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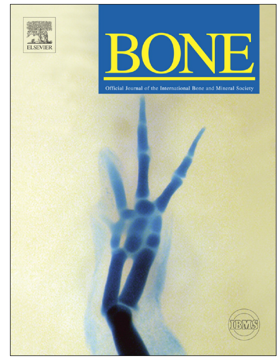

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Abstract

This study reports the effects of a recreational team handball exercise programme (randomised controlled trial, RCT) on bone health, postural balance and body composition in untrained postmenopausal women without previous experience of the sport. Sixty-seven postmenopausal women without previous experience of team handball practice (68.3±6.2 years, stature 156.9±5.8 cm, body mass 65.6±9.6 kg, body fat 40.9±5.9%, VO_{2peak} 25.2±3.6 $mL·min^{-1}·kg^{-1}$) were randomised into team handball (THG, n=41) and control (CG, n=26) groups. During the 16-week intervention period, THG performed two to three 60-min training sessions per week, while CG continued with their habitual physical activity. Bone mineral density (BMD) and content (BMC), biochemical bone formation (osteocalcin (OC), procollagen type-1 amino-terminal propeptide (P1NP)) and resorption markers (carboxy-terminal type-1 collagen crosslinks (CTX)), postural balance, body fat and lean mass were evaluated at baseline and post intervention. A time x group interaction ($p \leq 0.02$) was shown for lumbar spine BMD (+1.5%) and BMC (+2.3%), P1NP (+37.6±42.4%), OC (+41.9±27.0%) and postural balance (-7±37% falls), in favour of THG with no changes in CG. This RCT showed that short-term recreational team handball practice had an impact on bone turnover and was effective for improving bone health and postural balance in postmenopausal women without previous experience of the sport, hence potentially helping to reduce the risk of falls and fractures.

Keywords: team sports; intermittent exercise; bone content; bone metabolism; falls; menopause.

Abbreviations

ANCOVA analysis of covariance
ANOVA analysis of variance
BMC bone mineral content
BMD bone mineral density
CG control group
CI confidence interval
CTX carboxy-terminal type-1 collagen crosslinks
DXA dual-energy X-ray absorptiometry
EDTA ethylenediaminetetraacetic acid
HR heart rate
HR_{max} maximal heart rate
iSYS immunoassay system
OC osteocalcin
PA physical activity
P1NP procollagen type-1 amino terminal propeptide
RCT randomised controlled trial
RER respiratory exchange ratio
RPE rating of perceived exertion
SD standard deviation
SPSS Statistical Package for the Social Sciences
THG team handball group
VO_{2max} maximal oxygen uptake
VO_{2peak} peak oxygen uptake
YYIE1 Yo-Yo intermittent endurance test level 1

1. Introduction

Menopause is defined as the cessation of menses and occurs at a median age of 51 years [1], with women spending nearly one third of their lives in this irreversible condition. Both menopause and ageing involve hormonal changes, and menopause is characterised by a decrease in oestrogens levels [1, 2] that negatively impacts body composition by increasing body fat [3] and decreasing lean and bone mass [2], and ultimately increasing the risk of musculoskeletal disorders, such as sarcopenia and osteoporosis. These disorders are known to be associated with cardiovascular disease [4, 5], and to potentiate the risk of falls [6] and fractures [7], whereas higher lean mass [8] and lower body fat [9, 10] are associated with a decreased risk of fractures in postmenopausal women. Given that falls and fractures are associated with an increased risk of morbidity and mortality [6, 11], exercise programmes namely aerobic, resistance and flexibility training have been considered as effective strategies for counteracting these adverse health conditions and menopause-related morbidities [12]. However, despite the effectiveness of traditional exercise modes, other options, such as team sports, which combine aerobic and anaerobic training, seem to show a positive modulatory impact on various health-related parameters [13]. For instance, recreational football offers a multicomponent training approach that has the potential to act on a range of health and fitness aspects, being as effective for decreasing body fat and increasing lean and bone mass as aerobic and strength training separately [14]. Moreover, recreational team handball, which physical and physiological demands are similar to recreational football, has been shown to positively affect body composition and bone health in young men [15] and women [16] by increasing muscle mass, femur bone mineral density (BMD), whole-body bone mineral content (BMC) and bone formation markers, and decreasing body fat. It has also proven effective for improving physical fitness (e.g. balance) in adult/middle-aged men with previous experience of the sport [17]. In addition, it has recently been shown that recreational handball is effective for improving aerobic performance and cardiorespiratory fitness in postmenopausal women [18]. Nonetheless, the effects of recreational team handball on bone health and fall prevention in postmenopausal women have not yet been addressed. So, to the best of our knowledge, this is the first study to evaluate the effects of a recreational team handball-based exercise programme (randomised controlled trial, RCT) on bone health, postural balance and body composition in inactive postmenopausal women without previous experience of the sport.

2. Methods

2.1. Participants

Eighty inactive postmenopausal women aged 49–79 years with menopause for at least 3 years and without medical contraindications to perform moderate-to-vigorous physical activity (PA) were recruited to this study (Fig. 1). Nine participants dropped out for personal reasons, three before the baseline evaluations and six immediately afterwards. Seventy-one participants without previous experience of the sport were randomly allocated to team handball (THG) and control (CG) groups. After randomisation, two CG participants dropped out for personal reasons and one was excluded from the analysis because she had enrolled in another exercise programme. In THG, one participant was not able to start the exercise programme at the set date and complete the 16-week programme for personal reasons and was thus excluded from the analysis. The final sample therefore comprised sixty-seven participants (THG: n=41, age 67.3±6.5 years, stature 156.7±6.2 cm, body mass 66.9±9.7 kg, body fat 41.3±5.3%, VO_{2peak} 25.8±3.3 $mL \cdot min^{-1} \cdot kg^{-1}$; CG: n=26, age 69.9±5.4 years, stature 157.1±5.1 cm, body mass 63.5±9.3 kg, body fat 40.3±6.8%, VO_{2peak} 24.5±3.6 $mL \cdot min^{-1} \cdot kg^{-1}$) who performed baseline and post-intervention evaluations at 16 weeks.

Sample size estimation for the main outcome (maximal oxygen uptake (VO_{2max})) of this RCT was performed for a sample power of 95% with an effect size of 0.25 at a significance level of 5% and for a dropout rate of 20% [18]. The results presented here therefore represent an analysis of the secondary outcomes (BMD, BMC, biochemical bone markers, postural balance and body mass, body fat and lean mass) of this RCT. All participants signed a written informed consent providing information about the purpose of the study and its potential risks and benefits, and stating that they could withdraw at any time without penalty. The present study followed the Declaration of Helsinki, and the local Institutional Review Board provided ethical approval.

Figure 1 here

2.2.Study design

This was a randomised controlled trial. The participants were evaluated at baseline and post intervention (16 weeks) for body mass, body fat, lean mass, BMD, BMC, biochemical bone turnover markers and postural balance. After the baseline evaluations, the participants were stratified by peak oxygen uptake (VO_{2peak}) and randomly allocated (3:2 ratio, due to potentially higher drop-out in the intervention group than in the control group) to THG (n=41) and CG (n=26). THG underwent a 16-week recreational team handball intervention involving two to three 60-min sessions per week. CG was instructed to continue with their habitual daily PA. THG was also instructed to continue with their habitual PA in addition to the PA related to the intervention programme.

2.3.Measures and test procedures

All the participants were evaluated at baseline and at 16 weeks post intervention. The evaluations were performed on two separate days. The participants were instructed to have a light meal before the evaluations, except before the blood sampling, which was performed in the morning after an overnight fast (at least 8 hours). No exhausting PA was allowed in the

48 hours before testing. PA levels aside from those related to the exercise intervention were measured using the International Physical Activity Questionnaire [19].

Evaluation day 1

Body mass, stature and body composition were measured with the participants in light clothes and without shoes. Stature (rounded to the nearest 0.1 cm) was measured with a portable stadiometer (Seca 213, Hamburg, Germany) with the participant in an upright position, quiet, facing forwards with their arms hanging freely [20]. Body mass (kg), body fat (%) and lean mass (kg) were determined by whole-body dual-energy X-ray absorptiometry (DXA; Hologic Explorer QDR, Hologic Inc., Belford, MA, USA) following standard procedures. Lumbar spine and dominant femur BMD and BMC were determined by regional scanning.

Cardiorespiratory fitness was assessed using a standardised incremental treadmill (H/PHCosmos, Quasar, Germany) protocol [21]. Oxygen uptake and respiratory exchange ratio (RER) were determined by pulmonary gas exchange measurements (Oxycon Pro Metabolic Cart, Jaeger, CareFusion, Germany). VO_{2peak} was considered as the highest 15-second mean value. During the test, the participants' heart rate (HR) was continuously monitored with a heart-rate monitor (Polar Wearlink, Kempele, Finland). Age-predicted maximal HR (HR_{max}) was determined by the formula 208 – (age x 0.7) [21]. The test stopped at the participant's voluntary exhaustion and the results were considered as VO_{2peak} if two of the following criteria were met: RER ≥1.1; HR_{max} ≥85% of age-predicted HR_{max}; failure of oxygen consumption to increase with increased exercise intensity [21].

Evaluation day 2

To assess the plasma concentration of biochemical bone turnover markers, blood samples were drawn by a trained technician. A 6-mL blood sample was collected in a tube containing ethylenediaminetetraacetic acid (EDTA) and centrifuged. Plasma was pipetted and frozen at -80ºC for subsequent analysis of osteocalcin (OC), procollagen type-1 amino-terminal propeptide (P1NP) and carboxy-terminal type-1 collagen crosslinks (CTX). The markers were analysed by a chemiluminescence method using a fully automated immunoassay system, (iSYS; Immunodiagnostic System Ltd., Boldon, UK). Assay performance was verified using the manufacturer's control specimens. The intermediary precisions expressed as coefficients of variation for CTX were 5.3% (at CTX concentration 213 ng/L), 3.4% (869 ng/L) and 3.5% (2,113 ng/L) for iSYS. For P1NP, the intermediary precisions were 5.4% (18.96 µg/L), 6.5% (48.48 µg/L) and 6.1% (122.10 µg/L) for iSYS. For OC, the intermediary precisions were 3.0% (8.73 µg/L), 3.6% (27.6 µg/L) and 3.5% (68.7 µg/L).

After the blood was drawn, the participants had their regular breakfast. Nearly 30 min later, they performed a single-leg flamingo test to assess postural balance [22]. In this test, the participants had to stand on their dominant leg on a 3-cm-wide and 5-cm-high bar for 1 min. Every time the participant lost their balance, the time was paused until balance was regained. The non-dominant leg was flexed at the knee joint. The number of falls during the defined time was recorded.

Afterwards, the participants performed the Yo-Yo intermittent endurance test level 1 (YYIE1), preceded by a 10-min warm-up of running at different velocities with changes of direction. HR during the test was assessed [23].

2.4.Exercise programme

THG performed two to three weekly sessions of a recreational team handball-based exercise programme for 16 weeks, with a rest period of at least 48 hours between sessions. Each session lasted 60 min and consisted of a standardized warm-up (including running, coordination, strength, flexibility and balance exercises) and three 15-min periods of recreational team handball matches played as small-sided games (4v4, 5v5 or 6v6). The training sessions were performed on an indoor team handball court (40x20 m) adjusted to give an area of 34–36 m^2 per player. Some exceptions to official team handball rules were applied, namely: no exclusions; no substitutions; no dribbling; the participants rotated positions every 3 min in a random order, including the goalkeeper; the ball was immediately put back in play by the goalkeeper after a goal. To avoid injuries, no hard tackles and physical contact were allowed. The balls used were lighter than for conventional team handball and made of a soft material. All sessions were supervised by a physical education professional with good knowledge of the rules of the sport. Heart rate (Firstbeat Technologies Ltd., version 4.7.2.1, Jyväskylä, Finland) and rate of perceived exertion (RPE), 0–10 scale [24], were monitored in all training sessions. Individual HR_{max} was determined as the highest value reached during the VO_{2max} test, the YYIE1 or the training sessions [23].

2.5.Statistical analyses

Results are presented as mean ± standard deviations (SD) and 95% confidence intervals (95% CI). Group and intervention effects were analysed with two-way analysis of covariance (ANCOVA) with Bonferroni *post hoc* tests, with sedentary behaviour as the covariate to bone health, balance and body composition variables. Group and intervention effects for habitual PA were analysed with two-way analysis of variance (ANOVA) with Bonferroni *post hoc* tests. To analyse differences in pre-post delta values between the groups, a student's unpaired *t*-test was performed. A Pearson correlation was used to analyse associations in absolute and relative changes between osteogenic bone turnover markers. Practical significance was assessed by calculating Cohen *d* and interpreted as trivial (<0.2), small (0.2–0.5), medium (0.5–0.8) and large (>0.8) [25]. Statistical Package for the Social Sciences (SPSS Inc., version 25) was used for data analysis. Statistical significance was set at $p \leq 0.05$.

3. Results

3.1. Training sessions

The participants' mean training attendance was 1.9±0.4 (0.9–2.9) sessions per week, with a total of 31±7 (15–47) training sessions. Mean HR during matches was 128±16 bpm (76±6%HR_{max}), with peak values of 149±17 bpm (88±6%HR_{max}). HR was >80%HR_{max} for 44±20% (18±9 min) of total match duration, with 34±14% of the time spent at 80–90% of HR_{max} and 11±9% of the time spent at >90% of HR_{max}. Average RPE during match-play was 4.8±1.9 (0.1–9.3).

Table 1 here

3.2. Osteogenic response

A time x group interaction was shown for lumbar spine BMD and BMC ($p \leq 0.002$). THG increased lumbar spine BMD by 1.5% (0.892±0.129 to 0.905±0.130 g/cm^2; p<0.001; 95% CI: 0.62–2.31; d=0.586) and BMC by 2.3% (50.1±10.1 to 51.2±10.3 g; p<0.001; 95% CI: 0.98–3.53; d=0.593). An increase of 2.2% (25.3±3.6 to 25.8±3.5 g; p=0.004; 95% CI: 0.90–3.48; d=0.502) was also observed in femur BMC in THG (Table 1; Fig. 2).

Figure 2 here

A time x group interaction was shown for P1NP (p=0.017) and OC (p=0.008). At 16 weeks, THG showed significant higher P1NP levels than CG (67.5 versus 43.1 µg/L; p=0.014). From pre to post intervention, THG increased CTX (375.7±212.4 to 436.3±198.5 ng/L; p=0.017; 95% CI: 9.26–46.70; d=0.529), P1NP (49.9±18.9 to 67.5±28.8 µg/L; p<0.001; 95% CI: 17.82–57.33; d=1.300) and OC (18.8±7.1 to 27.7±14.2 µg/L; p<0.001; 95% CI: 29.28–54.57; d=2.807) concentrations by 28%, 38% and 42%, respectively (Table 1; Fig. 3). A correlation between absolute (r=0.433; p=0.015) and relative (r=0.444; p=0.012) delta values in femur BMC and P1NP was shown. Additionally, a correlation between relative delta values (r=0.381; p=0.034) in femur BMC and OC was also observed.

Figure 3 here

3.3. Postural balance

A time x group effect was observed for postural balance (*p*=0.010). At post intervention, THG had decreased the number of falls by 7%, corresponding to five falls less than at baseline (38±13 to 33±14 falls; *p*=0.011; 95% CI: -20.46–5.98; *d*=0.474) (Table 1; Fig. 4).

Figure 4 here

3.4. Body mass, body fat and lean mass

A time effect was observed for body fat (*p*=0.008). THG decreased body mass by 1.1% (66.9±9.7 to 66.2±9.4 kg; *p*=0.007; 95% CI: -1.85; -0.27; *d*=0.423) and body fat percentage by 1.1%-point (41.3±5.3 to 40.2±5.1%; *p*<0.001; 95% CI: -3.58; -1.46; *d*=0.795). CG decreased body fat percentage by 0.8%-points (40.3±6.8 to 39.5±6.6; *p*=0.019; 95% CI: -3.87; -0.57; *d*=0.432). No significant differences were observed for lean mass in either group or between groups after 16 weeks (Table 1).

3.5. Habitual physical activity

No significant differences (*p*>0.05) between or within groups were observed with regard to total PA, vigorous PA, moderate PA and walking between baseline and 16 weeks (Table 2). Although CG reported less sedentary behaviour than THG at baseline (142 vs 245 min/week; *p*=0.004) and at 16 weeks (137 vs 195 min/week; *p*=0.041), only THG had decreased sedentary behaviour at follow-up (245 to 195 min/week; *p*=0.011).

Table 2 here

4. Discussion

This is the first study to analyse the effects of a short-term (16 weeks) recreational team handball-based randomised controlled exercise programme on bone health, postural balance and body composition in inactive postmenopausal women without previous experience of the sport. The main findings were that 16 weeks of recreational team handball training, performed as small-sided games, induced an osteogenic response as well as improvements in postural balance and body mass.

4.1. Osteogenic response

THG increased lumbar spine BMD and BMC, and femur BMC, by 1.5, 2.3 and 2.2% (p≤0.004), respectively. It has been reported that during the first few years after menopause, BMD in lumbar spine and femur decreases 2.0% and 1.4% per year, respectively [26]. Thus, the present findings are of particular interest, since recreational team handball practice may counteract the normal BMD loss in this population. Additionally, bone remodelling to repair microfractures and replace old and fragile bone tissue with new bone is of the utmost importance for osteoporosis prevention [27]. For this, bone remodelling needs to take place through osteoclastic and osteoblastic activity [28]. Even though this process occurs irrespective of age and health, after menopause there is a greater increase in osteoclastic resorption than in osteoblastic activity [27], leading to a negative net bone balance. After 16 weeks, THG increased P1NP (37.6%), OC (41.9%) and CTX (28.0%). THG showed higher absolute delta values for biochemical bone formation markers than CG (P1NP: 17.7 vs 5.1 µg/L; OC: 8.9 vs 2.1 µg/L, $p \leq 0.009$). Even though recreational team handball training for postmenopausal women resulted in an increase in the bone resorption marker CTX (375.7±212.4 to 436.3±198.5 ng/L; $p=0.017$), it was accompanied by an increase in the osteoblastic activity markers P1NP and OC, which seems to indicate an overall osteogenic change in bone turnover.

In a previous study, after 4 months of recreational football practice comprising two to three 45–60-min sessions per week, increases of 1.0 and 1.1% in right and left femur BMD, respectively, were shown in older men (mean age 68.2 years) [29]. Additionally, after a year of intervention, right and left femur BMD increased by 5.4% and 3.8%, respectively. The authors suggested that the osteogenic response could take more time in older than in younger populations. Longer-term interventions may be required to understand whether recreational team handball is effective for improving femur BMD, since a 16-week intervention may not be enough to promote any significant change in this region. Indeed, the increase in biochemical bone markers may indicate a forthcoming alteration in bone structure. Moreover, it would be of interest to understand whether extending recreational team handball practice beyond 16 weeks induces additional improvements in lumbar spine BMD and BMC. Studies analysing the effect of team sports exercise interventions on lumbar spine BMD and BMC are scarce, even though both lumbar spine and femur are the areas for osteoporosis diagnostics [30]. Osteocalcin and P1NP were shown to increase by 41 and 45% respectively, with no change in CTX at the end of the fourth month of recreational football practice in older men [29]. An increase in P1NP (40%) was observed in postmenopausal women after 12 weeks of twice-weekly 60-min sessions of floorball practice, with no changes in CTX or OC [31]. However, after 15–16 weeks of recreational football training, an increase was seen in P1NP, OC and CTX in middle-aged women close to menopause (52%, 37% and 42%, respectively)

[32], and in 61-year-old men and women (52%, 23% and 38%, respectively) [33].

Increases in femur BMD (0.8 and 2.0%), P1NP (33 and 65%), OC (56 and 45%) and CTX (34 and 25%) were observed in 20–30-year-old women and men, respectively, after a 12-week recreational team handball intervention involving two to three sessions per week, which accords with the findings of this study [15, 16, 34].

Improvements in bone health can contribute to the prevention of osteoporosis, which is associated with cardiovascular mortality, morbidity and atherosclerosis [4], highlighting a possible multiple-health approach of this exercise mode for preventing the deleterious effects of menopause.

4.2.Postural balance

The consequences of falls include fractures, bruises, other injuries and physiological effects, including morbidity and even death [6]. Thus, the prevention of falls and improvement of postural balance are paramount, particularly for postmenopausal women, who are at higher risk than men of experiencing fractures [35]. Recreational team handball practice resulted in an improvement in postural balance after 16 weeks. Greater postural balance improvements were shown in two team sport interventions involving middle-age men (27%, 42.3 years) and women (29%, 36.5 years) using team handball [17] and football [36], respectively. Indeed, better results were shown in the flamingo balance test in a younger population (32.4 years) than in an older population (70.5 years) [37]. Additionally, long-term exposure to training is also a key factor in balance performance, with trained older men (69.6 years) reporting the same number of falls as untrained young men (32.4 years) [37].

A limitation of this study was not to have recorded the number of falls before, during and after the intervention, in daily life activities and during the training sessions. In future studies, it would also be of interest to analyse the fall pattern.

4.3.Total body mass, body fat and lean mass

THG reduced body mass by 0.7 kg, corresponding to 1.1%, though no changes were observed in lean mass. Curiously, both groups decreased body fat, THG by 1.1%-point and CG by 0.8%-points. In recreational team sports, changes in fat and lean mass were observed in several studies, namely using floorball for postmenopausal women [31, 38], team handball for young men and women [15, 16, 34], and football for men of the same mean age as our participants [39]. The decrease in body fat in THG is in accordance with previous training studies with team handball for young women (1.0%) [16] and overweight premenopausal women (1.4%) [34] playing recreational team handball twice a week for 12–16 weeks. In these studies, however, no changes were observed in body mass. Body mass decreases are of practical importance due to the association with health risks at older ages. Weight loss, even in small amounts, could be beneficial, namely for preventing obesity and its consequences [40]. It should be taken into account, though, that weight loss could induce loss of muscle mass, besides body fat, which is of particular concern in the older population [40].

4.4.Injuries

In order to minimise the risk of injury, no hard tackles or physical contact were allowed. Additionally, the balls used were made of soft material and the participants were continuously instructed how to hold, throw and catch the ball. During the 16 weeks, only one finger subluxation was reported, though this did not prevent completion of the intervention by the participant. Thus, the overall incidence was 0.8 injuries per 1000 hours of exposure. No severe injuries occurred during the programme, which is in accordance with previous studies [15, 16].

A previous study in this population had already reported the effectiveness of recreational team handball for improving aerobic performance and cardiorespiratory fitness, thus showing the positive cardiovascular health effect of this team sport practice in postmenopausal women [18]. However, this is the first RCT to analyse the effects of recreational team handball on bone health, balance and body composition in this population.

After the 16-week intervention, significant changes were shown in lumbar spine BMD and BMC, femur BMC, P1NP, OC, CTX, balance and body mass, though no alterations were shown in lean mass and femur BMD. This could be related to the duration of the intervention (16 weeks) being insufficient to induce significant alterations in these markers, and thus the effect of extending the intervention's duration on additional increases in BMD should be studied.

The increases in BMD, BMC and bone turnover could contribute to better skeletal mass and, together with the improvement in balance, reduce the risk of falls and fractures, which are associated with increased risk of mortality and morbidity. Taken together, data from the present study suggest that recreational team handball can be introduced as a high-attendance, high-intensity and low-risk exercise mode for improving bone density, content and metabolism, as well as postural balance.

5. Conclusion

Short-term recreational team handball practice is effective for improving bone health and postural balance in postmenopausal women without previous experience of the sport, and hence may potentially be helpful for counteracting the risk of falls, fractures and associated comorbidities in this population.

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Author contributions All authors read and approved the final version of the manuscript. RP conducted the training, testing, data collection and analysis, interpreted the study results and drafted the manuscript. JM and CC contributed to the study design, interpreted the study results and edited the manuscript. EC, RS and EWH interpreted the study results and edited the manuscript. NRJ carried out the analysis of the biochemical bone turnover markers and interpreted the study results. SP and PK conceived the study design, applied for the funding, interpreted the results and edited the manuscript.

Conflicts of interest The authors do not have any conflicts of interest to declare.

References

[1] R.J. Baber, N. Panay, A. Fenton, 2016 IMS Recommendations on women's midlife health and menopause hormone therapy, Climacteric 19(2) (2016) 109-50.

[2] M. Brown, Skeletal muscle and bone: effect of sex steroids and aging, Adv Physiol Educ 32(2) (2008) 120-6.

[3] G.B. Bernasochi, J.R. Bell, E.R. Simpson, L.M.D. Delbridge, W.C. Boon, Impact of Estrogens on the Regulation of White, Beige, and Brown Adipose Tissue Depots, Compr Physiol 9(2) (2019) 457-475.

[4] G.N. Farhat, J.A. Cauley, The link between osteoporosis and cardiovascular disease, Clin Cases Miner Bone Metab 5(1) (2008) 19-34.

[5] S.O. Chin, S.Y. Rhee, S. Chon, Y.C. Hwang, I.K. Jeong, S. Oh, K.J. Ahn, H.Y. Chung, J.T. Woo, S.W. Kim, J.W. Kim, Y.S. Kim, H.Y. Ahn, Sarcopenia is independently associated with cardiovascular disease in older Korean adults: the Korea National Health and Nutrition Examination Survey (KNHANES) from 2009, PLoS One 8(3) (2013) e60119.

[6] M. Terroso, N. Rosa, A. Torres Marques, R. Simoes, Physical consequences of falls in the elderly: a literature review from 1995 to 2010, Eur Rev Aging Phys Act 11 (2014) 51-59.

[7] J.D. Adachi, C. Berger, R. Barron, D. Weycker, T.P. Anastassiades, K.S. Davison, D.A. Hanley, G. Ioannidis, S.A. Jackson, R.G. Josse, S.M. Kaiser, C.S. Kovacs, W.D. Leslie, S.N. Morin, A. Papaioannou, J.C. Prior, E. Shyta, A. Silvia, T. Towheed, D. Goltzman, Predictors of imminent non-vertebral fracture in elderly women with osteoporosis, low bone mass, or a history of fracture, based on data from the population-based Canadian Multicentre Osteoporosis Study (CaMos), Arch Osteoporos 14(1) (2019) 53.

[8] E. Sornay-Rendu, F. Duboeuf, S. Boutroy, R.D. Chapurlat, Muscle mass is associated with incident fracture in postmenopausal women: The OFELY study, Bone 94 (2017) 108-113.

[9] A. Moayyeri, R.N. Luben, N.J. Wareham, K.T. Khaw, Body fat mass is a predictor of risk of osteoporotic fractures in women but not in men: a prospective population study, J Intern Med 271(5) (2012) 472-80.

[10] M.R. Mainenti, C. Rodrigues Ede, J.F. Oliveira, S. Ferreira Ade, C.M. Dias, A.L. Silva, Adiposity and postural balance control: correlations between bioelectrical impedance and stabilometric signals in elderly Brazilian women, Clinics (Sao Paulo) 66(9) (2011) 1513-8.

[11] T.V. Nguyen, Individualized fracture risk assessment: State-of-the-art and room for improvement, Osteoporos Sarcopenia 4(1) (2018) 2-10.

[12] N.M. Grindler, N.F. Santoro, Menopause and exercise, Menopause 22(12) (2015) 1351-8.

[13] C. Castagna, M. de Sousa, P. Krustrup, D.T. Kirkendall, Recreational team sports: The motivational medicine, J Sport Health Sci 7(2) (2018) 129-131.

[14] P. Krustrup, P. Aagaard, L. Nybo, J. Petersen, M. Mohr, J. Bangsbo, Recreational football as a health promoting activity: a topical review, Scand J Med Sci Sports 20 Suppl 1

(2010) 1-13.

[15] T. Hornstrup, F.T. Løwenstein, M.A. Larsen, E.W. Helge, S. Póvoas, J.W. Helge, J.J. Nielsen, B. Fristrup, J.L. Andersen, L. Gliemann, L. Nybo, P. Krustrup, Cardiovascular, muscular, and skeletal adaptations to recreational team handball training: a randomized controlled trial with young adult untrained men, Eur J Appl Physiol 119(2) (2019) 561-573.

[16] T. Hornstrup, J.M. Wikman, B. Fristrup, S. Póvoas, E.W. Helge, S.H. Nielsen, J.W. Helge, J.L. Andersen, L. Nybo, P. Krustrup, Fitness and health benefits of team handball training for young untrained women-A cross-disciplinary RCT on physiological adaptations and motivational aspects, J Sport Health Sci 7(2) (2018) 139-148.

[17] S.C.A. Póvoas, C. Castagna, C. Resende, E.F. Coelho, P. Silva, R. Santos, R. Pereira, P. Krustrup, Effects of a Short-Term Recreational Team Handball-Based Programme on Physical Fitness and Cardiovascular and Metabolic Health of 33-55-Year-Old Men: A Pilot Study, Biomed Res Int 2018 (2018) 4109796.

[18] R. Pereira, P. Krustrup, C. Castagna, E. Coelho, R. Santos, S. Martins, J.T. Guimarães, J. Magalhães, S. Póvoas, Effects of a 16-week recreational team handball intervention on aerobic performance and cardiometabolic fitness markers in postmenopausal women: A randomized controlled trial, Prog Cardiovasc Dis (2020).

[19] C.L. Craig, A.L. Marshall, M. Sjostrom, A.E. Bauman, M.L. Booth, B.E. Ainsworth, M. Pratt, U. Ekelund, A. Yngve, J.F. Sallis, P. Oja, International physical activity questionnaire: 12-country reliability and validity, Med Sci Sports Exerc 35(8) (2003) 1381-95.

[20] Ministry of Health, Protocol for Collecting Height, Weight and Waist Measurements in New Zealand Health Monitor (NZHM) Surveys., Ministry of Health, Wellington, NZ, 2008.

[21] American College of Sports Medicine, ACSM's Guidelines for Exercise Testing and Prescription, 9 ed.2014.

[22] B. Deforche, J. Lefevre, I. De Bourdeaudhuij, A.P. Hills, W. Duquet, J. Bouckaert,

Physical fitness and physical activity in obese and nonobese Flemish youth, Obes Res 11(3) (2003) 434-41.

[23] S.C.A. Póvoas, P. Krustrup, R. Pereira, S. Vieira, I. Carneiro, J. Magalhães, C. Castagna, Maximal heart rate assessment in recreational football players: A study involving a multiple testing approach, Scand J Med Sci Sports 29(10) (2019) 1537-1545.

[24] C. Foster, J. Florhaug, J. Franklin, L. Gottschall, L. Hrovatin, S. Parker, P. Doleshal, C. Dodge, A new approach to monitoring exercise training, J Strength Cond Res 15(1) (2001) 109-15.

[25] J. Cohen, Statistical power analysis for the behaviour sciences, Lawrence Erlbaum Associates, Hillsdale, NJ, 1988.

[26] J.S. Finkelstein, S.E. Brockwell, V. Mehta, G.A. Greendale, M.R. Sowers, B. Ettinger, J.C. Lo, J.M. Johnston, J.A. Cauley, M.E. Danielson, R.M. Neer, Bone mineral density changes during the menopause transition in a multiethnic cohort of women, J Clin Endocrinol Metab 93(3) (2008) 861-8.

[27] J.C. Gallagher, S.H. Tella, Prevention and treatment of postmenopausal osteoporosis, J Steroid Biochem Mol Biol 142 (2014) 155-70.

[28] R. Eastell, P. Szulc, Use of bone turnover markers in postmenopausal osteoporosis, Lancet Diabetes Endocrinol 5(11) (2017) 908-923.

[29] E.W. Helge, T.R. Andersen, J.F. Schmidt, N.R. Jorgensen, T. Hornstrup, P. Krustrup, J. Bangsbo, Recreational football improves bone mineral density and bone turnover marker profile in elderly men, Scand J Med Sci Sports 24 Suppl 1 (2014) 98-104.

[30] J.Y. Reginster, N. Burlet, Osteoporosis: a still increasing prevalence, Bone 38(2 Suppl 1) (2006) S4-9.

[31] K. Seidelin, M. Nyberg, P. Piil, N.R. Jorgensen, Y. Hellsten, J. Bangsbo, Adaptations with Intermittent Exercise Training in Post- and Premenopausal Women, Med Sci Sports

Exerc 49(1) (2017) 96-105.

[32] M. Mohr, E.W. Helge, L.F. Petersen, A. Lindenskov, P. Weihe, J. Mortensen, N.R. Jorgensen, P. Krustrup, Effects of soccer vs swim training on bone formation in sedentary middle-aged women, Eur J Appl Physiol 115(12) (2015) 2671-9.

[33] M.B. Skoradal, E.W. Helge, N.R. Jørgensen, J. Mortensen, P. Weihe, P. Krustrup, M. Mohr, Osteogenic impact of football training in 55- to 70-year-old women and men with prediabetes, Scand J Med Sci Sports 28 Suppl 1 (2018) 52-60.

[34] T. Hornstrup, S. Póvoas, J.W. Helge, P.S. Melcher, P. Fristrup, J.L. Andersen, R. Mogelvang, P.R. Hansen, L. Nybo, P. Krustrup, Cardiovascular and metabolic health effects of team handball training in overweight women: Impact of prior experience, Scand J Med Sci Sports 30(2) (2020) 281-294.

[35] F.P. Chen, T.S. Fu, Y.C. Lin, C.M. Fan, Risk factors and quality of life for the occurrence of hip fracture in postmenopausal women, Biomed J 41(3) (2018) 202-208.

[36] E.W. Helge, P. Aagaard, M.D. Jakobsen, E. Sundstrup, M.B. Randers, M.K. Karlsson, P. Krustrup, Recreational football training decreases risk factors for bone fractures in untrained premenopausal women, Scand J Med Sci Sports 20 Suppl 1 (2010) 31-9.

[37] E. Sundstrup, M.D. Jakobsen, J.L. Andersen, M.B. Randers, J. Petersen, C. Suetta, P. Aagaard, P. Krustrup, Muscle function and postural balance in lifelong trained male footballers compared with sedentary elderly men and youngsters, Scand J Med Sci Sports 20 Suppl 1 (2010) 90-7.

[38] M. Nyberg, K. Seidelin, T.R. Andersen, N.N. Overby, Y. Hellsten, J. Bangsbo, Biomarkers of vascular function in premenopausal and recent postmenopausal women of similar age: effect of exercise training, Am J Physiol Regul Integr Comp Physiol 306(7) (2014) R510-7.

[39] J. Uth, T. Hornstrup, J.F. Schmidt, J.F. Christensen, C. Frandsen, K.B. Christensen,

E.W. Helge, K. Brasso, M. Rorth, J. Midtgaard, P. Krustrup, Football training improves lean body mass in men with prostate cancer undergoing androgen deprivation therapy, Scand J Med Sci Sports 24 Suppl 1 (2014) 105-12.

[40] O. Bosello, A. Vanzo, Obesity paradox and aging, Eat Weight Disord (2019).

Table 1. Body mass, body composition, blood bone markers and postural balance at baseline and after 16 weeks of small-sided recreational team handball training or a continuation of usual lifestyle, with baseline habitual physical activity as the covariate.

	Team handball group (n=41)				**Control group (n=26)**				**Two-way ANCOVA**		
Variables	Baseline	16 weeks	Δ (abs)	Δ (%)	Baseline	16 weeks	Δ (abs)	Δ (%)	Time *p*	Group *p*	Interaction *p*
Bone health											
Lumbar spine BMD (g/cm^2)	0.892±0.129	0.905±0.130*	0.013±0.022	1.5±2.7	0.899±0.126	0.893±0.124	-0.006±0.014#	-0.6±1.6#	0.442	0.731	0.001
Lumbar spine BMC (g)	50.1±10.1	51.2±10.3*	1.1±1.8	2.3±4.1	49.5±8.1	49.1±7.9	-0.4±1.2#	-0.7±2.4#	0.492	0.909	0.002
Femoral neck BMD (g/cm^2)	0.718±0.098	0.724±0.097	0.006±0.025	0.9±3.6	0.693±0.125	0.693±0.131	-0.000±0.019	-0.2±2.8	0.547	0.841	0.302
Femoral neck BMC (g)	3.3±0.5	3.3±0.5	0.0±0.[illegible]	1.6±8.0	3.2±0.6	3.2±0.7	-0.0±0.2	-0.6±5.9	0.660	0.758	0.595
Femur BMD (g/cm^2)	0.833±0.101	0.838±0.098	0.004±0.019	0.6±2.3	0.826±0.111	0.828±0.117	0.003±0.018	0.3±2.2	0.223	0.474	0.674
Femur BMC (g)	25.3±3.6	25.8±3.5*	0.5±1.0	2.2±4.1	25.7±4.0	25.8±4.0	0.1±1.2	0.6±4.8	0.100	0.494	0.153
CTX (ng/L)	375.7±212.4	436.3±198.5*	60.6±115.2	28.0±40.0	309.1±245.4	338.6±249.3	29.5±50.2	16.6±38.3	0.367	0.232	0.568
P1NP (µg/L)	49.9±18.9	67.5±28.8*	17.7±16.6	37.6±42.4	38.0±27.5	43.1±28.4#	5.1±6.3#	18.1±27.2	0.003	0.028	0.017
Osteocalcin (µg/L)	18.8±7.1	27.7±14.2*	8.9±7.8	41.9±27.0	16.6±13.1	18.8±13.1	2.1±2.1#	16.9±16.7#	0.003	0.157	0.008

P1NP/CTX	156.9±64.8	162.4±42.9	5.5±64.3	14.5±37.0	166.0±68.0	181.8±97.4	15.8±83.6	11.7±43.2	0.240	0.508	0.952
Osteocalcin/CTX	57.3±18.2	65.7±22.0	8.4±22.1	20.5±43.4	75.5±38.5	82.9±57.1	7.4±43.2	10.8±40.9	0.223	0.114	0.794
Physical fitness											
Postural balance (n)	38±13	33±14*	-5±10	-7±37	35±13	38±12	3±8#	16±41#	0.902	0.909	0.010
Body composition											
Body mass (kg)	66.9±9.7	66.2±9.4*	-0.7±1.8	-1.1±2.5	63.5±9.3	63.2±9.6	-0.3±1.3	-0.5±2.2	0.200	0.450	0.301
Body fat (%)	41.3±5.3	40.2±5.1*	-1.1±1.4	-2.5±3.4	40.3±6.8	39.5±6.6*	-0.8±1.8	-1.6±5.5	0.008	0.806	0.487
Lean mass (kg)	37.2±4.1	37.4±4.1	0.3±0.9	0.8±2.4	35.7±3.5	36.0±3.8	0.3±1.3	0.9±3.8	0.230	0.329	0.890

Data is presented as mean±SD

* Significantly different from baseline ($p \le 0.005$)

Significantly different from the team handball group ($p \le 0.005$)

BMD: bone mineral density; BMC: bone mineral content; CTX: carboxy-terminal type-1 collagen crosslinks; P1NP: procollagen type-1 amino-terminal propeptide.

Table 2 Daily physical activity at baseline and after 16 weeks of small-sided recreational team handball training or a continuation of usual lifestyle.

	Team handball group (n=41)		**Control group (n=26)**		**Two-way ANOVA**		
	Baseline	16 weeks	Baseline	16 weeks	Time *p*	Group *p*	Interaction *p*
Total PA (MET-min/week)	3051±2834	3038±1936	2458±2364	3002±2685	0.459	0.545	0.438
Vigorous-intensity PA (MET-min/week)	657±1435	1194±1127	859±1775	947±1554	0.218	0.934	0.374
Moderate-intensity PA (MET-min/week)	1085±1395	827±1039	761±1162	1143±1491	0.753	0.988	0.109
Walking (MET-min/week)	1309±1140	1017±886	858±786	911±747	0.447	0.134	0.204
Sedentary behaviour (min/day)	245±161	195±127*	142±81#	137±69#	0.083	0.005	0.146

Data is presented as mean±SD

* Significantly different from baseline ($p \leq 0.005$)

Significantly different from the team handball group ($p \leq 0.005$)

PA: physical activity

Figures

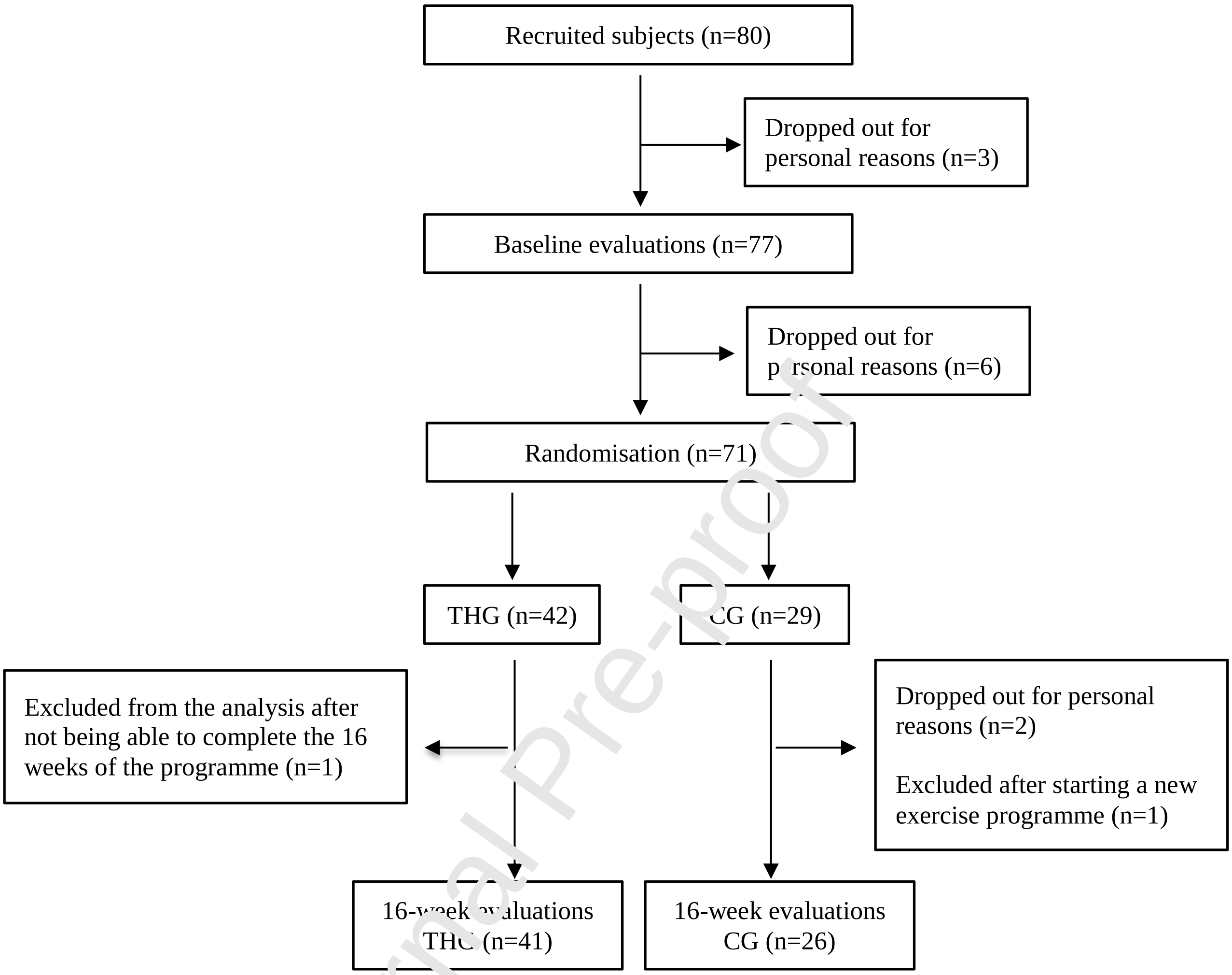
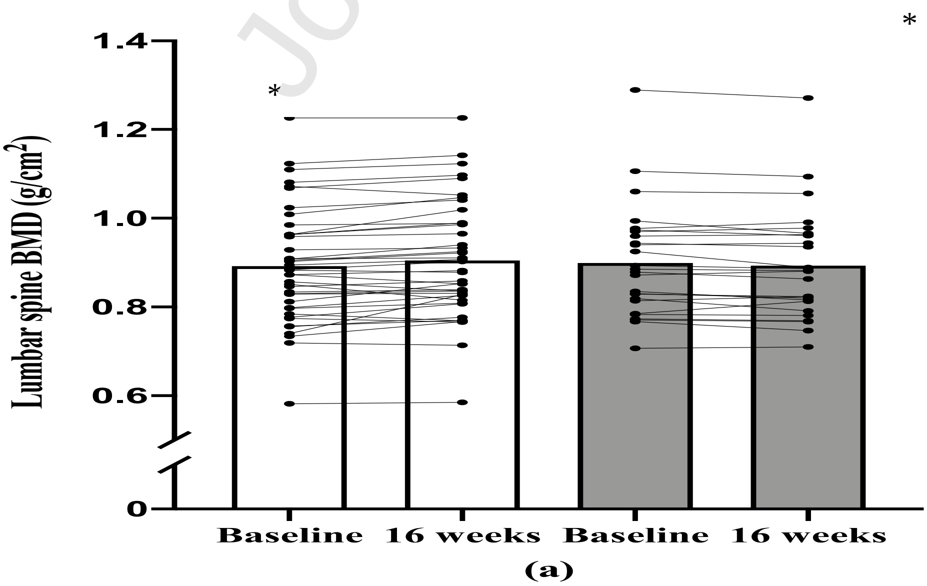


Fig. 1 Flow chart showing the number of participants enrolled, randomised and evaluated.



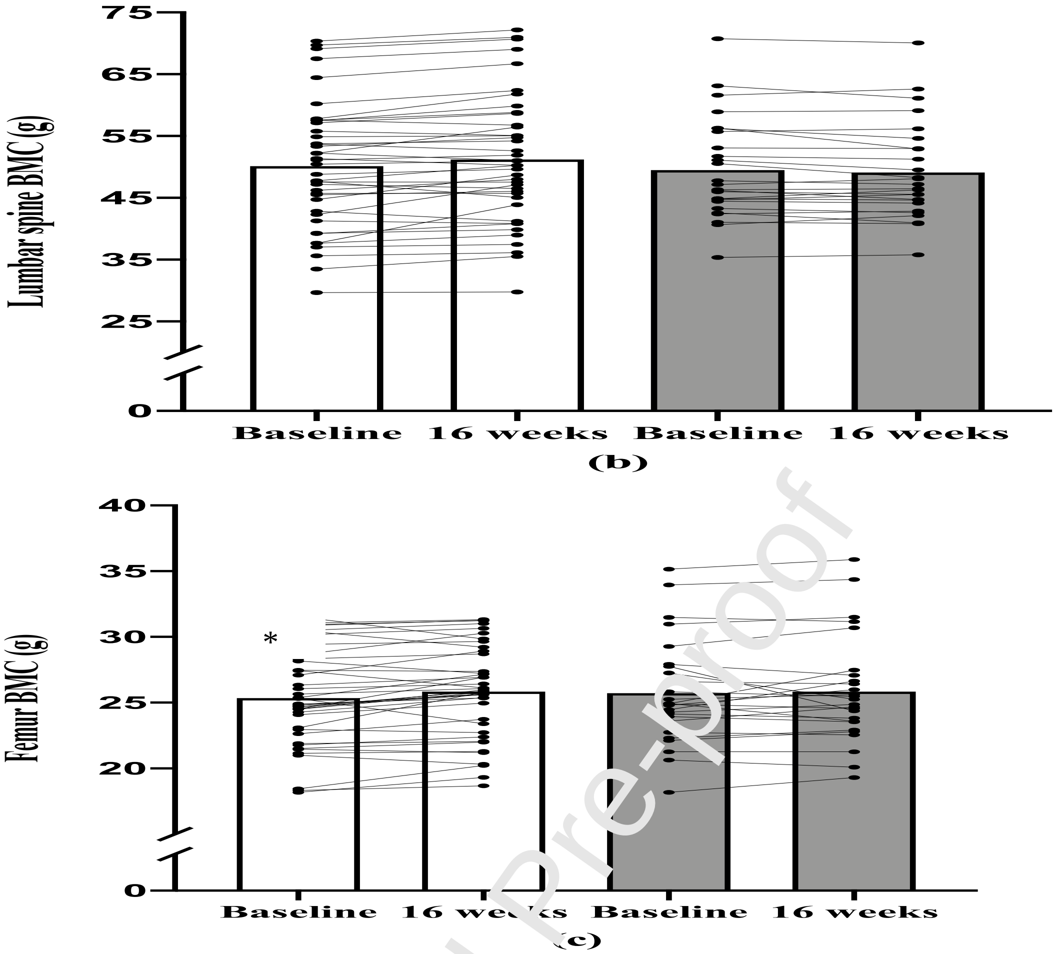


Fig. 2 Lumbar spine BMD (a), lumbar spine BMC (b) and femur BMC (c) at baseline and after 16 weeks of team handball training (THG, n=41: white bars) or a continuation of usual lifestyle (CG, n=26: grey bars). *Significantly different from baseline ($p \leq 0.005$).

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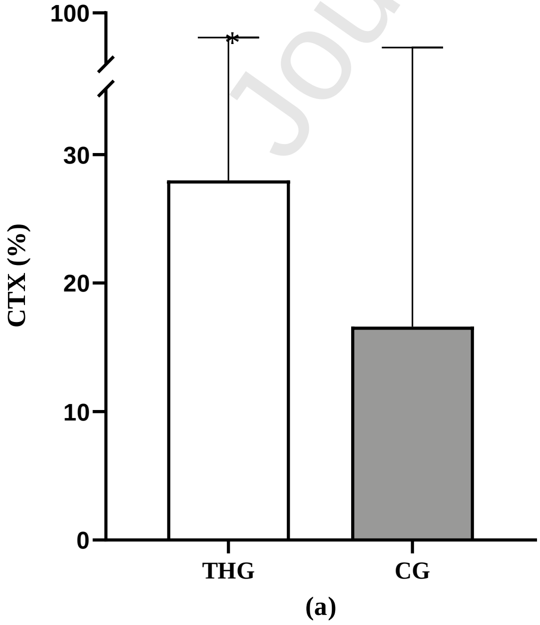
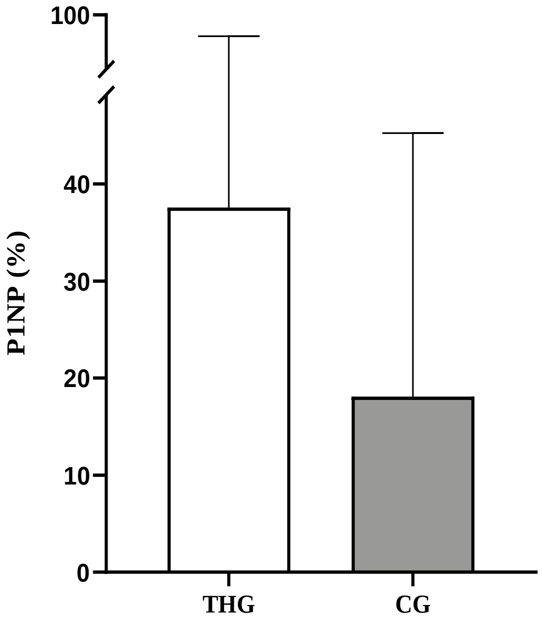
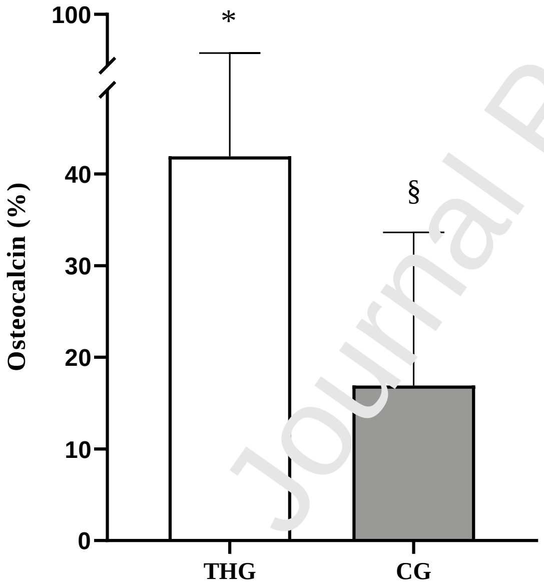




(b)



(c)

Fig. 3 CTX (a), P1NP (b) and osteocalcin (c), presented as delta values (%) between baseline and 16 weeks of team handball training (THG, n=41) or a continuation of usual lifestyle (CG, n=26). *Significant differences between baseline and 16 weeks ($p \leq 0.005$); #Significant difference between groups at 16 weeks ($p \leq 0.005$); §Significant differences in change score between groups ($p \leq 0.005$).

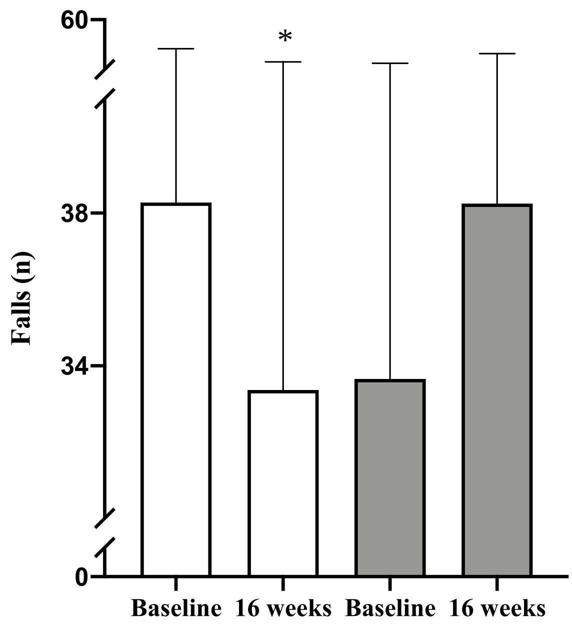


Fig. 4 Postural balance, evaluated as the number of falls in a flamingo balance test, at baseline and after 16 weeks of team handball training (THG, n=41: white bars) or a continuation of usual lifestyle (CG, n=26: grey bars). *Significantly different from baseline ($p \leq 0.005$).

Credit Author Statement

All authors read and approved the final version of the manuscript. RP conducted the training, testing, data collection and analysis, interpreted the study results and drafted the manuscript. JM and CC contributed to the study design, interpreted the study results and edited the manuscript. EC, RS and EWH interpreted the study results and edited the manuscript. NRJ carried out the analysis of the biochemical bone turnover markers and interpreted the study results. SP and PK conceived the study design, applied for the funding, interpreted the results and edited the manuscript.

Highlights

- Menopause predisposes women to augmented musculoskeletal degeneration
- Sarcopenia and osteoporosis potentiate the risk of falls and fractures
- Recreational team handball improves bone health and postural balance