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2 **A 12-month continuous and intermittent high-impact exercise intervention and its effects**
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4 **on bone mineral density in early postmenopausal women: a feasibility randomised**
5
6 **controlled trial**
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1 **ABSTRACT**
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4 **BACKGROUND:** Intermittent mechanical loading generates greater bone adaptations than
5 continuous mechanical loading in rodents but has never been evaluated in humans. This study
6 aimed to evaluate the feasibility of a continuous and intermittent countermovement jump
7 (CMJ) intervention for attenuating early postmenopausal BMD loss.
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10 **METHODS:** 41 healthy early postmenopausal women (age = 54.6 ± 3.4 years) were randomly
11 assigned to a continuous countermovement jumping group, an intermittent countermovement
12 jumping group or a control group for 12 months. Adherence and dropout rates were recorded
13 along with bone mineral density (BMD) at lumbar spine, femoral neck and trochanter sites at
14 baseline, 6 months and 12 months.
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24 **RESULTS:** 28 participants completed the study. Dropout rate during the intervention (from the
25 initiation of exercise) was 36% from continuous and 38% from intermittent countermovement
26 jumping groups. For the participants that completed the intervention, adherence was $60.0 \pm$
27 46.8% for continuous and $68.5 \pm 32.3\%$ for intermittent countermovement jumping. The
28 control group lost significant lumbar spine BMD (% difference = -2.7 [95%CI: -3.9 to -1.4])
29 and femoral neck BMD (% difference = -3.0% [95%CI: -5.1 to -0.8]). There was no statistically
30 significant change in BMD for either countermovement jumping group. There was no
31 statistically significant difference in BMD change between continuous or intermittent
32 countermovement jumping groups when compared with the control group.
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45 **CONCLUSIONS:** Adherence and dropout rates were in line with previous similar
46 interventions. To evaluate the effect of continuous and intermittent exercise on BMD, future
47 studies should focus on maintaining participant engagement and adherence to the exercise
48 intervention.
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1 Key words:
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4 Bone mineral density; Postmenopausal women; Exercise; Osteoporosis prevention
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7 TEXT

10 Introduction

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13 Postmenopausal women experience rapid declines in bone mineral density (BMD) in the early
14 years post-menopause which can increase the risk of developing osteoporosis and subsequent
15 fractures (1,2). In the EU, 46% of women over the age of 50 will experience an osteoporotic
16 fracture (3), with fracture treatments costing EU countries €37 billion each year (4).
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22 High-impact exercise can reduce postmenopausal bone loss, has been demonstrated to be safe
23 and can provide a cost-effective addition to pharmacological therapies (5). These exercise
24 regimes are often comprised of high-strain magnitudes along with high levels of muscular force
25 (6,7). In adult and aged animal models, the stimulus frequency is an important determining
26 factor for mechanoadaptation with intermittent mechanical loading generating greater bone
27 formation than continuous mechanical loading (8–10). The greater bone response may be due
28 to the longer rest interval during the intermittent stimulus frequency creating a “resensitisation”
29 effect on the mechanosensitivity of the bone (11). In support of this, repetitive continuous
30 stimulus frequency loading has shown to desensitise bone tissue, as the anabolic response to
31 bone loading becomes saturated after only 40 loading cycles (12). This highlights that there are
32 potential benefits of performing very short durations of high-impact exercise with relatively
33 few loading cycles at intermittent stimulus frequencies to stimulate bone adaptations (13).
34 However, the comparative effects of long-term mechanical loading at continuous and
35 intermittent stimulus frequencies, while controlling for loading variables (peak and gradient of
36 loading); have not been evaluated in human populations.
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1 For human populations, mechanical loading is generated through high-impact exercises which
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3 can be challenging for postmenopausal women despite the known benefits of high-impact
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5 exercise on bone health (14). It is common to find adherence rates ranging from 52 to 100 %
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7 in exercise interventions with osteopenic and osteoporotic populations, for which the most
8
9 commonly reported barriers to participating in exercise activity are lack of time and lack of
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11 transportation (15–17). For exercise interventions targeting bone health in adult populations,
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13 the average dropout rate is 21% [95% confidence intervals (CI): 17 to 26%] with 24% [95%
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15 CI: 20 to 28%] of the remaining participants not fully complying with the intervention (18,19).
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17 Furthermore, the longer the duration of the exercise intervention (from six months to two
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19 years), the higher the dropout rate and the higher the proportion of non-compliance within the
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21 intervention groups (18). There appears to be no meaningful difference in dropout rates or
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23 compliance rates when the exercise is supervised or unsupervised or when the exercise is
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25 completed in the home or at a designated facility (18). This presents a problem for the
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27 promotion of exercise interventions in order to benefit bone health and highlights the need for
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29 time-efficient and easily accessible exercise programmes aimed at improving or maintaining
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31 bone health in these adult populations. In light of the previous adherence issues highlighted
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33 with exercise interventions, the current study was designed so that exercise was; short in
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35 duration to reduce the time commitment, easily accessible to prevent transport issues, sufficient
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37 in duration to show changes in BMD but not excessively so and could be unsupervised if
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39 necessary.
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45 Therefore, the aim of this study was to evaluate the feasibility of a 12-month home-based, self-
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47 administered, short duration, countermovement jump (CMJ) intervention performed at either
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49 continuous or intermittent stimulus frequencies for attenuating early postmenopausal BMD
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51 loss. The secondary aim was to evaluate the effect of a countermovement jump (CMJ)
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53 intervention performed at either continuous or intermittent stimulus frequencies on bone
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1 mineral density in early postmenopausal women.
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7 **Materials and Methods**

8 *Study design and participants*

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13 This feasibility study was a randomised controlled trial with two intervention and one control
14 group. Participants performed either continuous CMJ (CTS), intermittent CMJ (INT) or a non-
15 exercising control group (CON). The protocol was approved by Hull and East Yorkshire
16 Hospitals NHS Trust ethics committee (HEY R&D Ref: R1723; REC Ref: 14/SW/1074;
17 Chairperson: Dr Rhona Bratt; Approval given 16/10/14). Written informed consent was
18 obtained on study enrolment. All procedures performed in studies involving human participants
19 were in accordance with the ethical standards of the University of Hull, Hull and East Yorkshire
20 Hospitals NHS Trust ethics committee and with the 1964 Helsinki declaration and its later
21 amendments or comparable ethical standards.
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34 The study was publicised by local media between September 2014 – September 2015. Study
35 participants were healthy early postmenopausal (1 – 5 years) women 48 to 59 years of age,
36 white European origin and free from osteoporosis. Inclusion and exclusion criteria are detailed
37 in the supplementary material.
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43 Bone adaptations were based on a Cohen's d effect size of $d = 0.41$ using the mean group
44 difference in lumbar spine BMD and three groups, with pre, mid and post intervention testing
45 (20).
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50 Feasibility of the two interventions were assessed against an adherence of 76% [95% CI: 72 to
51 80%] and a dropout rate of 21% [95% CI: 17 to 26%] in accordance with previous exercise
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1 interventions targeting bone mineral density (18).
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4 *Study procedures*
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7 Dual-energy x-ray absorptiometry (DXA) scans were performed at the lumbar spine (L1 – L4)
8 and right proximal femur by the same technician at Hull Royal Infirmary on a GE Lunar
9 Prodigy DXA scanner (GE Healthcare, Madison, WI, USA), whilst blinded to group allocation.
10 Participants received DXA scans at baseline, 6 months and 12 months during the investigation
11 to calculate BMD. DXA precision error was 0.9% and 1.4% for the lumbar spine and femoral
12 neck respectively (root mean square % coefficient of variation) (21). The least significant
13 change for lumbar spine and femoral neck BMD was 2.5% and 3.9% respectively (22).
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23 Blood was sampled at baseline using venepuncture and analysed for serum 25-hydroxy vitamin
24 D (25(OH)D), calcium and phosphate concentrations. Batch analysis occurred in the blood
25 sciences laboratory at Hull Royal Infirmary. (25(OH)D) was measured using a Waters Quattro
26 Premier XE mass spectrometer and Acuity UPLC System (Elstree, UK). The laboratory
27 participates in external quality control (EQA) schemes with DEQAS and NEQAS on to ensure
28 accuracy. Serum calcium ($\text{mmol}\cdot\text{L}^{-1}$) and inorganic phosphorus ($\text{mmol}\cdot\text{L}^{-1}$), were measured by
29 standard photometric AU and UV methods using Beckman Coulter analysers (Beckman
30 Coulter, CA, USA). The laboratory and tests are accredited under UKAS ISO 15189 for clinical
31 diagnostics.
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43 *Exercise intervention*
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46 Following adaptive randomisation, CTS and INT groups completed identical exercise
47 programmes in their own homes for 12 months, which only differed in the rest interval duration
48 between jumps (stimulus frequency). Countermovement jumping (CMJ) has shown to remain
49 consistent and similar in key mechanical loading parameters (peak acceleration and
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1 acceleration gradient) when performed at continuous or intermittent stimulus frequencies (23).
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3 Both groups performed 30 CMJ on three separate occasions per week that were at least 48
4 hours apart to reduce the desensitisation effect (12). Participants were told to complete the
5 exercises barefoot on a hard surface and to “jump as high as possible using the arms and land
6 on the balls of the feet with bent knees” to reduce the risk of injury. Participants were
7 familiarised with the CMJ technique prior to the start of the intervention, each participant’s
8 technique was checked to ensure safe jumping technique was practiced. CTS participants
9 performed 30 CMJs at a stimulus frequency of 15 jumps per minute (totalling two minutes of
10 exercise), INT participants performed 30 CMJs at a stimulus frequency of 4 jumps per minute
11 (totalling seven minutes and thirty seconds of exercise). Rest intervals were counted using a
12 metronome. Intervention participants kept monthly exercise logs and were regularly contacted
13 via email or telephone every 3 to 4 weeks to assess adherence. Control participants were
14 instructed to maintain their habitual physical activity during the trial.
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30 *Statistical analysis*

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33 Participants were adaptively randomised by the lead researcher (after DXA and blood
34 measures) to groups using their baseline femoral neck T-score and (25(OH)D) to standardise
35 the group baseline femoral neck and (25(OH)D) values to control for bias arising from
36 regression to the mean (24). The primary outcome measure was BMD (g/cm^2).
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42 Data were deemed to be normally distributed following visual interpretation of Q-Q plots, and
43 histograms and via the Shapiro-Wilk tests. Log transformations were applied to satisfy
44 assumptions of normality and reduce non-uniformity of error. Absolute changes in BMD pre
45 and post intervention are presented as mean difference (g/cm^2) and 95%CI. The mean between-
46 group differences were divided by the pooled between-subject SD (following adjustment for
47 small sample bias) of the baseline data, to quantify the magnitude of the standardised effect
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1 size (Cohens d). Cohen's d effect size was reported and evaluated using the following scale: 0-
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3 0.19 trivial, 0.2-0.59 small, 0.6-1.19 moderate, 1.2-1.99 large (25). Uncertainty in the
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5 population estimates are expressed as 95% CI.
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8 Using R (R Foundation for Statistical Computing 3.2.1, Vienna, Austria), between-group
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10 baseline variables were analysed with Welch's t-tests due to unequal group variances. A two-
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12 way (3 group x 3 time points) repeated measures ANOVA with a type 3 correction for unequal
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14 sample sizes was used to examine the effect of the intervention for group (CTS, INT and CON),
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16 time (pre, mid and post) and group \times time interaction. Post-hoc within-group pairwise
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18 comparisons were completed with paired t-tests adjusted for multiple comparisons using the
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20 Holm-Sidak method (26). Main effects for group (CTS, INT and CON) are presented, as are
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22 main effects for time (pre, mid and post) and group \times time interaction. Significance was set at
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24 $P < 0.05$. This study was not powered to detect differences in participant centred outcomes and
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26 therefore the results should be interpreted with caution.
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37 **Results**

38 *Feasibility and process outcomes*

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40 There were 49 participants were initially recruited of which 41 were randomly assigned to
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42 exercise and control groups. Of those, 28 completed the study and were included in the
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44 intention to treat analysis, following adherence checks, 17 participants were included in per-
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46 protocol analysis. During the intervention, four participants dropped out due to undisclosed
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48 prior conditions. One participant experienced a hip fracture due to an unrelated fall and was
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50 excluded from the analyses (Fig.1). The dropout rate during the intervention (from the
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52 initiation of exercise) was 36% from the CTS group, 38% from the INT group and 8% from
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1 the control group.
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4 Of the participants that completed the study (9 CTS group, 8 INT group), exercise adherence
5 was $60.0 \pm 46.8\%$ and $68.5 \pm 32.3\%$ respectively.
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10 << **Figure 1 Here** >>

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12 *Participant baseline characteristics*
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15 Participant baseline characteristics are presented in Table 1.
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22 There were no statistically significant changes in mass or body mass index during the
23 intervention across all groups.
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27 *Intention to treat analysis*
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30 *Lumbar spine bone mineral density (L1 – L4)*
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33 From baseline to final testing after 12 months, for lumbar spine BMD there was no statistically
34 significant main effect for group, time, or interaction term ($P = 0.672$; $P = 0.792$; $P = 0.922$).
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38 *Femoral neck bone mineral density*
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41 From baseline to final testing after 12 months, for femoral neck BMD there was no statistically
42 significant main effect for group, time, or interaction term ($P = 0.394$; $P = 0.840$; $P = 0.764$).
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47 *Trochanter bone mineral density*
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50 From baseline to final testing after 12 months, for trochanter BMD there was no statistically
51 significant main effect for group, time, or interaction term ($P = 0.320$; $P = 0.933$; $P = 0.983$),
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53 (Table 2).
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<< Table 2 Here >>

Per-protocol analysis

Lumbar spine bone mineral density (L1 – L4)

From baseline to final testing after 12 months, for lumbar spine BMD there was no statistically significant main effect for group ($P = 0.750$), but there was a statistically significant main effect for time, showing a reduction across groups ($P = 0.006$), the group-time interaction term was not statistically significant ($P = 0.307$), (Table 3).

Only the CON group experienced a statistically significant within-group loss in lumbar spine BMD over 12 months (Fig. 2). When compared to the least significant change, which was 2.5%, it was apparent that 20% of the CTS, 60% of the INT participants and 57% of the CON participants experienced clinically detectable reductions in lumbar spine BMD.

<< Figure 2 Here >>

Femoral neck bone mineral density

From baseline to final testing after 12 months, for femoral neck BMD there was no statistically significant main effect for group ($P = 0.307$), but there was a statistically significant main effect for time, showing a reduction across groups ($P < 0.001$), the group-time interaction term was not statistically significant ($P = 0.970$), (Table 3).

Only the CON group experienced a statistically significant within-group loss in femoral neck BMD over 12 months (Fig. 3). When compared to the least significant change, which was 3.9%, it was apparent that 20% of the CTS participants, 20% of the INT participants and 57% of the CON participants experienced clinically detectable reductions in femoral neck BMD.

<< Figure 3 Here >>

Trochanter bone mineral density

No statistically significant main effect on trochanter BMD was found for group, time or interaction ($P = 0.530$; $P = 0.091$; $P = 0.090$), (Table 3).

<< Table 3 Here >>

Discussion

Main Findings

Of the 17 intervention participants (9 CTS group, 8 INT group) that completed the study, adherence was $60.0 \pm 46.8\%$ and $68.5 \pm 32.3\%$ respectively, with four of those participants not returning exercise logs and therefore counting as 0%. The current adherence would be deemed as poor in comparison to previous exercise interventions targeting bone mineral density (76% [95% CI: 72 to 80%]), but within the expected range for unsupervised exercise interventions (82% [95% CI: 59 to 93%]) (17,18,27), and exercise adherence rates from patients with osteopenia or osteoporosis, albeit at the lower end of the observed adherence rates (52% to 100%) (15,16). For the 10 participants that completed the exercise protocol and were included in the final statistical analysis, adherence to sessions was good (5 CTS group, 5 INT group), ($98.2 \pm 5.9\%$ and $87.3 \pm 8.7\%$). However, the dropout rate of 36% from the CTS group and 38% from the INT group was much higher than previously reported for other bone health interventions (21% [95% CI: 17 to 26%]), but within the expected range for unsupervised exercise interventions (32% [95% CI: 19 to 48%]) (18,19). The adherence and dropout rates raises questions over the feasibility of a time-efficient, home-based CMJ programme for early

1 postmenopausal women, which would require a much greater initial cohort to ensure a larger
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3 final number of participants. Some control participants (36%) undertook extra exercise training
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5 during the study, which consequently meant elimination from the per-protocol analysis, as can
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7 commonly occur with a randomised control trial design (28). Despite frequent checks, future
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9 programmes may benefit from individual or group training sessions with an instructor, where
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11 adherence can be objectively recorded and a group environment could potentially increase
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13 quality of life and bolster adherence (29). Other factors such as exercise variation may improve
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15 adherence to the intervention as participants may find the programme more interesting,
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17 although the addition of multiple exercises would incorporate confounding variables into the
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19 exercise stimulus and makes standardising the exercise stimulus more complicated.
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23 The findings showed that the CTS and INT groups showed no statistically significant change
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25 in lumbar spine and femoral neck BMD levels whereas the control group experienced a
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27 statistically significant loss in both lumbar spine BMD (% difference = -2.7 [95%CI: -3.9 to -
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29 1.4]) and femoral neck BMD (% difference = -3.0% [95%CI: -5.1 to -0.8]). When comparing
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31 the magnitude of change between groups findings were either trivial or confidence intervals
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33 spanned substantially negative and substantially positive effect sizes. Therefore, more data are
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35 required to clarify whether there are beneficial effects of CTS or INT exercise programmes on
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37 reducing early postmenopausal BMD loss. To the authors' knowledge, this is the first study to
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39 directly evaluate the effect of stimulus frequency on human bone. It is also the first study to
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41 compare continuous and intermittent CMJ interventions for attenuating early postmenopausal
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43 BMD loss. Interestingly, the percentage of CON participants experiencing clinically
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45 meaningful reductions in both lumbar spine and femoral neck BMD was almost three times
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47 higher than that of the CTS and INT groups. The CON group displayed a 2.4 times higher level
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49 of postmenopausal bone loss when compared to a 47 to 63 year old population (30), this may
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51 be due to participants being in closer proximity to the menopause where rates of bone loss are
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1 known to be higher (31). The present study showed comparable lumbar spine postmenopausal
2 BMD loss when compared to a similar population of early postmenopausal women (2). Our
3 study supports the rapid BMD loss in close proximity to the menopause.
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8 Current findings are supported by previous studies that also found no effect of
9 countermovement jumping programmes on postmenopausal BMD loss (35–37). The most
10 likely explanation for the current study is that the focus was on the feasibility of the intervention
11 and that the study was not powered to detect these potential changes in BMD. This could result
12 from also be affected by a decreased oestrogen bioavailability, which increases bone
13 demineralisation (38). However, a variety exercise programmes have found positive bone
14 adaptations despite participants being oestrogen depleted postmenopausal women (5,39–43).
15 Furthermore, with a known osteogenic exercise stimulus in premenopausal women, the
16 addition of oestrogen via hormone replacement therapy for postmenopausal women has not
17 had any effect on BMD, which could suggest the influence of factors other than oestrogen that
18 may contribute to a blunted BMD response (35).
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33 It is unclear if the exercise programmes had any beneficial effects on skeletal parameters in the
34 current population of early postmenopausal women. Therefore, the question of whether
35 intermittent stimulus frequency exercise could provide a greater osteogenic stimulus than
36 continuous stimulus frequency exercise for early postmenopausal women as has been
37 previously demonstrated in animals, remains unanswered and highlights the need for higher
38 powered future intervention studies (8).
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47 *Strengths and Limitations*

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49 The programme was designed to be; easy to complete, accessible to all and minimise time
50 commitment. Judging by the high dropout rate, this programme was not easy to adhere to
51 however. Successful interventions with the current population have involved either resistance
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1 exercise or mixed loading protocols and could indicate that adherence is improved with an
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3 increased exercise variety (5,41,43). Anecdotally participants, particularly in the INT group,
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5 sometimes expressed boredom during the longer rest intervals, which could have affected
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7 dropout rate.
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10 It was not possible to determine the effect of CTS or INT exercise on early postmenopausal
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12 BMD loss, any future study in this area would require a greater number of participants in order
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14 to evaluate this concept more thoroughly. DXA scans are limited in determining geometric
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16 bone adaptations. It is possible that bone adaptation had occurred but was undetectable with
17
18 DXA scans. DXA and the addition of MRI or CT scans have been advocated for combined use
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20 in determining bone strength parameters and geometrical bone shape (44–46).
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24 It was difficult to determine the intensity of the home-based programme when participants were
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26 unsupervised. It is possible that exercise intensity could have been reduced and therefore may
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28 have reduced the bone stimulus (i.e. submaximal CMJ).
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32 Many participants were (25(OH)D) deficient at baseline. Seasonal fluctuations in (25(OH)D)
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34 status could have further reduced bioavailability, which could have blunted the osteogenic
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36 potential of the exercise programmes through reductions in calcium absorption and bone
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38 mineral accrual (47). The average T-score of the femoral neck for an age-matched population
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40 to the current study is -1.0 (48). Participants for the current study had higher T-scores at
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42 baseline of -0.4 ± 0.6 , -0.7 ± 0.7 and -0.2 ± 0.4 for the CTS, INT and CON groups respectively.
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45 Participants with higher BMD potentially require greater mechanical stimulation to initiate an
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47 adaptive response. The current exercise volume was relatively low at 30 CMJ, performed three
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49 times per week. Despite more than 36 loading cycles having shown little extra benefit for bone
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51 adaptation in animal populations, human bone potentially requires a greater number of loading
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53 cycles (12,49). This necessitates further research to establish potential thresholds for human
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1 bone adaptation.
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7 **Conclusions**

10 This study demonstrates that the time-efficient and easily accessible home-based exercise
11 intervention was feasible for a small number of participants, although the adherence and
12 dropout rates suggested that this intervention was less effective than other similar interventions.
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14 The low participant number meant that it was not possible to determine if there was an effect
15 of the exercise interventions on BMD. CTS and INT groups maintained lumbar spine and
16 femoral neck BMD whereas the control group experienced a statistically significant loss in
17 both lumbar spine and femoral neck BMD. A definitive inference cannot be made from the
18 observed effects of CTS and INT CMJ on reducing early postmenopausal BMD loss, at the
19 lumbar spine and femoral neck, when compared to the control group. Future studies should
20 focus on maintaining participant engagement and adherence to the exercise intervention in the
21 evaluation of continuous and intermittent exercise on BMD.
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NOTES

Conflicts of interest

This project was funded by the charity OSPREY.

Authors' contribution statement

GM, GA, CD, WE, MA and MD conceived the research idea and constructed the research protocol; GM performed the data analyses and initial interpretations; GM, GA, CD and MD drafted the manuscript; all authors reviewed and provided intellectual feedback on subsequent drafts of the manuscript.

Acknowledgements

With thanks to Dr Sue Steel, Syd Howey, Professor Michael Fagan, Ann Goodby, staff at the Centre for Metabolic Bone Disease and Blood Sciences laboratory at Hull Royal Infirmary and Stephen Hayes for their technical assistance.

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TABLES

Table 1. - Descriptive participant parameters at baseline

	Mean ± SD		
	Continuous (n = 15)	Intermittent (n = 14)	Control (n = 12)
BMD			
Lumbar Spine BMD (g/cm ²)	1.133 ± 0.161	1.153 ± 0.174	1.137 ± 0.130
Femoral Neck BMD (g/cm ²)	0.947 ± 0.086	0.956 ± 0.120	0.960 ± 0.091
Trochanter BMD (g/cm ²)	0.793 ± 0.091	0.757 ± 0.120	0.786 ± 0.092
Blood			
25-hydroxy vitamin D (25(OH)D) (nmol·l ⁻¹)	53.2 ± 19.8	50.4 ± 17.5	54.8 ± 18.5
Calcium (mmol·l ⁻¹)	2.3 ± 0.1	2.4 ± 0.1	2.3 ± 0.1
Phosphate (mmol·l ⁻¹)	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1
Age (y)	56.0 ± 3.0	53.3 ± 3.2	54.3 ± 3.8
Height (m)	1.63 ± 0.07	1.65 ± 0.06	1.64 ± 0.05
Mass (kg)	67.2 ± 6.6	67.7 ± 13.6	68.1 ± 9.7
Body Mass Index (kg·m ⁻²)	25.4 ± 2.0	25.0 ± 4.7	25.2 ± 2.6
BMD, bone mineral density			

Feasibility of a 12-month continuous and intermittent high-impact exercise intervention

Table 2. – **Intention to treat analysis** - Descriptive statistics for bone mineral density (BMD) parameters pre, mid and post intervention

	Continuous (n =9)			Intermittent (n = 8)			Control (n = 11)		
	Mean ± SD								
	PRE	MID	POST	PRE	MID	POST	PRE	MID	POST
BMD									
Lumbar	1.144 ±	1.142 ±	1.123 ±	1.097 ±	1.089 ±	1.078 ±	1.127 ±	1.141 ±	1.107 ±
Spine L1- L4 (g/cm ²)	0.182	0.182	0.187	0.148	0.146	0.170	0.130	0.128	0.126
Femoral	0.931 ±	0.929 ±	0.923 ±	0.892 ±	0.879 ±	0.871 ±	0.955 ±	0.935 ±	0.938 ±
Neck (g/cm ²)	0.097	0.104	0.107	0.112	0.107	0.109	0.093	0.065	0.095
Trochanter	0.806 ±	0.808 ±	0.788 ±	0.716 ±	0.728 ±	0.728 ±	0.780 ±	0.779 ±	0.771 ±
(g/cm ²)	0.111	0.097	0.106	0.134	0.111	0.122	0.094	0.097	0.087
BMD, bone mineral density									

Feasibility of a 12-month continuous and intermittent high-impact exercise intervention

Table 3. – **Per-protocol analysis** - Descriptive statistics for bone mineral density (BMD) parameters pre, mid and post intervention

	Continuous (n =5)			Intermittent (n = 5)			Control (n = 7)			Cohen's <i>d</i> [95% confidence intervals] PRE – POST		
	PRE	MID	POST	PRE	MID	POST	PRE	MID	POST	Continuous - Control	Intermittent - Control	Continuous - Intermittent
BMD												
Lumbar	1.105 ±	1.112 ±	1.105 ±	1.061 ±	1.044 ±	1.028 ±	1.117 ±	1.112 ±	1.088 ±	<i>d</i> = 0.16 [-0.04 to	<i>d</i> = -0.05 [-0.47 to	<i>d</i> = 0.19 [-0.13 to 0.51]; <i>P</i>
Spine L1- L4 (g/cm ²)	0.168	0.165	0.179	0.095	0.090	0.115	0.116	0.125	0.118	0.37]; <i>P</i> = 0.085	0.37]; <i>P</i> = 0.766	= 0.189
Femoral	0.936 ±	0.922 ±	0.916 ±	0.889 ±	0.875 ±	0.867 ±	0.959 ±	0.944 ±	0.930 ±	<i>d</i> = 0.10 [-0.61 to	<i>d</i> = 0.06 [-0.21 to	<i>d</i> = 0.01 [-0.46 to 0.47]; <i>P</i>
Neck (g/cm ²)	0.075	0.088	0.092	0.087	0.081	0.074	0.049	0.038	0.043	0.80]; <i>P</i> = 0.743	0.33]; <i>P</i> = 0.607	= 0.965
Trochanter	0.801 ±	0.820 ±	0.792 ±	0.722 ±	0.735 ±	0.743 ±	0.789 ±	0.791 ±	0.787 ±	<i>d</i> = -0.08 [-0.28 to	<i>d</i> = 0.18 [-0.10 to	<i>d</i> = -0.20 [-0.43 to 0.03];
(g/cm ²)	0.106	0.094	0.109	0.141	0.114	0.121	0.083	0.080	0.075	0.12]; <i>P</i> = 0.459	0.45]; <i>P</i> = 0.104	<i>P</i> = 0.072
BMD, bone mineral density												

TITLES OF FIGURES

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5 Figure. 1 - Participant inclusion flow diagram
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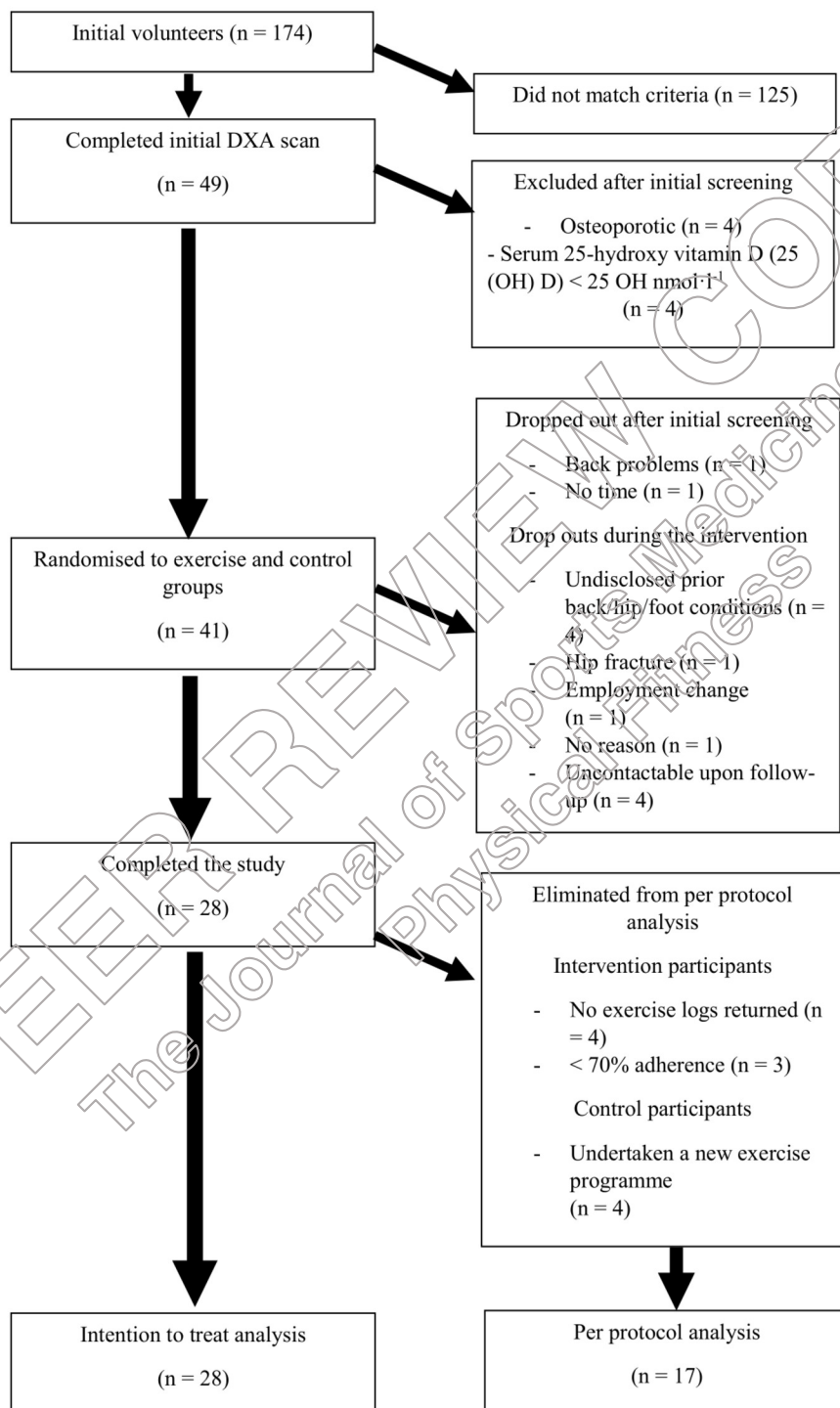
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8 Figure. 2 - Changes in lumbar spine (L1 – L4) bone mineral density (BMD) after 12 months.

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10 Data are mean differences \pm 95% CI; continuous group (CTS) n = 5, intermittent group (INT)
11 n = 5, control group (CON) n = 7
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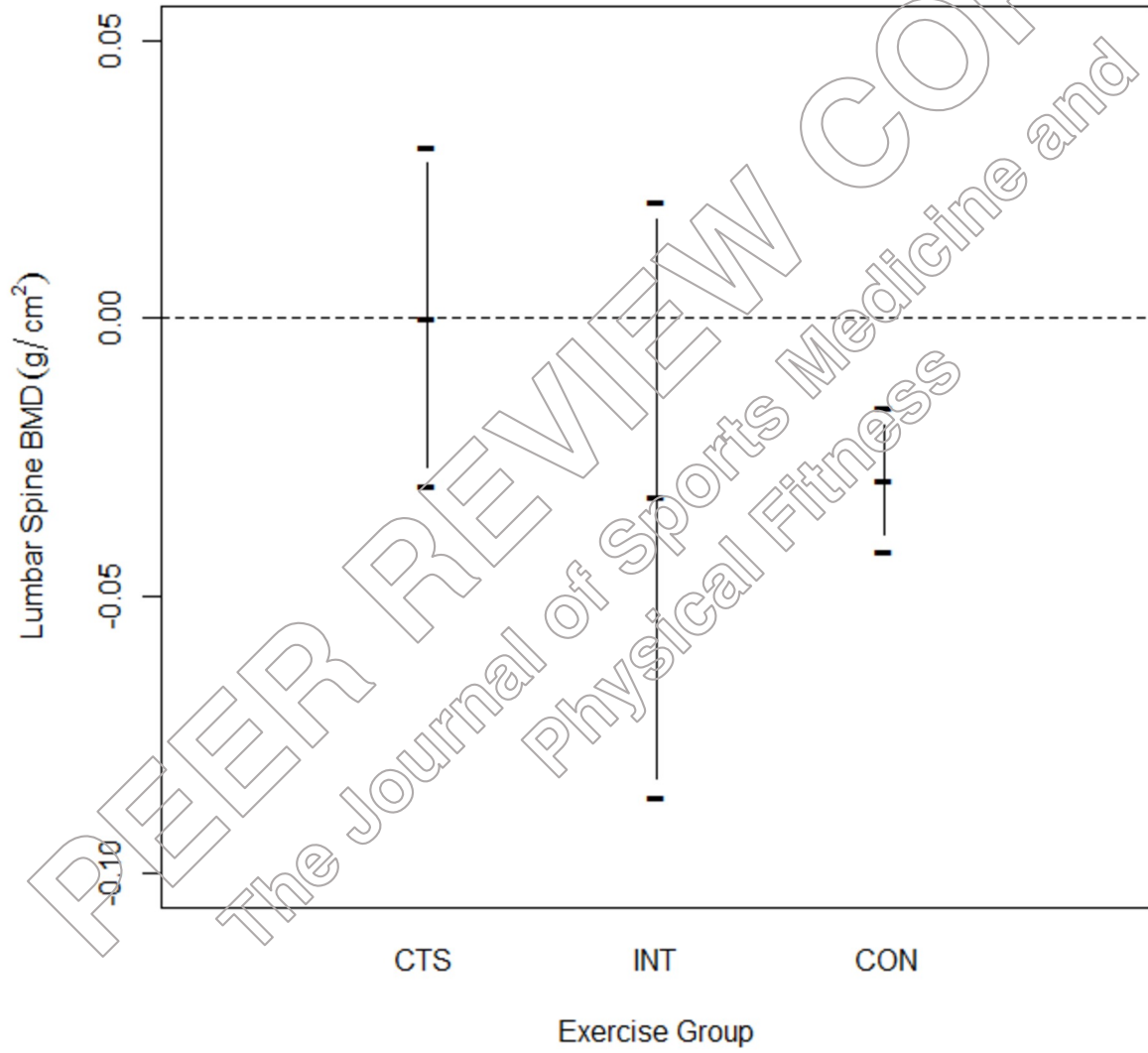
15 Figure. 3 - Changes in femoral neck bone mineral density (BMD) after 12 months. Data are

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17 mean differences \pm 95% CI; continuous group (CTS) n = 5, intermittent group (INT) n = 5,
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