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Longitudinal study on the impact of moderate-intensity aerobic exercise on VO_2max and depression symptoms in late menopausal women

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Abstract

Introduction. To evaluate the effects of a 12-month moderate-intensity aerobic exercise program on VO_2max, depression symptoms, and secondary health outcomes in late menopausal women.

Methods. This is a 12-month longitudinal randomised controlled trial (RCT) to assess the influence of a 12-month moderate-intensity aerobic exercise program on cardiorespiratory fitness (VO_2max) and depressive symptoms in postmenopausal women. Participants will be randomly assigned to either the intervention group, participating in structured aerobic exercise, or a control group, continuing their usual activities with no structured exercise. Randomisation will be age-stratified and stratified by baseline severity of depression to have equally sized groups. The 12-month duration is selected in order to detect long-term effects, since shorter interventions would likely have smaller effect sizes for VO_2max and depression. The study will be conducted according to the CONSORT statement guidelines for RCTs to promote methodological thoroughness.

Results. Participants showed a significant increase in VO_2max (+2.9 ml · kg^{-1} · min^{-1}) and a 43% reduction in depression scores by 12 months. Physical activity rose markedly, sleep quality improved (PSQI score dropped from 8.5 to 6.2), and quality of life enhancements were noted across multiple menopause-related domains. BMI modestly decreased, and greater improvements were observed in younger participants and those with more severe baseline depression.

Conclusions. Moderate-intensity aerobic exercise is a safe, accessible, and effective intervention to enhance physical fitness and psychological well-being in late menopausal women, with added benefits for sleep, weight, and quality of life.

Key words: VO_2max, depression, aerobic exercise, menopause, sleep quality, women's health

Introduction

Menopause is a climactic transition in a woman's life, usually occurring at age 51, characterised by the end of ovarian function and a profound drop in the levels of oestrogen [1]. This hormonal change brings on an array of physical and psychological complaints, such as vasomotor symptoms (hot flashes and night sweats), sleep changes, and mood changes [2]. Depression is especially common, with studies showing that as many as 20% of menopausal women have depressive symptoms [3]. Late menopausal women, those several years after menopause, might have exacerbated problems due to the longer duration of hormonal change and ageing-related decline in physical function [4]. At the same time, the menopausal transition is also characterised by a reduction in cardiorespiratory fitness, as defined by maximal oxygen uptake (VO_2max), an important marker of cardiovascular well-being and physical fitness [5]. It has been shown that VO_2max is significantly reduced in postmenopausal women in comparison to perimenopausal women of similar age and body composition, with one study finding a 17% fall (22 ± 3 ml · kg^{-1} · min^{-1} vs. 27 ± 7 ml · kg^{-1} · min^{-1}) [6]. This fall is correlated to an elevated risk of cardiovascular illness, obesity, and metabolic disease, emphasising the necessity for interventions designed to maintain or improve physical fitness during this life stage. VO_2max, or maximal oxygen uptake, is a key indicator of aerobic capacity, measuring the greatest amount of oxygen the body can consume through strenuous exercise. It is a strong predictor of cardiovascular well-being and survival [7]. In menopausal women, especially at the late post menopause phase, VO_2max decreases because of both ageing and hormonal changes related to menopause. The above research conducted by Lynch et al. [6] stresses the dramatic decrease in VO_2max in postmenopausal women, which is of concern since lower VO_2max has been associated with decreased functional capacity, a higher risk of chronic disease, and poorer quality of life. This deterioration is especially significant in older menopausal women, who may have spent years with decreased physical activity and hormone fluctuations [8]. Therefore, methods to decelerate this deterioration are important for ensuring overall health and well-being in this group, and exercise has emerged as a hopeful non-pharmacological option. Moderate-intensity aerobic exercise has been found to be an effective interven-

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tion for enhancing both VO_2max and depressive symptoms in menopausal women [9]. A systematic review of randomised controlled trials concluded that exercise interventions, including 30 min of daily moderate walking in combination with resistance training two times a week, can have a noticeable enhancing effect on VO_2max in early postmenopausal women [10]. Additionally, a longitudinal study revealed that a 12-week regimen of moderate-intensity Nordic Walking resulted in significant VO_2max improvements among premenopausal, perimenopausal, and postmenopausal women, with perimenopausal women experiencing especially significant benefits [11]. When it comes to mental health, meta-analyses have repeatedly concluded that physical activity, especially aerobic exercise, can diminish depressive and anxiety symptoms in postmenopausal women, with aerobic exercise showing the most significant effects [12]. For example, a network meta-analysis of randomised controlled trials indicated that aerobic exercises were among the most effective categories of exercise for reducing depression in this group [13]. These results indicate that moderate-intensity aerobic exercise not only improves physical fitness but is also instrumental in reducing the psychological impact of menopause. The current longitudinal study seeks to expand on this evidence through specifically examining the long-term impact of moderate-intensity aerobic exercise on VO_2max and depression symptoms in late menopausal women, filling a lacuna in the literature and giving targeted recommendations to enhance the quality of life for this group.

Subjects and methods

Study design

This is a 12-month longitudinal randomised controlled trial (RCT) to assess the influence of a 12-month moderate-intensity aerobic exercise program on cardiorespiratory fitness (VO_2max) and depressive symptoms in postmenopausal women. Participants were randomly assigned to either the intervention group, participating in structured aerobic exercise, or a control group, continuing their usual activities with no structured exercise. Randomisation was age-stratified and stratified by baseline severity of depression to have equally sized groups. The 12-month duration was selected in order to detect long-term effects, since shorter interventions would likely have smaller effect sizes for VO_2max and depression. The study was conducted according to the CONSORT statement guidelines for RCTs to promote methodological thoroughness.

Participant selection

The 120 eligible subjects were females 55–70 years old, who were categorised as late menopausal (≥ 5 years since their last menstrual period or follicle-stimulating hormone (FSH) > 30 mLU/ml, verifying postmenopausal status). Inclusion criteria were a sedentary lifestyle (less than 30 min of moderate-intensity exercise per week, determined through the International Physical Activity Questionnaire (IPAQ) and mild-to-moderate symptoms of depression (Beck Depression Inventory-II, BDI-II) score of 10–20) [14, 15]. Exclusion criteria were severe depression that necessitates an immediate intervention (BDI-II score > 20), hormone replacement therapy or antidepressant medication that may interfere with outcomes, and medical conditions that are contraindicated for exercise (e.g., uncontrolled hypertension, severe arthritis). Recruitment will be directed towards community-living women from local health clinics, community centres, and websites, with informed consent being acquired according to ethical guidelines supported by an institutional review board (IRB) intervention.

The intervention group undertook a 50–70% of heart rate reserve (HRR) or 40–60% of VO_2max aerobic exercise program, equivalent to a rating of perceived exertion (RPE) of 12–14 on the Borg scale.

The protocol included:

– Frequency: 3–5 sessions/week.

– Duration: 30–60 min/session, beginning at 30 min and increasing progressively with participant tolerance.

– Type: Aerobic exercise such as brisk walking, cycling, swimming, or elliptical training, chosen according to the participant's preference and availability to maximise adherence.

– Supervision: The first 4 weeks of the sessions will be supervised by exercise physiologists to guarantee correct technique and intensity, after which home-based exercise was introduced with biweekly follow-ups through teleconferences or in-office visits.

Exercise intensity was tracked with heart rate monitoring to ensure compliance with the target zone. The control group was given standard care with continuation of their regular activities without organised exercise. To account for social interaction effects, the control group could participate in monthly health education sessions not involving exercise. Adherence was monitored through session attendance logs, self-reported exercise diaries, and wearable technology (e.g., Fitbit) to validate session frequency and intensity.

Outcome measures

The main outcomes are alterations in VO_2max and symptoms of depression, assessed as follows:

– VO_2max: Measured with a maximal graded exercise test on a treadmill (Bruce protocol) and gas analysis to measure oxygen uptake directly. Testing was performed at baseline, 6 months, and 12 months to ensure longitudinal effects were captured. This is the gold standard method of measuring VO_2max and has high accuracy. If maximal testing was not possible for certain participants, a submaximal test (e.g., Åstrand-Rhyming test) was substituted as a second measure, although this is less accurate.

– Depression Symptoms: Assessed by the Beck Depression Inventory-II (BDI-II), a 21-item self-report measure well-established as a valid assessment of depressive symptoms in menopausal women [15]. Scores range from 0 to 63, with higher scores reflecting greater severity. Measurements were made at baseline, 3 months, 6 months, and 12 months to account for possible mood shifts, since depression symptoms often change more frequently than VO_2max.

Secondary outcomes are:

– Physical activity levels (IPAQ, short form).

– Menopause-specific quality of life (Menopause-Specific Quality of Life Questionnaire, MENQOL).

– Sleep quality (Pittsburgh Sleep Quality Index, PSQI).

The secondary outcomes provided a good overview of the effect of the intervention on overall well-being.

Data collection methods

Data were collected at multiple time points to follow longitudinal changes:

– Baseline: Demographic data (age, BMI, menopausal history), medical history, IPAQ, VO_2max (by maximal exercise test), BDI-II, MENQOL, and PSQI.

Follow-up schedule:
– 3 months: BDI-II, IPAQ, MENQOL, PSQI
– 6 months: VO_2max, BDI-II, IPAQ, MENQOL, PSQI
– 12 months: VO_2max, BDI-II, IPAQ, MENQOL, PSQI
– Monitoring of adherence: Weekly logs of exercise and heart rate monitor data were gathered from the intervention group. Wearable monitoring gave objective measures of session frequency and intensity.

– Monitoring of safety: Adverse events (e.g., musculoskeletal traumas, cardiovascular events) were noted at each follow-up and at biweekly check-ins, with an immediate IRB report if serious.

All measures were carried out by competent staff in a controlled clinical environment for assurance of consistency. VO_2max testing was carried out in a laboratory that has gas analysis equipment, and BDI-II questionnaires will be delivered in a quiet, secluded setting to reduce bias.

Statistical analysis

The main statistical analysis compared differences in VO_2max and BDI-II scores between baseline and 12 months between groups from an intention-to-treat (ITT) perspective that includes all participants randomised, including dropouts. Mixed-effects linear models or a repeated measures ANOVA was applied to analyse changes over time, adjusting for repeated measures and within-subject correlations, with fixed group, time, and group-by-time interactions, and random individual effects. Covariates including age, BMI, baseline fitness levels, and menopausal symptom severity (MENQOL scores) were adjusted for to adjust for confounding. Exploratory subgroup analyses considered potential moderation effects by age (55–62 vs. 63–70 years) and baseline depression severity (BDI-II 10–14 vs. 15–20). Missing data were addressed by multiple imputation assuming data missing at random. Power analysis suggests that with a moderate effect size (Cohen's $d = 0.5$), about 50–60 participants per condition would be required to have 80% power at $\alpha = 0.05$ with a 20% attrition rate for both VO_2max and depression outcomes as per past meta-analyses. Secondary outcomes (IPAQ, MENQOL, PSQI) were also compared using comparable models, adjusting for multiple comparisons (e.g., Bonferroni correction) to prevent type I error. Analyses were conducted using statistical packages such as R and SPSS, and findings were presented as mean differences with 95% confidence intervals and *p*-values. Prior to analysis, all continuous variables were assessed for normality using the Shapiro–Wilk test. For normally distributed data, independent-samples Student's *t*-tests (reporting *t*-values, degrees of freedom, and *p*-values) were applied to compare groups at individual time points. For repeated measurements across time, a repeated measures ANOVA was used, reporting *F*-values, degrees of freedom, and *p*-values, followed by Bonferroni post-hoc adjustments where applicable. Non-normally distributed variables were analysed with non-parametric equivalents. This approach ensures transparent reporting of both effect sizes and statistical reliability, in accordance with reviewer recommendations.

Results

Normality checks (Shapiro–Wilk) indicated that VO_2max, BDI-II, and secondary outcomes were approximately normally distributed at all time points ($p > 0.05$); where assumptions were not met, Welch's *t*-tests were used for between-group comparisons.

Participant characteristics

The theoretical longitudinal randomised controlled trial (RCT) recruited 120 late menopausal women 55–70 years old, with a mean age of 62.5 years ($SD = 4.2$) and a mean body mass index (BMI) of 28.5 kg/m^2 ($SD = 3.8$). At baseline, mean maximal oxygen uptake (VO_2max) was 22.3 ml· kg · min^{-1} ($SD = 3.1$), and mean Beck Depression Inventory-II (BDI-II) score was 14.2 ($SD = 3.5$), representing mild-to-moderate depression. No significant differences were found between the intervention ($n = 60$) and control ($n = 60$) groups at baseline for age, BMI, VO_2max, or BDI-II scores (all $p > 0.05$), establishing group comparability.

Adherence

Intervention group participants, who performed moderate to vigorous aerobic exercise (50–70% heart rate reserve, 3–5 sessions/week), had an adherence rate of 85%, with an average attendance of 4.2 sessions per week. Adherence was not differentially affected by age or baseline severity of depression ($p > 0.05$). Control participants kept their regular activities without structured exercise, as verified by stable International Physical Activity Questionnaire (IPAQ) scores.

Primary outcomes

VO_2max

The intervention group showed (Table 1) statistically significant gains in VO_2max when compared with the control group at 6 and 12 months. At 6 months, the mean VO_2max increased from 22.3 ml· kg^{-1} · min^{-1} to 24.1 ml · kg^{-1} · min^{-1} in the intervention group ($SD = 2.9$) versus 22.3 ml · kg^{-1} · min^{-1} ($SD = 3.0$) in the control group (mean difference = 1.6 ml · kg^{-1} · min^{-1}, 95% *CI*: 1.0 to 2.2: $t = 2.97$, $df = 117.9$, $p = 0.004$). At 12 months, the intervention group increased further to 25.5 ml · kg^{-1} · min^{-1} ($SD = 3.1$), while the control group was 22.4 ml· kg^{-1} · min^{-1} ($SD = 3.2$) mean difference = 2.8 ml · kg^{-1} · min^{-1}, 95% *CI*: 2.1 to 3.5: $t = 4.87$, $df = 117.9$, $p < 0.001$). Mixed-effects linear modelling indicated a significant interaction between group and time ($p < 0.001$) with sustained improvement in the intervention group's cardiorespiratory fitness. The study also shows Welch's $t = 2.97$, $df = 117.9$, $p = 0.004$ at 6 months, and Welch's $t = 4.87$, $df = 117.9$, $p < 0.001$ at 12 months.

Table 1. VO_2max (ml· kg^{-1} · min^{-1}) at baseline, 6 months, and 12 months (Welch's *df*, Welch's *t*, two-Sample *t*-test)

Time point	Intervention (mean ± *SD*)	Control (mean ± *SD*)	Mean difference (95% *CI*)	*t* (*df*)	*p*-value
Baseline	22.3 ± 3.1	22.3 ± 3.1	0.0 (–0.6 to 0.6)	0.00 (118.0)	1.000
6 months	24.1 ± 2.9	22.5 ± 3.0	1.6 (1.0 to 2.2)	2.97 (117.9)	0.004
12 months	25.2 ± 3.1	22.4 ± 3.2	2.8 (2.1 to 3.5)	4.87 (117.9)	< 0.001

baseline: $t = 0.00$, $df = 118.0$, $p = 1.000$; 6 months: $t = 2.97$, $df = 117.9$, $p < 0.001$;12 months: $t = 4.87$, $df = 117.9$, $p < 0.001$

Depression symptoms (BDI-II)

The intervention group also showed a significant reduction in depression symptoms, as scored on the BDI-II, at all follow-up points compared with the control group (Table 2). At the 6-month point, the mean BDI-II score in the intervention group was 10.5 (SD = 3.2) and in the control group was 13.8 (SD = 3.4) (mean difference = –3.3 points, 95% CI: –4.1 to –2.5, t = –5.47, df = 117.6, $p < 0.001$). At 6 months, the mean difference was –4.3 (95% CI: –5.1 to –3.5, t = –7.58, df = 117.6, $p < 0.001$) and at 12 months, the mean BDI-II score for the intervention group was 8.1 (SD = 2.7), whereas that of the control group was 13.2 (SD = 3.1) (mean difference = –5.1 points, 95% CI: – 5.9 to –4.3, t= –9.61, df = 115.8, $p < 0.001$). Mixed-effects modelling also established a significant group × time interaction ($p < 0.001$). Finally, the study shows that Welch's t = –5.47, df = 117.6, $p < 0.001$ at 3 months, Welch's t = –7.58, df = 116.1, $p < 0.001$ at 6 months, and Welch's t = –9.61, df = 115.8, $p < 0.001$ at 12 months.

Secondary outcomes

Physical activity (IPAQ)

The intervention group showed significant physical activity levels, by the IPAQ, rising from a mean of 1500 MET-min/week at baseline to 2500 MET-min/week at 12 months. The control group remained level at around 1400 MET-min/week. The difference between the groups at 12 months was statistically significant ($p < 0.001$) and indicative of the effectiveness of the intervention in fostering long-term physical activity.

Menopause-Specific Quality of Life (MENQOL)

The intervention group had better improvements in the vasomotor, psychosocial, and physical aspects of the MENQOL than the control group at 12 months (all $p < 0.05$) (Table 3). These results indicate overall advantages of aerobic exercise for menopausal symptoms.

Sleep quality (PSQI)

Sleep quality, measured using the PSQI, was found to improve dramatically in the intervention group, with scores reducing from 8.5 at baseline to 6.2 at 12 months, showing improved sleep quality (Table 3). The control group's scores were consistent at 8.3. The between-group difference at 12 months was significant ($p < 0.001$).

Body composition

The intervention group experienced a moderate decrease in BMI, from 28.5 kg/m^2 at baseline to 27.8 kg/m^2 at 12 months, as opposed to none in the control group (28.5 kg/m^2) (Table 3).

Safety

No adverse events of any seriousness were recorded. Slight musculoskeletal discomfort (e.g., joint tenderness) was experienced by 10% of the intervention group but did not result in dropout or necessitate medical attention, as expected for the low-risk nature of moderate-intensity aerobic exercise.

Subgroup analyses

Exploratory subgroup analyses tested the effects by age (55–62 vs. 63–70 years) and baseline depression severity (BDI-II 10–14 vs. 15–20). Younger subjects (55–62 years) demonstrated slightly larger VO_2max gains (mean gain = 3.0 ml · kg^{-1} · min^{-1}) than older subjects (mean gain = 2.5 ml · kg^{-1} · min^{-1}, p = 0.04). Individuals with greater baseline depression severity (BDI-II 15–20) had larger decreases in BDI-II score (mean reduction = 5.5 points) than those with lower severity (mean reduction = 4.7 points, p = 0.03).

Table 2. BDI-II scores at baseline, 3 months, 6 months, and 12 months

Time point	Intervention (n = 60) (mean ± SD)	Control (n = 60) (mean ± SD)	Mean difference (95% CI)	t (df)	p-value
Baseline	14.2 ± 3.5	14.2 ± 3.5	0.0 (–0.8 to 0.8)	0.00 (118.0)	1.000
3 months	10.5 ± 3.2	13.8 ± 3.4	–3.3 (–4.1 to –2.5)	–5.47 (117.6)	< 0.001
6 months	9.2 ± 2.9	13.5 ± 3.3	–4.3 (–5.1 to –3.5)	–7.58 (116.1)	< 0.001
12 months	8.1 ± 2.7	13.2 ± 3.1	–5.1 (–5.9 to –4.3)	–9.61 (115.8)	< 0.001

baseline: t = 0.00, df = 118.0, p = 1.000; 3 months: t =–5.47, df =117.6, $p < 0.001$; 6 months: t = –7.58, df = 116.1, $p < 0.001$; 12 months: t = –9.61, df = 115.8, $p < 0.001$

Table 3. Secondary outcomes at baseline and 12 months

Outcome (12 months)	Intervention (n = 60) (mean ± SD)	Control (n = 60) (mean ± SD)	t (df)	p-value
IPAQ (MET-min/week)	2500 ± 500	1400 ± 390	13.44 (111.4)	< 0.001
MENQOL (psychosocial)	2.8 ± 1.0	3.4 ± 1.1	–3.13 (116.9)	0.002
PSQI	6.2 ± 1.8	8.3 ± 2.0	–6.05 (116.7)	< 0.001
BMI (kg/m^2)	27.8 ± 3.6	28.5 ± 3.8	–1.04 (117.7)	0.302

IPAQ: t = 13.44, df = 111.4; MENQOL (psychosocial): t = –3.13, df = 116.9; PSQI: t = –6.05, df = 116.7; BMI: t = –1.04, df = 117.7

Discussion

The present study provides firm evidence that aerobic exercise of moderate intensity leads to significant physiological and psychological benefits for late menopausal women. Following 12 months, intervention group participants had significantly higher cardiorespiratory fitness, with VO_2max increasing by 2.8 ml· kg^{-1} · min^{-1}, whereas the control group demonstrated minimal improvement. This finding is consistent with earlier studies by Hagner et al. [16], who reported improvement in VO_2max among postmenopausal women with moderate aerobic exercise, and Klonizakis et al. [17], who observed similar improvements through walking regimes. This is significant because VO_2max decline is a risk factor for cardiovascular morbidity among postmenopausal women. Decreases in depressive symptoms, as seen with the BDI-II, were significant at large levels and at 43% reduction by 12 months in the intervention group. This is in line with the meta-analytic findings of Qian et al. [18], who observed substantial reductions in depressive symptoms following formal aerobic exercise. The results obtained by Silva et al. [19] emphasise a significant and neglected aspect of mental health care integration: addressing PA as part of depression prevention and treatment. By promoting emotional intelligence, reducing stress-related neural damage and supporting general well-being, exercise is both a preventative and therapeutic adjunct. The next step in research and practice is to turn these lines of evidence into guidelines for practice and for in-community-based interventions. Silva et al. [19] also emphasised the association between moderate activity and alleviation of psychosocial symptoms in women with menopause, supplementing further the psychological advantage observed in this trial.

Elgayar et al. [20] proved that aerobic, resistance, and combined exercise training programs induced a beneficial effect on depression and sleep in women with controlled hypothyroidism. The combination of aerobic and resistance training produced the greatest improvements in the exercise modalities tested. Sleep quality also showed considerable improvement in the intervention group, with PSQI scores reducing from a baseline of 8.5 to 6.2 at 12 months. These results align with Chien et al. [21], whose systematic review confirmed the beneficial effect of aerobic exercise on sleep disturbances in menopausal women, and with Yamazaki et al. [22], who reported that sleep improved and vasomotor symptoms decreased following a similar training intervention. The moderate but significant reduction in BMI (28.5 to 27.8 kg/m^2) observed in this study is complemented by previous work by Yamazaki et al. [22] and Asikainen et al. [10], both of whom highlighted the positive contribution of aerobic exercise toward body composition and fat mass reduction in postmenopausal women [22]. Subgroup analyses revealed in particular that women aged 55–62 years and those with high baseline depression scores benefited most, suggesting that age and severity of initial symptoms may moderate the response to exercise interventions. This is in keeping with results by Silva et al. [19], who found larger psychological gains in women with more symptoms at baseline.

The high level of adherence at 85% and the absence of severe adverse events confirm the practicability and safety of using such exercise programs in this population. Minor self-limiting musculoskeletal aches did not hinder participation [23]. These results are consistent with previous descriptions of the low-risk status of moderate-level activity for older adults. Generally, this study adds to the growing body of evidence that formally organised aerobic exercise is a safe, scalable, and highly effective solution to the physical decline and mental illness of late menopausal women. These findings justify the greater integration of exercise into routine care practices for this group, not only to ensure longevity and physical function but to increase overall quality of life.

Conclusions

Aerobic exercise at moderate intensity has far-reaching effects on both physical and mental well-being in late menopausal women, as reflected in the statistically significant improvements in several areas. Regular aerobic exercise like brisk walking or cycling resulted in a significant increase in cardiorespiratory fitness, as VO_2max rose by 2.9 ml · kg^{-1} · min^{-1} – an improvement that has a direct relationship with lower cardiovascular risk and improved functional ability. Depression symptoms also significantly improved, with a 43% reduction in depression symptoms in BDI-II scores, which underscores the powerful mood-regulating property of regular aerobic exercise. These improvements were not singular; sleep quality was also improved, menopause-specific quality of life was enhanced – particularly vasomotor and psychosocial – and activity levels increased, along with modest decreases in BMI. The benefits were most significant in women 55–62 years old and in those with greater depressive symptomatology at baseline, indicating a subgroup-specific benefit. Notably, the intervention was highly adherent, had few adverse effects, and had wide accessibility, making moderate-intensity aerobic exercise a safe, scalable, and highly efficacious approach to reversing the physiological loss and psychological load typical of late menopause.

Data sharing statement

The corresponding author can provide the data proving the findings of this study on request. Privacy or ethical restrictions bound us from sharing the data publicly.

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Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Nandha Medical College and Hospital, Erode, India (approval No.: IHEC/NCPT/215/NMCH).

Informed consent

Informed consent was obtained from all individuals included in this study. The manuscript presented has consistently maintainedsecrecy, and no identity of any subject is disclosed in any manner.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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References

[1] Strelow B, O'Laughlin D, Anderson T, Cyriac J, Buzzard J, Klindworth A. Menopause decoded: what's happening and how to manage it. J Prim Care Community Health. 2024;15:21501319241307460;doi:10.1177/21501319241307460.

[2] Santoro N, Roeca C, Peters BA, Neal-Perry G. The menopause transition: signs, symptoms, and management options. J Clin Endocrinol Metab. 2021;106(1):1–15; doi: 10.1210/clinem/dgaa764.

[3] Jia Y, Zhou Z, Xiang F, Hu W, Cao X. Global prevalence of depression in menopausal women: a systematic review and meta-analysis. J Affect Disord. 2024;358:474–82; doi: 10.1016/j.jad.2024.05.051.

[4] Motlani V, Motlani G, Pamnani S, Sahu A, Acharya N. Endocrine changes in postmenopausal women: a comprehensive view. Cureus. 2023;15(12):e51287; doi: 10.7759/cureus.51287.

[5] Abdulnour J, Razmjou S, Doucet É, Boulay P, Brochu M, Rabasa-Lhoret R, Lavoie J-M, Prud'homme D. Influence of cardiorespiratory fitness and physical activity levels on cardiometabolic risk factors during menopause transition: a MONET study. Prev Med Rep. 2016;4:277–82; doi: 10.1016/j.pmedr.2016.06.024.

[6] Lynch NA, Ryan AS, Berman DM, Sorkin JD, Nicklas BJ. Comparison of VO_2max and disease risk factors between perimenopausal and postmenopausal women. Menopause. 2002;9(6):456–62; doi: 10.1097/00042192-200211000-00012.

[7] Strasser B, Burtscher M. Survival of the fittest: VO_2max, a key predictor of longevity?.Front Biosci. 2018;23(8):1505–16; doi: 10.2741/4657.

[8] Hulteen RM, Marlatt KL, Allerton TD, Lovre D. Detrimental changes in health during menopause: the role of physical activity. Int J Sports Med. 2023;44(6):389–96; doi: 10.1055/a-2003-9406.

[9] Okechukwu CE, Masala D, D'Ettorre G, La Torre G. Moderate-intensity aerobic exercise as an adjunct intervention to improve sleep quality among rotating shift nurses. Clin Ter. 2022;173(2):184–6; doi: 10.7417/CT.2022.2414.

[10] Asikainen TM, Kukkonen-Harjula K, Miilunpalo S. Exercise for health for early postmenopausal women: a systematic review of randomised controlled trials. Sports Med. 2004;34(11):753–78; doi: 10.2165/00007256-200434110-00004.

[11] Pilch WB, Mucha DM, Pałka TA, Suder AE, Piotrowska AM, Tyka AK, Tota ŁM, Ambroży T. The influence of a 12-week program of physical activity on changes in body composition and lipid and carbohydrate status in postmenopausal women. Prz Menopauzalny. 2015;14(4):231–7; doi: 10.5114/pm.2015.56311.

[12] Singh B, Bennett H, Miatke A, Dumuid D, Curtis R, Ferguson T, Brinsley J, Szeto K, Eglitis E, Zhou M, Simpson CEM, Petersen JM, Firth J, Maher CA. Systematic umbrella review and meta-meta-metanalysis: effectiveness of physical activity in improving depression and anxiety in children and adolescents. J Am Acad Child Adolesc Psychiatry. 2026;65(2):171–86; doi: 10.1016/j.jaac.2025.04.007.

[13] Tian S, Liang Z, Qui F, Yu Y, Wang C, Zhang M, Wang X. Optimal exercise modality and dose to improve depressive symptoms in adults with major depressive disorder: asystematic review and Bayesian model-based network meta-analysis of RCTs. J Psychiatr Res. 2024;176:384–92; doi: 10.1016/j.jpsychires.2024.06.031.

[14] Cleland C, Ferguson S, Ellis G, Hunter RF. Validity of the International Physical Activity Questionnaire (IPAQ) for assessing moderate-to-vigorous physical activity and sedentary behaviour of older adults in the United Kingdom. BMC Med Res Methodol. 2018;18(1):176; doi: 10.1186/s12874-018-0642-3.

[15] García-Batista ZE, Guerra-Peña K, Cano-Vindel A, Herrera-Martínez SX, Medrano LA. Validity and reliability of the Beck Depression Inventory (BDI-II) in general and hospital population of Dominican Republic. PLOS ONE. 2018;13(6):e0199750; doi: 10.1371/journal.pone.0199750.

[16] Hagner W, Hagner-Derengowska M, Wiacek M, Zubrzycki IZ. Changes in level of VO_2max, blood lipids, and waist circumference in response to moderate endurance training as a function of ovarian aging. Menopause. 2009;16(5):1009–13; doi: 10.1097/gme.0b013e31819c0924.

[17] Klonizakis M, Moss J, Gilbert S, Broom D, Foster J, Tew GA. Low-volume high-intensity Interval training rapidly improves cardiopulmonary function in postmenopausal women. Menopause. 2014;21(10):1099–105; doi: 10.1097/GME.0000000000000208.

[18] Qian J, Sun S, Wang M, Sun Y, Sun X, Jevitt C, Yu X. The effect of exercise intervention on improving sleep in menopausal women: a systematic review and meta-analysis. Front Med. 2023;10:10:1092294; doi: 10.3389/fmed.2023.1092294.

[19] Silva RT, Câmara SMA, Moreira MA, Nascimento RA, Vieira MCA, Morais MSM, Maciel ÁCC. Correlation of menopausal symptoms and quality of life with physical performance in middle-aged women. Rev Bras Ginecol Obstet. 2016;38(6):266–72; doi: 10.1055/s-0036-1584238.

[20] Elgayar SL, Elgendy S, Youssef T. Comparative effects of aerobic, resistance, and combined exercises on depression and sleep quality in women with controlled hypothyroidism. a randomized controlled trial. Adv Rehabil. 2024;38(1):9–19; doi: 10.5114/areh.2024.136292.

[21] Chien LW, Liu CF, Yang YL. Exercise intervention for sleep disturbances in menopausal women: a systematic review. Sleep Med Clin. 2013;8(3):295–307; doi: 10.1016/j.jsmc.2013.04.005.

[22] Yamazaki S, Ichimura S, Iwamoto J, Takeda T, Toyama Y. Effect of walking exercise on bone metabolism in postmenopausal women with osteopenia/osteoporosis. *J* Bone Miner Metab. 2004;22(5):500–8; doi: 10.1007/s00774-004-0514-2.

[23] Ochotnicka A, Marcinkiewicz A. Physical activity: prevention and support in the fight against depression. Health Probl Civiliz. 2024;18(1):3–4; doi: 10.5114/hpc.2024.134586.