disciplinary RCT on physiological adaptations and motivational aspects

Therese Hornstrup [a], Johan M. Wikman [a], Bjørn Fristrup [a], Susana Póvoas [b], Eva W. Helge [a], Signe H. Nielsen [a], Jørn W. Helge [c], Jesper L. Andersen [d], Lars Nybo [a], Peter Krustrup [e,f,*]

[a] Department of Nutrition, Exercise and Sports, University of Copenhagen, Copenhagen N 2200, Denmark

[b] Research Center in Sports Sciences, Health Sciences and Human Development, CIDESD, University Institute of Maia, ISMAI, Maia 4475-690, Portugal

[c] Center of Healthy Aging, Department of Biomedical Sciences, University of Copenhagen, Copenhagen N 2200, Denmark

[d] Institute of Sports Medicine Copenhagen, Bispebjerg Hospital, Copenhagen NV 2400, Denmark

[e] Department of Sports Science and Clinical Biomechanics, SDU Sport and Health Sciences Cluster (SHSC), University of Southern Denmark, Odense 3450, Denmark

[f] Sport and Health Sciences, University of Exeter, Exeter, EX1 2LU, UK

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Abstract

Purpose: The present study evaluated the effects of regular participation in small-sided team handball training on body composition, osteogenic response, physical performance, and cardiovascular risk factors, as well as well-being and motivation, in young untrained women.

Methods: Twenty-eight untrained 20- to 30-year-old women were randomized to a handball training group (HG; $n = 14$, height 170 ± 5 cm, weight 73 ± 11 kg, VO_{2peak} 37.7 ± 4.1 mL/min/kg) that trained 1.7 ± 0.3 times per week over 12 weeks (70 min 4 v 4 handball sessions) or an inactive control group (CG; $n = 14$, 169 ± 5 cm, 71 ± 12 kg, 38.1 ± 3.7 mL/min/kg). Physiological and psychological and motivational training adaptations were assessed pre- and post-intervention by dual-energy X-ray Absorptiometry (DXA) scans, blood sampling, physical tests, and questionnaires.

Results: The average heart rate (HR) over all training sessions was equal to 85% ± 6% HR_{max}. Between-group intervention effects were observed in favor of HG for muscle mass (2.1%, $p = 0.024$), proximal femur bone mineral density (0.8%, $p = 0.041$), Yo-Yo IE1 intermittent endurance test level 1 (IE1) performance (35%, $p < 0.001$), and incremental treadmill test performance (11.5%, $p = 0.003$), but not total fat mass ($p = 0.176$), mean arterial blood pressure ($p = 0.328$), resting HR ($p = 0.219$), or blood lipids ($p = 0.298–0.854$). In CG, no changes were observed in any of the measured physiological variables after the training period. Compared to CG, HG had an increase in intrinsic motivation ($p < 0.001$) and in the well-being subscale "energy" ($p = 0.010$).

Conclusion: Participation in regular recreational team handball training organized as small-sided games has marked beneficial effects on physical performance, musculoskeletal fitness, well-being, and motivation in untrained young women.

Keywords: Bone mineral density (BMD); Intensity; Intermittent; Motivation; Muscle mass; Physical performance; Recreational handball; Well-being

1. Introduction

The prevalence of lifestyle diseases associated with low cardiovascular and metabolic fitness is reaching pandemic proportions.[1] Thus, the expected increases in people with type 2 diabetes (T2DM) signifies the major societal challenge associated with a sedentary life.[2] It has been shown that regular participation in physical activities can markedly benefit individual health and that supervised training interventions can be used for both the prevention and treatment of lifestyle diseases.[3,4] However, the long-term adherence rates to exercise on prescription programs are poor.[5]

In Denmark, the sporting associations Danmarks Idrætsforbund and Danmarks Gymnastik & Idrætsforeninger, supported by the Danish government, have a vision that, by 2025, 50%

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* Corresponding author.
E-mail address: pkrustrup@health.sdu.dk (P. Krustrup).

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of the Danish population should be members of a local sporting association and 75% should be physically active.[6] The sporting associations find it difficult keeping young members interested in their teenage years and reaching out to sedentary people with no or little experience of sport where competition is not a major element.[6] Furthermore, it has been shown that the dropout rate with traditional "exercise on prescription programs" is high both in Denmark and worldwide,[5,7] and new strategies for the prevention of lifestyle diseases should be aimed at identifying activities that can motivate participants to remain active and hence provide an effective, long-lasting lifestyle change with prolonged physiological perspectives. Previous observations from studies conducted on team sport, performed as small-sided games, have shown marked beneficial health effects and development of social relationships in untrained sedentary men and women as well as people with hypertension, T2DM, and prostate cancer.[8–19] However, different team sports may attract and motivate different populations and increase individual incentive for sustained participation and therefore induce long-lasting lifestyle changes. We believe that handball is a team sport that may have great potential to reach out to sedentary populations in Denmark and other European countries because of its popularity in terms of television time, fan base, and appeal. However, it remains unknown whether small-sided handball training provides a physiological training stimulus that is as potent for fitness and health effects as small-sided football, while the motivational and psychological aspects of participation in an intervention involving small-sided handball training also remain unevaluated.

A recent study by Póvoas et al.[17] concluded that handball (7 v 7) in 33- to 55-year-old untrained men is an intermittent high-intensity exercise mode with physical and physiological demands in the range of those found to have a positive effect on aerobic, anaerobic, and musculoskeletal fitness in adult individuals. Similarly, it seems that team sports, like other physical activity, can increase well-being in participants,[16] and it can be expected that recreational handball will produce similar effects in sedentary individuals. Also, little is known about the effects of recreational handball on motivation in sedentary individuals. However, it seems that team sports in general can be motivating for participants that are sedentary or unfamiliar with sports club participation.[15,16,19] From the perspective of self-determination theory,[20] team sports seem to be intrinsically motivating, meaning that individuals take part in the activity for the sake of the activity itself.[21] Research suggests that intrinsic motivation is a strong predictor of participation and adherence.[15,22]

We hypothesized that recreational handball could provide broad-spectrum fitness and health benefits analogously to recreational football, with combined effects on cardiovascular, metabolic and musculoskeletal fitness. The present study was therefore conducted with the aim of providing a novel and cross-disciplinary evaluation of cardiovascular, metabolic, and musculoskeletal adaptations, as well as well-being and motivational aspects of health, in young untrained healthy 20- to 30-year-old women following a 12-week period of small-sided 4 v 4 handball training.

2. Methods

2.1. Subjects

Forty-five untrained healthy 20- to 30-year-old women indicated an interest in participating in the study following an initial meeting (Fig. 1). To be eligible for participation, the subjects were not allowed to have any known familiar diseases, to be using daily medication, or to have smoked in the past 2 years. Additionally, the subjects were obliged to have a regular menstrual cycle length (25 to 32 days) with or without use of contraceptives. Furthermore, the subjects were not allowed to have been involved in any regular physical training for at least 2 years before recruitment. To ensure the subjects were untrained, they were required to have a peak oxygen uptake (VO_{2peak}) of 25–45 mL/min/kg. Three subjects did not meet the inclusion criterion for VO_{2peak} and were excluded after the medical screening. Another 2 subjects dropped out during baseline testing for personal reasons and illness, respectively. Forty subjects completed baseline testing. After baseline testing, the subjects were stratified for VO_{2peak} and body fat percentage and randomly assigned to either a handball training group (HG) ($n = 20$) or an inactive control group (CG) ($n = 20$). Two thirds of the subjects in HG had some experience with handball, except from playing in physical education classes in schools, but none had played club-based handball for a number of years. Four subjects in HG and 4 subjects in CG left the study for personal reasons. Another 2 in HG dropped out due to concussion outside the study and an ankle injury during a training session, respectively. The last 2 in CG dropped out due to pregnancy and illness, respectively. For the participants who completed the study (FG, $n = 14$; CG, $n = 14$), there were no group differences in baseline values for age or any of the physiological parameters (Table 1). The subjects were informed of the risks

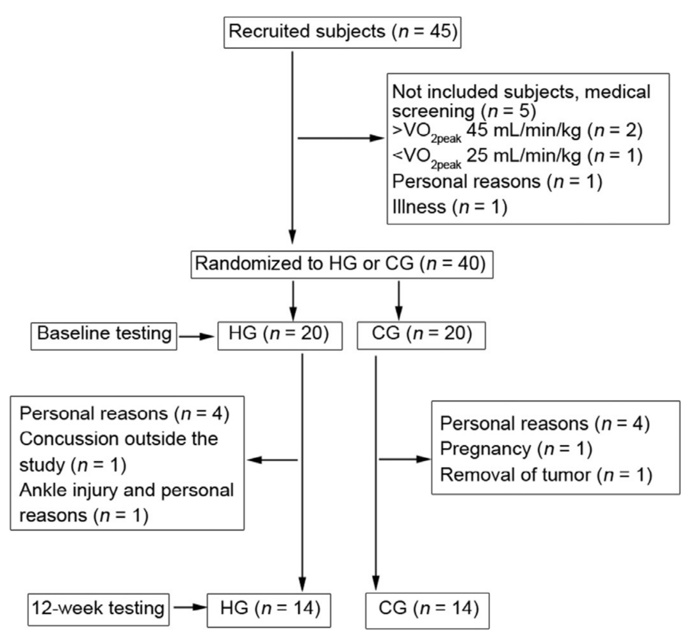

Fig. 1. Flow chart showing the process for recruiting untrained healthy 20- to 30-year-old female subjects.

Table 1
Age, body composition, bone mineral density and bone markers, exercise endurance capacity, cholesterol, systolic and diastolic blood pressure, HbA1c, well-being and motivation subscale values in young untrained women before (0 week) and after 12 weeks of small-sided handball training (HG) or continuation of an inactive lifestyle (CG) (mean ± SD).

	HG ($n = 14$)		CG ($n = 14$)		ANOVA		Group × time
	0 week	12 weeks	0 week	12 weeks	Time	Group	
Age (year)	23.9 ± 2.4	24.2 ± 2.4	24.1 ± 3.2	24.1 ± 3.2	–	–	–
Weight (kg)	73.0 ± 11.0	73.3 ± 10.1	70.8 ± 11.8	70.8 ± 11.9	0.376	0.575	0.393
Height (cm)	169.9 ± 4.9	–	169.1 ± 5.1	–	–	–	–
Total muscle mass (kg)	43.5 ± 4.3	44.4 ± 4.5***,#	42.8 ± 4.9	42.9 ± 5.1	0.007	0.535	0.024
Total fat percentage (%)	36.4 ± 4.9	35.4 ± 4.8*	35.4 ± 5.5	35.3 ± 5.5	0.025	0.759	0.072
Total fat mass (kg)	27.0 ± 7.3	26.4 ± 7.0†	25.5 ± 7.7	25.4 ± 7.7	0.078	0.658	0.176
Proximal femur BMD (g/cm^2)	1.084 ± 0.094	1.092 ± 0.087*,#	1.047 ± 0.129	1.045 ± 0.133	0.256	0.330	0.041
CTX-I (μg/L)	0.38 ± 0.14	0.51 ± 0.29*	0.40 ± 0.26	0.41 ± 0.23	0.037	0.630	0.063
P1NP (μg/L)	52.7 ± 25.7	70.0 ± 28.3*	55.4 ± 34.6	56.7 ± 36.5	0.046	0.648	0.083
Osteocalcin (μg/L)	20.6 ± 6.8	32.1 ± 8.8***,#	23.1 ± 9.5	24.3 ± 9.7	<0.001	0.423	<0.001
VO_{2peak} (mL/min/kg)	37.7 ± 4.1	38.1 ± 3.7	38.1 ± 3.7	37.6 ± 3.7	0.129	0.234	0.124
Yo-Yo IE1 performance (m)	1073 ± 318	1452 ± 397***,#	1151 ± 509	1169 ± 574	<0.001	0.567	<0.001
TTE (s)	393 ± 70	438 ± 64**,#	398 ± 101	387 ± 106	0.059	0.464	0.003
HR at 8 km/h (bpm)	169 ± 12	158 ± 8*	167 ± 11	163 ± 15	<0.001	0.568	0.056
TC (mmol/L)	4.5 ± 0.6	4.5 ± 0.5	4.4 ± 1.0	4.2 ± 1.1	0.606	0.323	0.854
HDL-C (mmol/L)	1.5 ± 0.3	1.6 ± 0.4	1.5 ± 0.4	1.5 ± 0.3	0.463	0.647	0.298
LDL-C (mmol/L)	2.6 ± 0.6	2.4 ± 0.5	2.6 ± 0.9	2.4 ± 0.9	0.048	0.866	0.682
TG (mmol/L)	1.1 ± 0.5	1.2 ± 0.5	0.8 ± 0.4	0.9 ± 0.4	0.261	0.086	0.618
Systolic blood pressure (mmHg)	103 ± 8	102 ± 7	103 ± 12	102 ± 12	0.926	0.961	0.311
Diastolic blood pressure (mmHg)	69 ± 5	67 ± 5	67 ± 8	68 ± 8	0.433	0.951	0.123
Mean arterial pressure (mmHg)	80 ± 6	78 ± 5	79 ± 9	79 ± 9	0.328	0.989	0.328
Resting HR (bpm)	59 ± 9	57 ± 8	61 ± 8	62 ± 8	0.465	0.280	0.219
HbA1c (mmol/L)	5.2 ± 0.4	5.2 ± 0.4	5.2 ± 0.3	5.1 ± 0.4	0.291	0.844	0.378
Anxiety	1.42 ± 0.32	1.40 ± 0.30	1.53 ± 0.62	1.74 ± 0.53	0.210	0.202	0.112
Energy	2.67 ± 0.44	3.06 ± 0.64*,#	2.79 ± 0.71	2.65 ± 0.69	0.219	0.533	0.010
Positive well-being	3.12 ± 0.42	3.14 ± 0.46	3.11 ± 0.65	2.93 ± 0.80	0.362	0.633	0.225
Intrinsic motivation to accomplish	4.23 ± 1.26	5.12 ± 0.99***,#	4.75 ± 1.17	3.60 ± 1.18**	0.603	0.217	<0.001
Intrinsic motivation to know	3.77 ± 1.20	4.35 ± 0.97†	3.71 ± 1.07	2.85 ± 1.33**,#	0.534	0.067	0.003
Intrinsic motivation to experience stimulation	5.08 ± 0.64	5.42 ± 0.99	4.75 ± 1.18	4.65 ± 1.15	0.539	0.130	0.258
Extrinsic motivation identified regulation	3.77 ± 0.94	4.12 ± 1.12	3.56 ± 1.30	3.63 ± 1.07	0.410	0.359	0.566
Extrinsic motivation introjected regulation	4.44 ± 1.02	4.62 ± 1.23	5.19 ± 1.72	4.63 ± 1.22	0.399	0.436	0.118
Extrinsic motivation external regulation	2.65 ± 1.16	3.14 ± 1.52	3.08 ± 1.54	3.31 ± 1.60	0.206	0.562	0.649

Time × group interaction.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, significantly different from 0 week within group. † $p < 0.1$, tended to increase or decrease, compared with 0 week within group.
Abbreviations: BMD = bone mineral density; CTX-1 = carboxy-terminal type-1 collagen crosslinks; HbA1c = glycosylated haemoglobin; HDL-C = high-density lipoprotein cholesterol; HR = heart rate; LDL-C = low-density lipoprotein cholesterol; P1NP = procollagen type-1 amino-terminal propeptide; TC = total cholesterol; TG = triglyceride; TTE = time to exhaustion; VO_{2peak} = peak oxygen uptake; Yo-Yo IE1 = Yo-Yo intermittent endurance test level 1.

and discomforts associated with the experimental procedures, and all provided written consent. The study was carried out in accordance with the guidelines set out in the Declaration of Helsinki and was approved by the National Committee on Health Research Ethics of Region Hovedstaden (Reference No.: H-15008361).

2.2. *Training and testing procedures*

The participants in HG were trained for 12 weeks, while the subjects in CG continued their normal everyday activities during the same period. The subjects were tested on 4 separate days before the study and after the 12-week intervention period. The study represented a comprehensive interventional protocol investigating musculoskeletal and cardiovascular adaptions as well as changes in physical performance and health status for the participants. The study included test Day 1—submaximal and progressive maximal treadmill testing; test Day 2—dual-energy X-ray Absorptiometry (DXA) scans (iDXA; Lunar Corporation, Madison, WI, USA) (whole-body and proximal femur), blood pressure and resting heart rate (HR) measurements, fasting blood samples, and well-being questionnaires; test Day 3—Yo-Yo intermittent endurance test level 1 (Yo-Yo IE1); test Day 4—muscle strength and balance tests. Data from test Day 4 are not covered in this article.

2.3. *Training intervention*

Indoor handball training was performed for 70 min twice a week for 12 weeks at the Department of Nutrition, Exercise and Sports, University of Copenhagen. The subjects in HG chose from 3 weekly training sessions, and for each subject there was at least 40 h between training sessions. The handball training consisted of a 12 min warm-up followed by

4×10 min periods of match-play (mainly 4 v 4, sometimes 3 v 3) on a 14 m wide and 19 m long handball pitch interspersed with 3 min breaks. The average number of training sessions during the intervention period was 21 ± 4, corresponding to 1.7 ± 0.3 sessions per week. All, except 1 participant, attended training >1.5 times per week on average.

2.4. *Habitual physical activity level*

The subjects were told not to change their normal diet during the 12-week intervention period. In addition, the subjects were told not to engage in other regular sporting activities in their spare time beyond the handball training for HG. The subjects were instructed to report any changes. Furthermore, the amount of daily activity was measured using the International Physical Activity Questionnaire. This questionnaire measures vigorous and moderate physical activity during work, in the garden, in the home, during transport, and in leisure time. Except for during leisure time, where there would be a change due to the handball training, the results showed that the subjects had no changes in activity patterns in relation to transport, gardening, and work during the 12-week intervention (results not shown).

2.5. *Measurements and test procedures*

Subjects were given detailed instructions in preparation for the pre- and post-testing. No exhausting physical activities were allowed 2 days before testing and the subjects were to refrain from alcohol and caffeine consumption 24 h and 12 h before testing, respectively. In addition, test Day 2, involving DXA scans, blood sampling, blood pressure measurements, and peripheral endothelial function assessments between 7 a.m. and 10 a.m., followed an overnight fast. Most of the women's hormone levels were constant during the menstrual cycle due to their intake of contraceptives, but for those who did not use contraceptives test Day 2 was scheduled between Days 5 and 12 in the mid-follicular phase when progesterone is low and before ovulation. This was done to reduce the impact of changes in hormone levels on test results during pre- and post-testing. In a few cases, it was not possible to hold test Day 2 in the mid-follicular phase and the second best option was therefore to schedule pre- and post-testing at the same time in the menstrual cycle but during another menstrual period. These subjects were not tested in the 2 days before menstruation and at the beginning of their menstrual cycle because of fluid accumulation and general exhaustion.

2.6. *Body composition and bone mineral density (BMD)*

A whole-body DXA scan and a regional DXA scan specific to the proximal femur were carried out before and after the 12-week intervention period (iDXA). Total fat percentage, total muscle mass, and total fat mass were determined by the whole-body scan, while BMD in the proximal femur was determined by the regional DXA. Additionally, body height and body weight were measured before the 2 DXA scans.

2.7. *Incremental treadmill testing (VO_{2peak}) and intermittent endurance performance*

Before and after the 12-week intervention period, pulmonary gas exchange (OxyconPro; Viasys Healthcare, Hoechberg, Germany) and HR (Polar Team System; Polar Electro Oy, Kemple, Finland) were measured during a standardized incremental treadmill test. The test protocol consisted of 5 min at each of 2 steady-state speed levels (6 and 8 km/h) followed by 4 min rest periods. Average VO_2 and average HR values were determined from 3 to 4 min of exercise at 6 and 8 km/h, respectively. The incremental test to exhaustion was carried out after the break, starting at 8 km/h for 2 min and then increasing by 1 km/h every 1 min until total exhaustion. A leveling off in oxygen uptake with an increase in work rate at the end of the test was used to objectively confirm achievement of VO_{2peak}. VO_2 was determined as mean values over 30 s and VO_{2peak} was defined by the highest 30 s mean value. Time to exhaustion (TTE) was noted and maximal heart rate (HR_{max}) was determined as the highest value measured during a 15 s period.

A Yo-Yo IE1 test was performed to determine intermittent endurance capacity before and after the 12-week intervention period. The test consisted of 2×20 m shuttle runs performed at increasing speeds interspersed with 5 s of active recovery during which the participants jogged around a cone placed 2.5 m behind the starting−finishing line. The speeds were controlled by audio signals from a CD. The test was performed indoors on a wooden floor after a standardized 10 min low-intensity warm-up. The test was terminated when the subject was no longer able to maintain the required speed. The total distance (m) covered represented the test result for each individual. HR_{max} was determined as the highest value measured during a 15 s period.

2.8. *Blood pressure and resting HR*

Systolic and diastolic blood pressure as well as resting HR were measured 6 times with the subject in the supine position using an automatic upper-arm blood pressure monitor (M7; OMRON, Vernon Hills, IL, USA) and an average value was calculated. The measurements were performed after an overnight fast and after at least 15 min of rest in the supine position. Resting HR was determined as the lowest value obtained during the 6 measurements.

2.9. *Blood sample collection and analysis*

A 3 mL blood sample diluted with EOTA was collected and analyzed for basal levels of glycosylated hemoglobin (HbA1c) using liquid chromatography in a clinical laboratory. Additionally, a 4 mL blood sample diluted with lithium heparin was also collected and analyzed for total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglyceride (TG) using automated analyzers (Cobas Fara; Roche, Neuilly sur Seine, France) with enzymatic kits (Roche Diagnostics, Mannheim, Germany; Tosoh G7, Tosoh Europe, Tessenderlo, Belgium). A proportion of the blood samples was collected in 2 mL syringes diluted with 30 μL Ethylene-bis(oxyethylenenitrilo) tetraacetic acid (EGTA) and centrifuged for 2 min, after which the plasma was pipetted and frozen at −80°C for later analysis of the plasma concentrations of biomechanical bone turnover markers such as osteocalcin, procollagen type-1 amino-terminal propeptide (P1NP), and carboxy-terminal type-1 collagen crosslinks (CTX-1), which were evaluated by a fully automated immunoassay system (iSYS; Immunodianostic Systems Ltd., Bolintensdon, UK) using a chemiluminescence method.

2.10. Intensity and time−motion during training

In HG, HR was recorded at 1 s intervals using an HR monitor (Polar Team System) during Weeks 3, 8, and 11. Data were transferred to a computer for subsequent analysis using the Polar Team2 system software (Polar Electro Oy). Data are expressed in relation to individual HR_{max}. Individual HR_{max} was determined as the highest value reached during either the incremental treadmill test to exhaustion, the Yo-Yo IE1 test, or training. Two training sessions consisting of 4 × 10 min periods of 4 v 4 matches were videoed for later time−motion analysis. The digital video cameras (GR-D23E; JVC, Tokyo, Japan) were positioned 15 m from the pitch. The videos were later replayed on a monitor for computerized coding of the activity pattern. Locomotor categories applied in previously studies[23,24] was also used in this study: standing (0 km/h); walking and jogging (0−6 km/h); moderate-intensity running (>6−13 km/h); high-intensity running (>13 km/h); sidesteps (>0 km/h); and backwards running (>0 km/h). The time taken for the player to pass markers on the pitch was used to calculate the speed for each locomotion activity. The frequency of specific actions, such as jumps, turns, throws, catches, and shots, was also noted during the 40 min total playing time.

2.11. Questionnaires

A Danish version of the Well-Being Questionnaire (WBQ) was used to assess the participants' quality of life.[25] It comprises 22 items measuring 4 subscales of well-being, namely anxiety (6 items), depression (6 items), energy (4 items), and positive well-being (6 items). The questions have a Likert-scale answering format from 0 (*not at all*) to 3 (*all the time*). When calculating the WBQ subscales, a mean of the 4 or 6 items in a particular scale was calculated.

A Danish version of the Sport Motivation Scale (SMS) was used to measure motivation.[26] The SMS measures 3 forms of intrinsic motivation, namely to accomplish, to experience stimulation, and to know, and 3 forms of extrinsic motivation, namely identified, introjected, and external regulation. Additionally, demotivation was assessed. Each of these subscales is measured with 4 items, giving a total of 28 questions, using a Likert-scale answering format from 1 (*Does not correspond at all*) to 7 (*Corresponds exactly*). When calculating the SMS subscales, a mean of the 4 items belonging to a particular scale was calculated.

Internal consistency for the subscales of WBQ and SMS was tested with a Cronbach's α test using a threshold value of 0.60 given the low number of respondents ($n = 25$) and relatively low number of items in each subscale (4 or 6). This threshold was not met by the WBQ depression subscale (Cronbach's α values of 0.37 at pre, and 0.65 at post) and the SMS demotivation subscale (0.50 and 0.90), so it was decided not to proceed with analyzing them. The WBQ subscales of anxiety (0.79 and 0.66), energy (0.75 and 0.82) and well-being (0.80 and 0.90), as well as the SMS subscales of intrinsic motivation to know (0.72 and 0.91), intrinsic motivation to accomplish (0.77 and 0.85), intrinsic motivation to experience stimulation (0.63 and 0.78), extrinsic motivation—identified regulation (0.71 and 0.65), extrinsic motivation—introjected regulation (0.87 and 0.84), and extrinsic motivation—external regulation (0.86 and 0.93) met the threshold value of 0.60 and it was decided to proceed with analyzing them.

2.12. Statistics

Potential between-group differences in baseline measurements were tested with an unpaired t test. Between- and within-group changes after 12 weeks for HG and CG were analyzed using a two-way repeated-measures analysis of variance (ANOVA). When a significant time × group interaction was found, Tukey's honest significance *post hoc* tests were conducted. All ANOVA main effects (time effect, group effect, and time × group effect) are presented in the right-hand column of Table 1. All data are presented as means ± SD. Statistical analyses were performed using SigmaPlot, Version 11.0 (Systat Software, Inc., San Jose, CA, USA). For all comparisons, significance was set at p value <0.05.

3. Results

3.1. Body composition

A time × group interaction ($p = 0.024$) in favor of HG was observed for total muscle mass from 0 to 12 weeks. In HG, total muscle mass was 2.1% higher ($p < 0.001$) after 12 weeks, corresponding to an increase in muscle mass of 0.9 kg from 43.5 ± 4.3 kg to 44.4 ± 4.5 kg. In CG, total muscle mass did not change ($p > 0.05$). No time × group interaction ($p = 0.072$, $p = 0.176$) was observed for total fat percentage and total fat mass from 0 to 12 weeks, even though total fat percentage decreased ($p < 0.05$) over time in HG from 36.4% ± 4.9% to 35.4% ± 4.8%. In CG, total fat percentage and total fat mass did not change ($p > 0.05$) (Table 1).

3.2. BMD and bone markers

A time × group interaction ($p = 0.041$) was observed in favor of HG for proximal femur BMD from 0 to 12 weeks. In HG, proximal femur BMD was 0.8% higher ($p < 0.05$) after 12 weeks, corresponding to an increase of 0.008 g/cm^2 from 1.084 ± 0.094 g/cm^2 to 1.092 ± 0.087 g/cm^2. Furthermore, a time × group interaction ($p < 0.001$) was observed in favor of HG for the bone marker osteocalcin from 0 to 12 weeks. In HG, osteocalcin increased ($p < 0.001$) by 55.8% from 20.6 ± 6.8 μg/L to 32.1 ± 8.8 μg/L. In HG, the bone markers CTX-I and P1NP also increased by 34.2% ($p < 0.05$) and 32.8% ($p < 0.05$), respectively, but there was no time × group interaction ($p = 0.063$, $p = 0.083$) from 0 to 12 weeks. In CG, proximal femur BMD, osteocalcin, CTX-I, and PINP did not change ($p > 0.05$) (Table 1).

3.3. Performance and VO_{2peak}

A time × group interaction ($p < 0.001$, $p = 0.003$) was observed in favor of HG for Yo-Yo IE1 performance and TTE test performance from 0 to 12 weeks. In HG, Yo-Yo IE1 performance increased ($p < 0.001$) by 35.3% after 12 weeks from 1073 ± 318 m to 1452 ± 397 m. Furthermore, HG increased ($p < 0.01$) TTE in the treadmill test by 11.5% from 393 ± 70 s to 438 ± 64 s. No time × group interaction ($p = 0.124$, $p = 0.056$) was observed for VO_{2peak} and for HR at 8 km/h from 0 to 12 weeks, even though HR at 8 km/h decreased ($p < 0.05$) in HG from 169 ± 12 bpm to 158 ± 8 bpm. In CG, Yo-Yo IE1 performance, TTE, VO_{2peak}, and HR at 8 km/h did not change ($p > 0.05$) (Table 1).

3.4. Blood pressure, plasma cholesterol, and HbA1c

No time × group interaction ($p > 0.05$) was observed for systolic blood pressure, diastolic blood pressure, mean arterial pressure, resting HR, TC, HDL-C, LDL-C, TG, and HbA1c from 0 to 12 weeks. Furthermore, there was no development over time for any of the variables in HG and CG ($p > 0.05$) (Table 1).

3.5. Intensity and time−motion during training

Mean HR during the four 10 min exercise periods during the handball training was 172 ± 14 bpm (mean ± SD), corresponding to 85% ± 6% of HR_{max}. Time spent in HR zones corresponding to <70.0%, 70.0%−79.9%, 80.0%−89.9%, 90.0%−94.9%, and 95.0%−100.0% HR_{max} was 5% ± 9%, 13% ± 15%, 47% ± 14%, 32% ± 17%, and 3% ± 3% of total playing time, respectively (Fig. 2A). Time for standing, walking, moderate-intensity running, high-speed running, sidesteps, and backwards running accounted for 37.1% ± 5.2%, 21.6% ± 6.7%, 19.3% ± 3.9%, 4.9% ± 2.2%, 10.5% ± 4.7%, and 7.0% ± 4.1% of total playing time, respectively (Fig. 2B). The frequency of specific actions such as jumps, turns, catches, throws, and shots was 8.5 ± 3.3, 5.5 ± 1.3, 35.7 ± 8.1, 28.5 ± 9.4, and 7.2 ± 2.9 during a 10 min match, respectively (Fig. 2C).

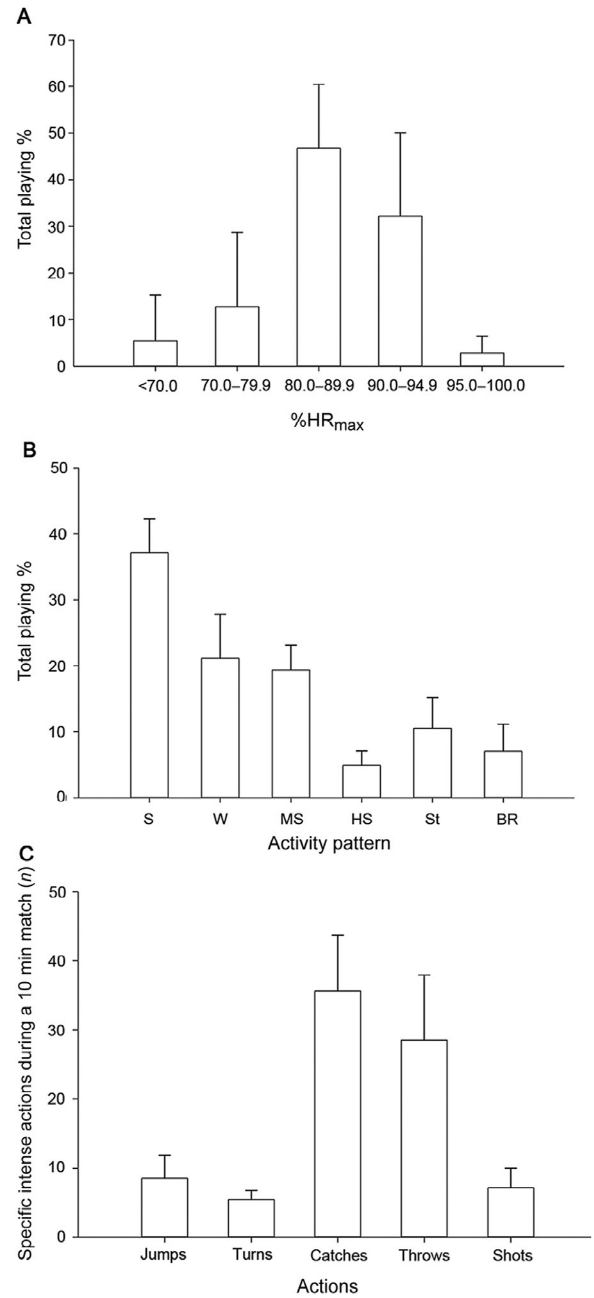

Fig. 2. (A) Heart rate distribution; (B) activity pattern in various locomotor modes: standing (S), walking (W), moderate-speed running (MS), high-speed running (HS), sidesteps (St), and backwards running (BR); and (C) numbers of actions: jumps, turns, catches, throws, and shots. Mean ± SD are presented.

3.6. Well-being

A time × group interaction ($p = 0.01$) was observed in favor of HG for the energy subscale from 0 to 12 weeks. In HG, energy was 14.6% ($p < 0.05$) higher after 12 weeks. In CG, energy did not change ($p > 0.05$). No time × group interaction was observed for the subscales of anxiety or positive well-being from 0 to 12 weeks ($p = 0.112$ and $p = 0.225$). There was no development over time for any of the variables in HG and CG (Table 1).

3.7. Motivation

A time × group interaction ($p < 0.001$) was observed in favor of HG for intrinsic motivation to accomplish from 0 to 12 weeks. In HG, intrinsic motivation to accomplish was 21.0% ($p < 0.001$) higher after 12 weeks. In CG, intrinsic motivation to accomplish was 24.2% ($p < 0.01$) lower after 12 weeks. A time × group interaction ($p = 0.003$) was observed for intrinsic motivation to know from 0 to 12 weeks. In HG, intrinsic motivation to know tended to be higher ($p < 0.1$) after 12 weeks. In CG, intrinsic motivation to know was 23.2% ($p < 0.01$) lower after 12 weeks (Table 1).

4. Discussion

The major findings of the present study were that 12 weeks of recreational handball training performed as small-sided games led to improvements in total muscle mass and osteogenic response for the proximal femur, supported by a pronounced rise in the bone marker osteocalcin. Furthermore, physical performance evaluated by Yo-Yo IE1 and incremental treadmill tests increased markedly in HG. HG also increased in the well-being subscale of energy and the motivation subscales of intrinsic motivation to accomplish and to know after 12 weeks of recreational handball.

4.1. *Body composition and osteogenic response*

The increase in total muscle mass of 0.9 kg in HG is in agreement with data from previous studies of recreational football in men and premenopausal women.[8,27] Higher muscle mass (relative to body size) is associated with health benefits such as better insulin sensitivity and lower risk of developing prediabetes mellitus.[28] Along with the increase in muscle mass, total fat mass tended to fall. This combination is of major importance for lowering the risk of developing T2DM and cardiovascular disease.

Another important finding was that 12 weeks of small-sided handball increased BMD in the proximal femur by 0.8%. We chose to evaluate changes in the proximal femur because this area, together with the spine, is where osteoporosis is diagnosed. One third of all women will at some time have a fracture in the proximal femur or the spine, and the prevalence of osteoporosis is continuing to escalate worldwide.[29] Intervention studies, including football studies,[8,12,30] have failed to demonstrate a short-term training response in total BMD and leg BMD when BMD is evaluated by whole-body DXA scans. When a regional DXA scans for the proximal femur or pQCT scans of tibia have been performed, an increased BMD, has been observed in middle-aged women after 15 weeks of recreational football.[30] It seems that the method used is of major importance in detecting training-induced changes in BMD. The osteogenic response in HG was supported by a 55.8% increase in the bone formation marker osteocalcin. The bone formation marker P1NP and bone resorption marker CTX-1 were not significantly changed compared to CG.

Time−motion analysis in the present study shows that recreational handball, like recreational football, involves multiple intense movements in different directions (high-speed running, accelerations, decelerations, jumps, turns, and rapid side-cutting movements), which seems of major importance for the adaptations in muscle mass and the osteogenic response after 12 weeks of training. This is in agreement with studies that have observed that positive bone formation stimuli depend on the presence of high mechanical impact, which may be evoked by large ground reaction and muscle forces exerted on the bone tissue at a high strain rate and in varied directions in relation to the longitudinal bone axis.[31−34]

4.2. *VO_{2max} and physical performance*

Yo-Yo IE1 performance and TTE during treadmill testing increased markedly in HG, by 35.3% and 11.5%, respectively. The time−motion analyses in the present study show that recreational handball is an intermittent high-speed exercise mode with HRs over 90%HR_{max}. It is surprising that the present study was not able to detect an improvement in VO_{2peak} given that physical performance was markedly improved. VO_{2peak} seems to be important for intermittent exercise performance and incremental treadmill test performance in untrained individuals, whereas the anaerobic energy system seems more important in trained individuals.[35] VO_{2peak} has a major influence on mortality and is therefore an important parameter when it comes to preventing lifestyle diseases.[36−38] A similar study of young men already conducted in our laboratory (data not published) showed that VO_{2peak} was increased by 11% ($p < 0.05$) after 12 weeks of recreational handball.

4.3. *Cardiovascular risk factors*

Positive effects on cardiovascular risk factors such as systolic and diastolic blood pressure, resting HR, TC, LDL-C and HDL-C, and TG concentrations were not observed after 12 weeks of small-sided handball. Systolic and diastolic blood pressure were low for both groups before the intervention period, with values of 103/69 and 103/67 mmHg, respectively (Table 1). The lack of effect on blood pressure accords with observations in football studies for those groups who had low baseline values.[14] The resting HR in HG and CG was at the lower end of the curve compared to the general population[39] before the intervention period, with values of 59 and 61 bpm, respectively. Nevertheless, several intervention studies, including football studies, demonstrated positive effects. In a study by Krustrup et al.,[27] it was observed that recreational football in premenopausal women lowered resting HR from 62 to 57 bpm after 16 weeks of training. Taking into account that the subjects in HG had a high intensity of 85%HR_{max} during training and for 30% of the time worked at intensities above 90% HR_{max}, it seems reasonable to suggest that the lack of effect on resting HR was due to the subjects' relatively high VO_{2peak} at baseline combined with the lower attendance rate (1.7 times per week) compared to the study by Krustrup and colleagues.[27]

As with the other cardiovascular risk factors, there was no effect on lipid profile after 12 weeks of small-sided handball. The subjects in the study had no indication of dyslipidemia, which could explain the absence of effects. Aerobic exercise, however, is associated with beneficial effects on TC, HDL-C, and TG concentrations.[40] According to Bozetto et al.,[41] lipid-lowering effects of a training program are related to the amount of energy expended, which is determined by the duration and intensity of the physical activity. As mentioned earlier, the intensity observed during training in HG was high. However, the attendance rate was lower compared to studies with recreational football, which have seen an effect on LDL-C and LDL/HDL ratio.[8,22] In a study by de Sousa et al.,[42] an even more pronounced effect on lipid profile in terms of TC, LDL-C, LDL/HDL ratio, and TG was observed when the 12 weeks of recreational football training was combined with a calorie-restricted diet. In the present study, we did not control the subjects' dietary intake but recommended that they continued their normal lifestyle patterns. Changes in diet affect lipid concentration in plasma after just 3 days[43] and it seems that the lack of effect on lipid profile may be due to a combination of the lower attendance rate compared to other studies in healthy untrained subjects and possible changes in diet during the intervention study.

4.4. Well-being

Positive effects on mental energy were observed after 12 weeks of small-sided handball. This confirms earlier findings that participation in physical activity increases feelings of energy.[44] Effects on anxiety and positive well-being were not observed. This is in contrast with earlier studies, in which positive effects on a variety of well-being parameters were found.[44,45] However, this group of young women had low levels of anxiety (ranging from 1.40 to 1.74 on a scale from 1 to 4), making it possible that the intervention could not provide further improvements. Finally, looking at the positive well-being subscale, the values seem to be centered around 3 (ranging from 2.93 to 3.14) on a scale from 1 to 4, making it unlikely that there is a ceiling effect.

4.5. Motivation

The handball group experienced better development in intrinsic motivation to accomplish and to know. The effects were brought on by an increase in motivation in HG (albeit $p = 0.071$ for intrinsic motivation to know) as well as a decrease in motivation in CG (significant for both intrinsic motivation to accomplish and to know). For intrinsic motivation to experience stimulation, similar tendencies were found, but they were not significant. Taken together with the results for intrinsic motivation to accomplish and to know, it seems plausible that an effect on intrinsic motivation to experience stimulation could be found given a larger sample. Overall, it seems that 12 weeks of small-sided handball, compared with inactivity, increases intrinsic motivation. This is in line with earlier studies in which it was found that team games were intrinsically motivating for previously inactive participants.[15,16] These studies have highlighted that team games are particularly motivating because they have a high degree of social interaction and technical and tactical challenges, and therefore satisfy basic psychological needs for competence and relatedness, which in turn increases intrinsic motivation. It seems likely that there is a similar effect for the handball activities in this study. No effects were observed for any of the extrinsic motivation subscales. While it is possible that extrinsic motivation could increase for HG through motives such as better health, better looks, or feelings of responsibility toward other participants or oneself, this result was not obtained in this study. Nielsen et al.[15] and Pedersen et al.[19] mentioned that an increase in intrinsic motivation takes precedence over any possible increases in extrinsic motivation, making the results of this study plausible and in corroboration of existing research.

4.6. Injuries

In the present study, no severe injuries were observed. One participant had an ankle sprain and dropped out from the study. Elite Handball has shown to have an injury rate of 1.5 per match of which 84% of the injuries is caused by body-contact.[46] There are no previous studies that have shown the incidence of injuries in recreational handball. The rules applied in the present study did not allow hard tackles, thus it was expected that the injury rate would be far less than in elite handball. Furthermore, it is observed that the risk of injuries in recreational football is 5−10 times less when playing small-sided football compared to 11 v 11 match-play.[9] At last the warm-up was composed of a well-organized program inspired from FIFA 11+, which had been shown to be associated with a 30−50 percent reduction of injuries.[10,11] Therefore, recreational handball, does not give cause for concern when it comes to injuries, but future large-scale studies are warranted to investigate this further.

5. Conclusion

For young women, recreational handball represents intermittent high-intensity exercise that leads to beneficial effects on bone mineral density, muscle mass, and performance. It will be interesting to observe whether future studies in other populations are able to detect changes in cardiovascular fitness, which the present study failed to demonstrate. The young women in the present study had a superior cardiovascular risk profile, which may partly explain why there were no changes in cardiovascular fitness. In addition, recreational handball seems to increase some aspects of well-being and motivation. These results can likely be applied to other populations, though it remains to be investigated whether the results would be even better in sample populations with a more vulnerable psychological profile.

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Authors' contributions

TH conceived of the study design, applied for funding, conducted the training and testing, carried out the data collection and analysis, interpreted the study results, and drafted the manuscript; JMW conceived of the psycho-social part of the study design, carried out data collection, interpreted the study results, and edited the manuscript; BF conducted the training, carried out the video analysis, and edited the manuscript; SP, EWH, JWH, JLA, and LN contributed the study design, interpreted the study results, and edited the manuscript; SHN conducted the training, carried out the analysis of HR data, and edited the manuscript; PK conceived of the study design, applied for funding, interpreted the study results, and edited the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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