



# The effect of the pilates method on psychobiological factors and blood pressure in women with hypertension: a randomized controlled trial

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## Abstract

**Purpose** This study investigated the effects of a Pilates Method (PM) program including mat and apparatus-based exercises on psychobiological aspects and blood pressure (BP) in women with hypertension using antihypertensive medication.

**Methods** This randomized controlled trial involved 28 women with hypertension (39–59 years) randomized into Control (CG=14) or Pilates (PG=14). The CG received usual care (continuing antihypertensive treatment and lifestyle guidance) without additional structured exercise training, while the PG underwent 55 min sessions, twice/week for 13 weeks. Psychobiological variables (anxiety, depression, stress, mood, attention, sleep quality, and health-related quality of life [HRQoL]) and BP were assessed pre/post using validated methods.

**Results** The PG significantly improved in depression, anxiety, and stress (all  $p < 0.001$ ), with stress reduction greater than CG ( $p = 0.003$ ). PG also improved in Pittsburgh Sleep Quality Index global score and most sleep components ( $p < 0.001$  to  $p = 0.023$ ), with between-group differences favoring PG. Mood states (tension, depression, vigor, fatigue) improved in PG ( $p < 0.001$  to  $p = 0.002$ ), all differing from CG except anger. PG showed faster attention time ( $p < 0.001$ ) and fewer errors ( $p = 0.026$ ), with a between-group difference for time ( $p < 0.001$ ). HRQoL increased in PG ( $p = 0.012$ ), with significant between-group differences ( $p = 0.001$ ). PG reduced diastolic BP ( $p = 0.002$ ) and mean BP ( $p = 0.002$ ), while systolic BP decreased in both groups. CG showed no significant changes for most variables.

**Conclusion** A 13-week PM program significantly improved anxiety, depression, stress, mood, attention, sleep quality, and HRQoL in women with hypertension using antihypertensive medications. Additionally, it promoted reductions in BP, supporting its role as a complementary non-pharmacological strategy.

**Keywords** Exercise training · Comprehensive pilates program · Mental health · Affective symptoms · Sleep disturbance · Well-being

## Introduction

Systemic arterial hypertension (SAH), a chronic and multifactorial disease characterized by elevated blood pressure (BP), represents a significant global public health challenge and is a leading modifiable risk factor for cardiovascular diseases and premature death (Carvalho et al. 2020; Barroso et al. 2021).

Thus, SAH represents a significant social and economic challenge to global public health (Fernández-Rodríguez et al. 2019). It is estimated that a large proportion of SAH cases are associated with living conditions and lifestyle, with physical inactivity (Carey et al. 2018; Arnett et al. 2019; Précoma et al. 2019; Writing Committee Members et al. 2025) and psychosocial and psychobiological factors (Lusardi et al. 1999; Lipp et al. 2007; Barroso et

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al. 2021; Visseren et al. 2021; Bezerra et al. 2021) being major contributors to its high prevalence. In this context, living conditions refer to aspects such as socioeconomic status, occupational demands, and environmental stressors (e.g., noise, pollution). Psychosocial factors include stress, anxiety, depression, and social isolation, whereas psychobiological factors involve mechanisms such as autonomic nervous system imbalance, sleep disturbances, and hormonal alterations. Collectively, these elements may trigger inflammatory processes and cardiovascular dysregulation, highlighting the importance of addressing psychobiological well-being in hypertension management (Zhang et al. 2023; He et al. 2024).

Currently, the main strategies for managing SAH include pharmacological therapy and lifestyle modifications. Anti-hypertensive agents such as diuretics, beta-blockers, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers, and calcium channel blockers are effective in reducing BP and preventing cardiovascular complications (Barroso et al. 2021; Writing Committee Members et al. 2025). In parallel, lifestyle interventions—particularly dietary improvements, weight management, and regular physical activity—are strongly recommended and can significantly reduce BP.

Exercise training is indicated both as a non-pharmacological treatment and for the prevention of SAH (Carvalho et al. 2020; Barroso et al. 2021) as well as for the treatment and control of psychobiological aspects (Mello et al. 2005). Its benefits in SAH are mainly attributed to improved autonomic balance through reduced sympathetic overactivity and enhanced vagal tone (Li et al. 2025), along with improved endothelial function and vascular compliance mediated by increased nitric oxide bioavailability and arterial remodeling (Zhou et al. 2022). Among the most effective modalities, aerobic, resistance, and combined training have been consistently shown to reduce BP in hypertensive populations (Edwards et al. 2023; Tian et al. 2025). However, adherence to these traditional programs is often limited due to barriers such as lack of time, motivation, or comorbidities, justifying the need to explore alternative and more engaging training modalities (Lopes et al. 2021; Li et al. 2024).

Pilates Method (PM) is increasingly sought after and is more frequently recommended by physicians, especially for benefits related to chronic lower back pain. However, recent evidence also indicates that PM can reduce BP and improve psychobiological outcomes such as anxiety, depression, sleep quality, and quality of life (Caldwell et al. 2009; Eyigor et al. 2010; Leopoldino et al. 2013; Mokhtari et al. 2013; Torabian et al. 2013; Martins-Meneses et al. 2015; González-Devesa et al. 2024; Barbosa et al. 2025). These findings support its potential as a complementary strategy for hypertension management.

PM, originally developed by Joseph Pilates in the early 20th century, comprises two main modalities: mat-based and apparatus-based exercise (Gallagher et al. 1999; Delgado and Marco 2016). A recent systematic review and meta-analysis concluded that PM is safe for patients with hypertension and can reduce both systolic (SBP) and diastolic BP (DBP), although results are not necessarily superior to other exercise modalities and further high-quality studies are warranted (González-Devesa et al. 2024). Nevertheless, evidence remains limited, especially regarding programs that integrate both mat and apparatus-based Pilates.

Importantly, women remain underrepresented in exercise science research, despite the high burden of hypertension in this population and sex-specific differences in cardiovascular and psychobiological responses to exercise (Davis et al. 2000; Regitz-Zagrosek and Seeland 2011; Costello et al. 2014). Addressing this gap is essential to provide evidence-based exercise prescriptions tailored to women.

While some research suggests PM can improve psychobiological variables, the specific effects of PM including both mat and apparatus-based exercises in hypertensive individuals, particularly regarding the interplay between psychobiological improvements and BP changes, remain notably under-explored. This study aimed to evaluate the effects of PM including both mat and apparatus-based exercises intervention on BP and psychobiological factors in women with hypertension using antihypertensive medication.

## Methods

### Study design and registration

The present study followed the CONSORT 2025 statement for reporting randomized clinical trials (Hopewell et al. 2025). This was a two-arm, randomized, controlled, longitudinal trial designed to evaluate the effects of the PM, including both mat and apparatus-based exercises, on psychobiological and blood pressure variables in women with hypertension. The psychobiological variables—including depression, anxiety, stress, sleep quality, mood, attention, and quality of life—were defined as the primary outcomes of the trial, as these represent the main focus of the investigation. BP and other hemodynamic parameters were considered secondary outcomes.

The trial was approved by the Research Ethics Committee of the Federal University of São Paulo (CAAE: 08645319.4.0000.5505) and is registered in the Brazilian Clinical Trials Registry (ReBEC; RBR-87ymt3c).

The study protocol adheres to the ethical principles of the Declaration of Helsinki (1975). All participants provided written informed consent prior to enrollment.

## Participants

Women aged 30–59 years with a medical diagnosis of hypertension, under stable antihypertensive medication of any class, were eligible. Additional inclusion criteria were: sedentary for at least 6 months (determined by anamnesis and confirmed using the International Physical Activity Questionnaire [IPAQ]), non-smokers, not using hormone replacement or contraceptives, without any condition that could compromise exercise execution or cardiovascular response, and medical clearance for exercise training.

Exclusion criteria included: changes in antihypertensive medication during the experimental period (type, class, or dose), COVID-19 infection and sequelae during the experimental period, and attendance < 75% of training sessions.

## Sample size calculation

Sample size was calculated in G\*Power software based on the between-group comparison of anxiety values reported in a previous randomized controlled trial on Pilates training (Aibar-Almazán et al. 2019). In that study, anxiety scores were  $4.76 \pm 3.73$  for the Pilates group and  $9.37 \pm 3.52$  for the control group. With 80% power and  $\alpha = 0.05$ , the minimum required sample size was 11 participants per group. To ensure robustness and compensate for potential attrition, 63 women were initially recruited. This conservative approach was adopted due to the long intervention period, the challenges of maintaining adherence in supervised exercise programs for hypertensive women, and the additional uncertainties imposed by the COVID-19 pandemic.

A total of 28 participants completed the trial and were included in the final analysis.

## Randomisation and allocation

Participants were randomized (1:1) to the Pilates Group (PG) or Control Group (CG) using simple randomization. In total, 63 participants were randomized (PG:  $n = 32$ ; CG:  $n = 31$ ). Allocation was disclosed after baseline assessments. Due to the nature of the intervention, blinding of participants and the instructor was not possible. Outcome assessments were performed by the same researcher (DTR), who was not blinded to group allocation.

## Intervention

Participants in the PG underwent a PM program including both mat and apparatus-based exercises, performed according to the original method developed by Joseph Pilates. Training sessions lasted 55 min, twice per week, for 13 weeks, conducted by the same certified professional. A

2-week adaptation period was included to familiarize participants with the PM principles and basic movements. Intensity was prescribed to maintain perceived exertion between 13 and 15 on the Borg scale (6–20). Exercises were performed using a progressive repetition scheme, starting from the minimum number recommended and increasing to the maximum required by each exercise.

The mat and reformer were included in all sessions from the beginning, while other apparatus (wall unit/cadillac, wunda chair, arm chair, electric chair, barrel, and magic circle) were gradually introduced from the 10th session. Equipment was from the classic line of Equipilates®. The complete training protocol, with detailed weekly progression, exercise repertoire, and possible adaptations, is provided in the Supplementary Material (Online Resource).

To participate in a training session, participants could not have SBP values > 160 mmHg and/or DBP > 105 mmHg. If this occurred, they were dismissed and the class was rescheduled for another day.

The CG received usual care, which included continuing their prescribed antihypertensive medication and lifestyle recommendations provided by their physicians, without additional structured exercise training. To maintain engagement, CG participants were included in a WhatsApp group where general information about Pilates was shared. After the experimental period, CG participants were invited to join the Pilates program.

## Outcomes

The primary outcomes of this manuscript were psychological variables assessed before and after the intervention.

Depression, anxiety, and stress were assessed using the Depression, Anxiety, and Stress Scale-21 (DASS 21) questionnaire (Vignola and Tucci 2014). The instrument contains 21 items divided into three subscales (seven items each), scored on a four-point Likert scale ranging from 0 (“did not apply to me at all”) to 3 (“applied to me very much or most of the time”). Subscale scores are summed and multiplied by two, resulting in a range from 0 to 42 points for each domain. Cut-off points are used to classify symptom severity as normal, mild, moderate, severe, or extremely severe: Depression (0–9, 10–13, 14–20, 21–27,  $\geq 28$ ), Anxiety (0–7, 8–9, 10–14, 15–19,  $\geq 20$ ), and Stress (0–14, 15–18, 19–25, 26–33,  $\geq 34$ ) (Vignola and Tucci 2014).

Sleep quality was evaluated using the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989), a questionnaire validated for the Brazilian population (Bertolazi et al. 2011). The instrument is divided into seven components, evaluated in the following order: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, sleeping medication, and daytime sleepiness.

Each component is scored from 0 to 3, where 0 indicates “very good” and 3 “very poor.” The sum of these components yields the global score, ranging from 0 to 21 points. A global score  $\geq 5$  indicates poor sleep quality (Buysse et al. 1989).

Mood state was assessed using the Brunel Mood Scale (BRUMS) (Rohlfes et al. 2008). The instrument consists of 24 items describing different feelings, rated on a five-point Likert scale ranging from 0 (“not at all”) to 4 (“extremely”), based on how the participant feels at the moment of assessment. Items are grouped into six subscales—tension, depression, anger, vigor, fatigue, and mental confusion—each composed of four items. Subscale scores range from 0 to 16, with higher values indicating greater manifestation of the respective mood state. A positive mood profile is characterized by high vigor scores and low scores in the negative dimensions (tension, depression, anger, fatigue, and mental confusion) (Rohlfes et al. 2008).

Attention was assessed using the Portuguese Stroop Neuropsychological Test (Castro et al. 2009). The test comprises two tasks: (i) word reading and (ii) color naming, both using color words printed in incongruent ink colors, which induces the classic Stroop interference effect. Performance was recorded as the total time to complete each task (maximum 120 s) and the number of errors made. Higher times and greater error counts indicate lower attention. The test does not have universally established cut-off points; results are interpreted comparatively between groups and over time.

Health-related quality of life (HRQoL) was evaluated using the questionnaire developed by Bulpitt and Fletcher and translated and validated by Gusmão and Pierin (Gusmão and Pierin 2009), which is specific for assessing HRQoL in individuals with hypertension. The instrument is self-administered and includes 46 questions addressing physical, psychological, social, professional, affective, and sexual aspects possibly affected by hypertension or its treatment. Responses are mostly dichotomous (yes/no), with some open-ended items. Scoring is based on a health index ranging from 0 (death) to 1 (optimal quality of life), with intermediate values reflecting different levels of impairment (e.g., 0.125 = confined to bed, 0.500 = in constant rest, 0.800 = hypertension interfering with social/leisure activities, 0.975 = < 30% of symptoms, 1.0 = no reported symptoms). Lower scores indicate poorer quality of life, whereas higher scores indicate better health status.

Secondary outcomes included hemodynamic variables: SBP, DBP, mean blood pressure (MBP), heart rate (HR), and double product (DP). BP and HR were measured using a validated oscillometric device (Microlife, model BP 3BT0-A), after 5 min of seated rest, following the recommendations of the Brazilian Hypertension Guidelines (Barroso et

al. 2021). Two consecutive readings were taken, and their mean value was used for analysis. DP was calculated as SBP  $\times$  HR.

It is important to note that all assessments were conducted in both groups (CG and PG) before and after the experimental period, with the latter conducted two days after the end of the training protocol to avoid acute interference from the last exercise session.

## Statistical analysis

All analyses were performed using R Core Team software (2023).

For the baseline characteristics of the groups, independent sample T-tests and Fisher’s exact tests were used to compare continuous and categorical variables, respectively. The assumptions of normality and homogeneity of variances were verified using the Shapiro-Wilk test and Levene’s test, respectively.

For comparisons between groups (CG and PG) and times (Pre and Post) for depression, anxiety, stress, overall sleep quality, HRQoL (%), HRQoL (score), SBP, DBP, mean BP (MBP), and HR variables, a two-way repeated measures analysis of variance (ANOVA) was employed. For variables in which interaction effects were found, multiple comparisons were conducted using Tukey’s method to verify specific differences between groups and times.

The effect sizes for the ANOVA were calculated using partial eta-squared ( $\eta_p^2$ ), which allows quantifying the magnitude of the observed differences in each factor and their interactions. The  $\eta_p^2$  provides a measure of the proportion of the total variability in the dependent variables explained by the independent factors, helping to interpret the practical significance of the effects found.

Residual normality was assessed using the QQ plot, whereas homogeneity of variances was verified using Levene’s test. When the model assumptions were not satisfied, square root transformations were applied to the corresponding models.

For variables that did not follow a normal distribution or exhibited variance homogeneity issues, a non-parametric repeated-measures ANOVA was performed. The *nparLD* package in R software was used to handle longitudinal or repeated measures data in situations where parametric methods were inappropriate. For variables with interaction effects, the groups and times were compared pairwise.

To verify if the classifications of anxiety, depression, stress variables, and sleep quality components differed between the groups at each time point, Fisher’s exact test was conducted.

A significance level of  $p \leq 0.05$  was adopted for all tests.

For visualization, forest plots were constructed for psychobiological variables, showing mean change scores ( $\Delta = \text{Post} - \text{Pre}$ ) with 95% confidence intervals. Blood pressure values were represented separately as mean  $\pm$  standard deviation at each time point (Pre and Post).

The results of the statistical analyses performed are presented in tables as Supplementary Material (Online Resource).

## Results

Of the 63 women who met the initial inclusion criteria, 19 discontinued the intervention and 16 were subsequently excluded based on exclusion criteria; data from 28 women ( $49.8 \pm 6.5$  years) were included in the final analysis (Fig. 1).

Baseline characteristics are shown in Table 1. No statistically significant differences were observed between groups.

The results of the DASS 21 questionnaire are shown in Fig. 2; Table 2, according to the score and percentage classification, respectively. At post-intervention, the PG showed a significantly greater reduction in stress compared with the CG (mean difference = 2.05 [95% CI: 0.60 to 3.50],  $p = 0.003$ ). No between-group differences were detected for depression or anxiety, although within-group reductions occurred in PG ( $p < 0.001$ ). PG demonstrated a significant improvement only in the stress variable in its classification results when comparing pre- and post-periods, while the CG did not show any significant changes in any variable based on the scores and classification.

Figure 3 presents changes in sleep quality components and PSQI global score, while Table 3 details the percentage

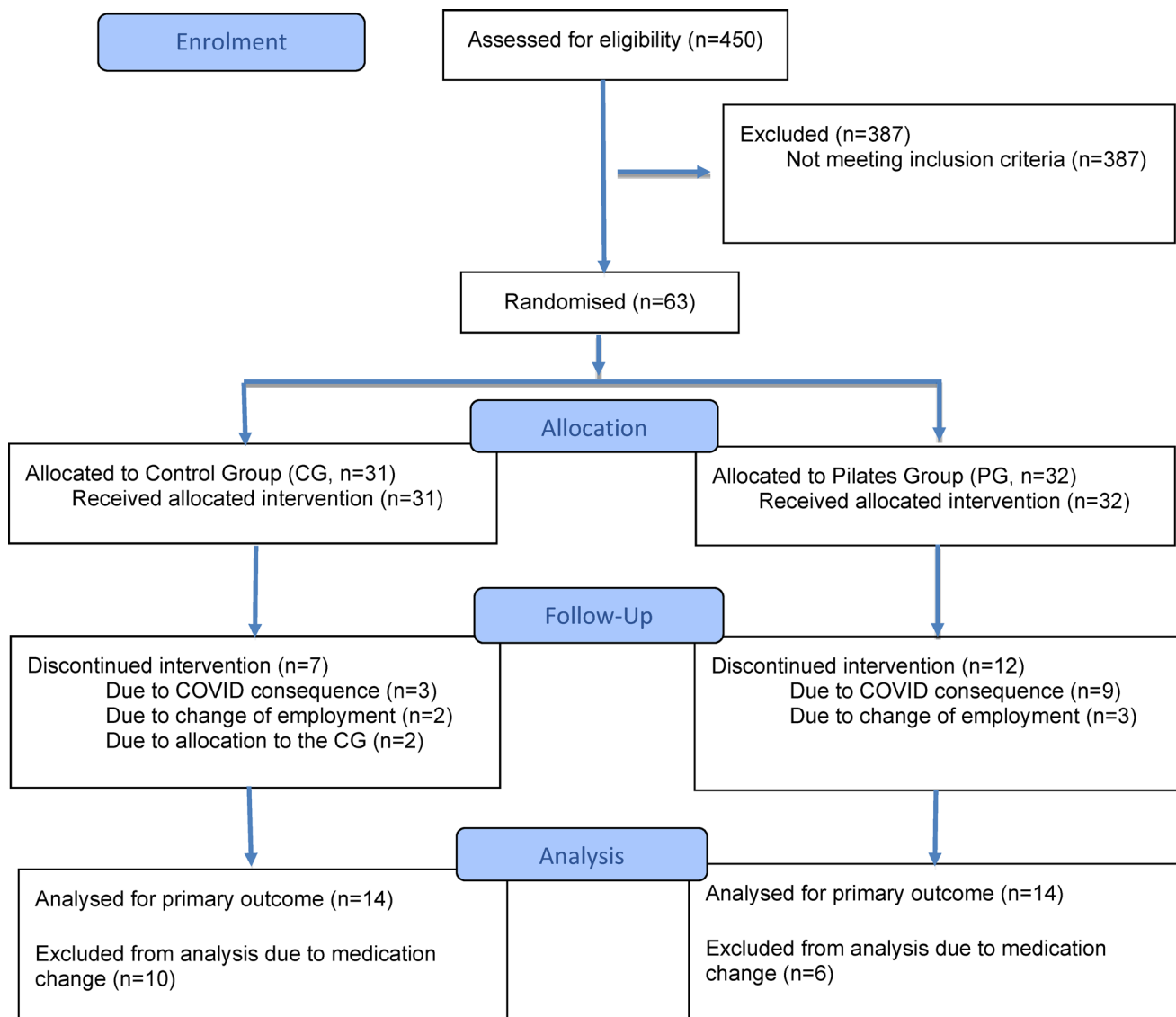


Fig. 1 CONSORT 2025 flow diagram of participants through the trial

**Table 1** Baseline characteristics in the control (CG) and Pilates groups (PG) presented as mean and standard deviation or number

|                                 | CG (n=14)  | PG (n=14)  |
|---------------------------------|------------|------------|
| Age (years)                     | 48.0±7.0   | 51.6±5.6   |
| Menopause – yes/no              | 10/4       | 9/5        |
| SBP rest (mmHg)                 | 129.2±17.2 | 119.8±19.7 |
| DBP rest (mmHg)                 | 86.9±11.7  | 82.6±12.7  |
| MBP rest (mmHg)                 | 101.0±12.3 | 95.0±14.3  |
| N° de antihypertensive drug     | 1 (1-2)    | 1 (1-2)    |
| Diuretics                       | 1          | 6          |
| Beta-blocker                    | 2          | 0          |
| Angiotensin II receptor blocker | 13         | 13         |
| ACE inhibitor                   | 1          | 1          |

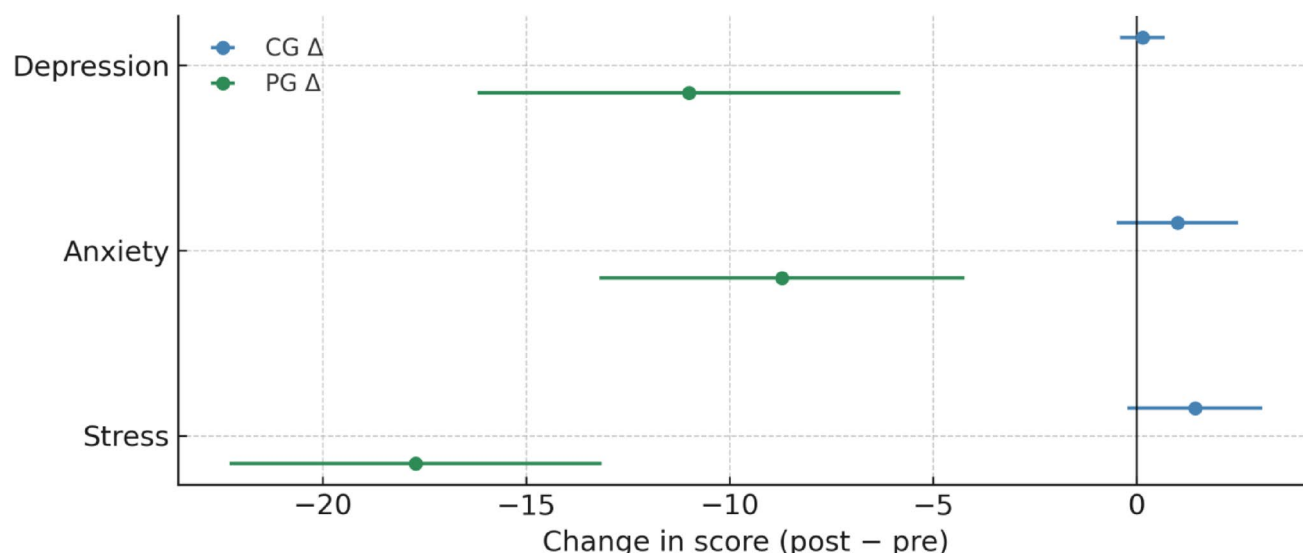
SBP rest systolic blood pressure at rest, DBP rest diastolic blood pressure at rest, MBP rest mean blood pressure at rest, ACE angiotensin-converting enzyme

classification of each PSQI component. Compared with CG, PG exhibited significantly greater improvements in the sleep quality ( $p<0.001$ ), sleep duration ( $p<0.001$ ), sleep

disturbance ( $p<0.001$ ), daytime sleepiness ( $p=0.003$ ), and PSQI global score ( $p<0.001$ ). In the categorical classifications, PG also showed significantly better outcomes for sleep quality ( $p<0.001$ ), sleep latency ( $p=0.024$ ), sleep duration ( $p=0.006$ ), sleep disturbance ( $p<0.001$ ), and daytime sleepiness ( $p=0.023$ ) compared to the CG (Table 3). The CG did not exhibit any significant changes in any of the PSQI variables based on scores or classifications.

Figure 4 presents the results of mood state evaluation assessed by the BRUMS. PG showed significantly greater improvements (reductions in negative mood states and increases in vigor) than CG in tension ( $p<0.001$ ), depression ( $p=0.002$ ), vigor ( $p<0.001$ ), and fatigue ( $p<0.001$ ). For anger, no significant between-group difference was found, despite overall improvement.

Table 4 displays the outcomes for attention and HRQoL. In the attention test, PG demonstrated a significantly greater reduction in completion time compared to CG at post-intervention ( $p<0.001$ ), while no between-group difference was

**Fig. 2** Changes in depression, anxiety, and stress scores (mean  $\Delta \pm 95\%$  CI) after the intervention in the control (CG) and Pilates groups (PG)**Table 2** Results of the classification of the Depression, Anxiety, and Stress Scale-21 (DASS 21) Questionnaire presented in percentage (%) in the control (CG) and Pilates groups (PG), pre and post-experimental period

|                   | CG     |      |          |        |              | PG     |      |          |        |              |
|-------------------|--------|------|----------|--------|--------------|--------|------|----------|--------|--------------|
|                   | Normal | Mild | Moderate | Severe | Extr. Severe | Normal | Mild | Moderate | Severe | Extr. Severe |
| <b>Anxiety</b>    |        |      |          |        |              |        |      |          |        |              |
| Pre               | 57.5   | 7    | 7        | 7      | 21.5         | 43     | 0    | 21       | 7      | 29           |
| Post              | 57.5   | 7    | 7        | 7      | 21.5         | 72     | 14   | 14       | 0      | 0            |
| <b>Depression</b> |        |      |          |        |              |        |      |          |        |              |
| Pre               | 72     | 7    | 7        | 7      | 7            | 36     | 14   | 21       | 0      | 29           |
| Post              | 79     | 0    | 7        | 7      | 7            | 93     | 0    | 7        | 0      | 0            |
| <b>Stress</b>     |        |      |          |        |              |        |      |          |        |              |
| Pre               | 36.5   | 14   | 14       | 14     | 21.5         | 14     | 36   | 0        | 21     | 29           |
| Post              | 29     | 14   | 21       | 7      | 29           | 86     | 14   | 0        | 0      | 0 *          |

Ext. Severe Extremely Severe

\*Within-group differences ( $p \leq 0.05$ )

**Fig. 3** Changes in sleep quality components and PSQI global score (mean  $\Delta \pm 95\%$  CI) after the intervention in the control (CG) and Pilates groups (PG)

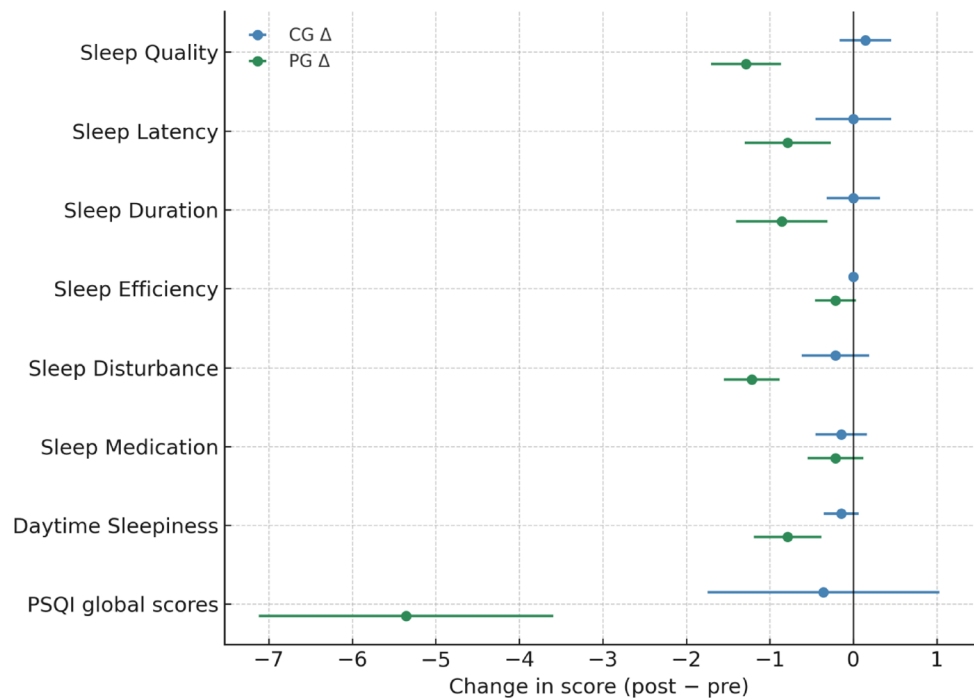


**Table 3** Results of the classification of variables obtained from the Pittsburgh Sleep Quality Index (PSQI) questionnaire in percentage (%) in the control (CG) and Pilates groups (PG), pre and post-experimental period

|                     | CG        |             |            |          | PG        |             |            |          |
|---------------------|-----------|-------------|------------|----------|-----------|-------------|------------|----------|
|                     | Very good | Fairly good | Fairly bad | Very bad | Very good | Fairly good | Fairly bad | Very bad |
| Sleep Quality       |           |             |            |          |           |             |            |          |
| Pre                 | 7         | 57          | 36         | 0        | 14        | 36          | 43         | 7        |
| Post                | 7         | 43          | 50         | 0        | 86        | 14          | 0          | 0†       |
| Sleep Latency       |           |             |            |          |           |             |            |          |
| Pre                 | 21        | 29          | 43         | 7        | 36        | 21          | 21         | 21       |
| Post                | 36        | 7           | 43         | 7        | 50        | 43          | 7          | 0†       |
| Sleep Duration      |           |             |            |          |           |             |            |          |
| Pre                 | 7         | 50          | 21         | 21       | 43        | 7           | 29         | 21†      |
| Post                | 14        | 36          | 29         | 21       | 64        | 36          | 0          | 0†       |
| Sleep Efficiency    |           |             |            |          |           |             |            |          |
| Pre                 | 71        | 29          | 0          | 0        | 71        | 29          | 0          | 0        |
| Post                | 71        | 22          | 7          | 0        | 93        | 7           | 0          | 0        |
| Sleep Disturbance   |           |             |            |          |           |             |            |          |
| Pre                 | 0         | 29          | 57         | 14       | 7         | 50          | 43         | 0        |
| Post                | 7         | 36          | 43         | 14       | 86        | 14          | 0          | 0†       |
| Sleeping Medication |           |             |            |          |           |             |            |          |
| Pre                 | 71        | 14          | 14         | 0        | 86        | 7           | 7          | 0        |
| Post                | 79        | 14          | 7          | 0        | 100       | 0           | 0          | 0        |
| Daytime Sleepiness  |           |             |            |          |           |             |            |          |
| Pre                 | 29        | 36          | 21         | 14       | 36        | 36          | 29         | 0        |
| Post                | 35        | 29          | 29         | 7        | 86        | 14          | 0          | 0†       |

†Between-groups differences ( $p \leq 0.05$ )

observed for the number of errors, despite improvements in both groups ( $p=0.026$ ). Regarding HRQoL, PG achieved significantly greater improvements than CG in both percentage values (mean difference =  $-0.86$  [95% CI:  $-2.06$  to

$-0.49$ ],  $p=0.001$ ) and test scores (mean difference =  $-0.13$  [95% CI:  $-0.21$  to  $-0.05$ ],  $p=0.001$ ).

Figure 5 presents the results of SBP, DBP, and MBP. At post-intervention, DBP and MBP were significantly lower in PG than in CG (mean difference =  $17.43$  [95% CI:  $7.60$

**Fig. 4** Changes in BRUMS subscales (mean  $\Delta \pm 95\%$  CI) after the intervention in the control (CG) and Pilates groups (PG)

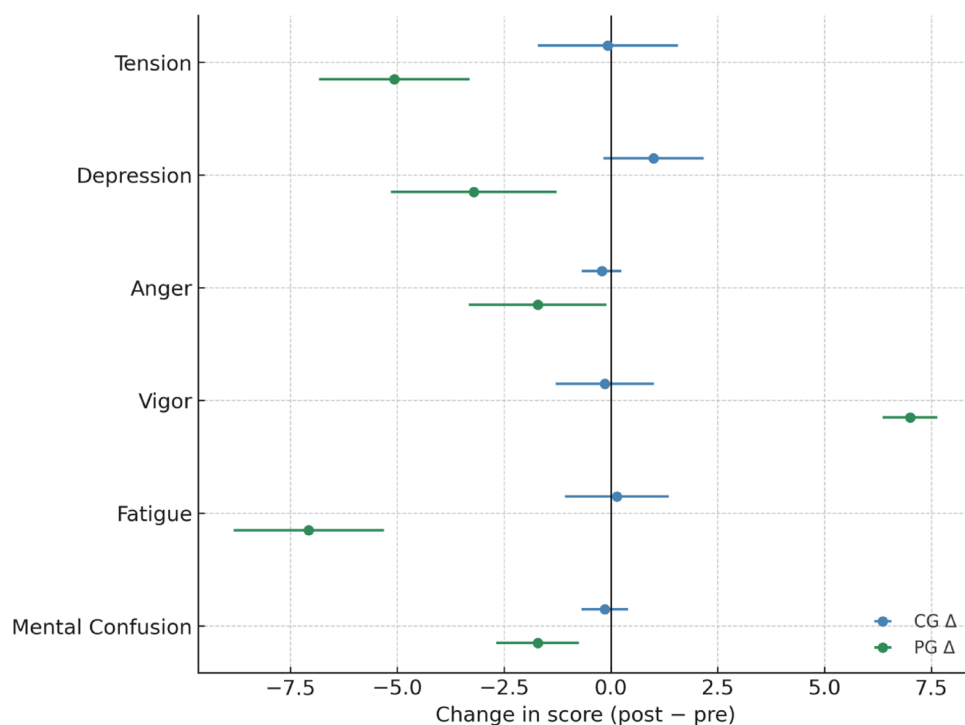


**Table 4** Variables related to mood, attention and quality of life in the control (CG) and Pilates groups (PG), pre and post-experimental period

| Variables                         | CG   |      |        |      | PG   |      |        |                    |
|-----------------------------------|------|------|--------|------|------|------|--------|--------------------|
|                                   | Mean | SD   | Median | IQR  | Mean | SD   | Median | IQR                |
| Attention (time) <sup>a</sup>     |      |      |        |      |      |      |        |                    |
| Pre                               | 1.0  | 0.4  | 1.0    | 0.5  | 1.0  | 0.2  | 1.1    | 0.1                |
| Post                              | 1.0  | 0.3  | 1.0    | 0.1  | 0.6  | 0.1  | 0.6    | 0.0* <sup>†</sup>  |
| Attention (error) <sup>a</sup>    |      |      |        |      |      |      |        |                    |
| Pre                               | 1.1  | 1.2  | 1.0    | 1.0  | 0.9  | 1.0  | 1.0    | 1.7                |
| Post                              | 0.9  | 1.3  | 1.0    | 1.0* | 0.1  | 0.4  | 0.0    | 0.0*               |
| Life Quality (%) <sup>b</sup>     |      |      |        |      |      |      |        |                    |
| Pre                               | 68.8 | 13.1 | 67.1   | 23.6 | 74.9 | 21.3 | 81.4   | 32.9               |
| Post                              | 67.1 | 15.1 | 62.9   | 25.7 | 89.0 | 10.1 | 90.0   | 10.0* <sup>†</sup> |
| Life Quality (score) <sup>b</sup> |      |      |        |      |      |      |        |                    |
| Pre                               | 0.7  | 0.1  | 0.7    | 0.2  | 0.7  | 0.2  | 0.8    | 0.3                |
| Post                              | 0.7  | 0.1  | 0.6    | 0.2  | 0.9  | 0.1  | 0.9    | 0.1* <sup>†</sup>  |

SR standard deviation, IQR interquartile range

\*Within-group differences ( $p \leq 0.05$ )

<sup>†</sup>Between-groups differences ( $p \leq 0.05$ )

<sup>a</sup>Stroop Neuropsychological Test

<sup>b</sup>Health-related quality of life (HRQoL) questionnaire

to 27.26] and 17.24 [95% CI: 7.78 to 26.70], respectively; both  $p < 0.001$ ). SBP decreased over time in both groups ( $p = 0.014$ ), with no significant group  $\times$  time interaction ( $p = 0.113$ ), indicating similar reductions between groups. The results for HR and DP are presented in Table 5. No significant between-group differences were observed for these variables.

## Discussion

This study demonstrated that the practice of the PM, including both mat- and apparatus-based exercises, led to significant improvements in psychobiological variables and reductions in BP in women with hypertension undergoing pharmacological treatment. These findings support the notion that alternative exercise modalities such as PM can serve as effective complementary interventions for

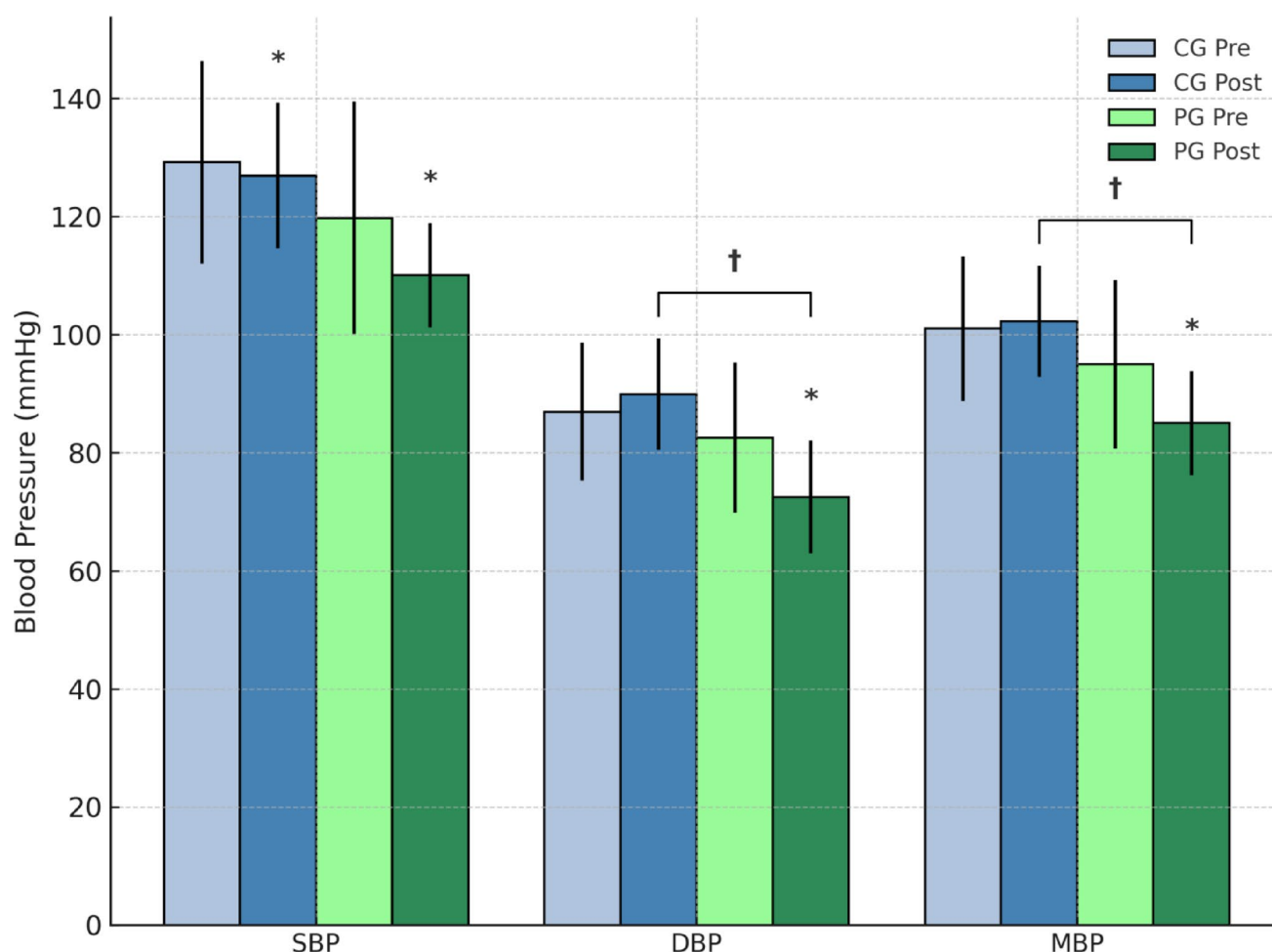


**Fig. 5** Systolic (SBP), diastolic (DBP), and mean blood pressure (MBP) in the control (CG) and Pilates groups (PG), pre and post-experimental periods presented as mean and standard deviation. \* Within-group differences ( $p \leq 0.05$ ). † Between-groups differences ( $p \leq 0.05$ )

**Table 5** Hemodynamic data presented as mean and standard deviation in the control (CG) and Pilates groups (PG), pre and post-experimental period

|               | CG            |               | PG            |               |
|---------------|---------------|---------------|---------------|---------------|
|               | Pre           | Post          | Pre           | Post          |
| HR (bpm)      | 75.2±13.2     | 74.6±10.6     | 78.1±10.3     | 76.6±8.7      |
| DP (mmHg×bpm) | 9836.8±2748.4 | 9515.5±1884.3 | 9322.1±1706.1 | 8451.9±1349.0 |

managing hypertension, particularly among individuals who struggle to adhere to conventional aerobic or resistance exercise programs. Importantly, while a recent systematic review and meta-analysis identified 11 studies investigating Pilates for patients with hypertension, most protocols were mat-based and focused primarily on BP (González-Devesa et al. 2024). To our knowledge, the present study is the first to evaluate a comprehensive Pilates program integrating both mat and apparatus-based exercises, with psychobiological variables defined as primary outcomes, highlighting its originality.

The observed improvements in stress, anxiety, and depression align with existing evidence suggesting that physical exercise regulates the hypothalamic-pituitary-adrenal axis and stimulates neurotransmitters release, such

as serotonin and dopamine (Mello et al. 2005). PM, with its emphasis on concentration, breath control, and body awareness, may further promote psychological relaxation and emotional regulation, thereby reducing allostatic load and cardiovascular reactivity (Sandhiya et al. 2020). Similar improvements in psychological outcomes have also been reported with other exercise modalities, such as isometric handgrip training in women with hypertension (Shakoor et al. 2024) and combined exercise and weight loss interventions in adults with hypertension (Smith et al. 2007).

Enhanced sleep quality and attentional performance observed after the PM intervention may be linked to reductions in affective symptoms such as anxiety, depression, psychological stress, and mood disturbances (e.g., tension, fatigue, mental confusion). These emotional improvements

may contribute to better autonomic regulation and cardiovascular health. Sleep disturbances are strongly associated with cardiovascular disease risk (Li et al. 2014; Badran et al. 2015), and their improvement could contribute to better BP control. Prior studies have also demonstrated associations between better sleep and enhanced cognitive performance, particularly in attention (Caldwell et al. 2010). Together, these results underscore the importance of psychobiological health in hypertension management.

Regarding BP, we found significant reductions in DBP and MBP in the PG. These results are consistent with prior studies that also reported improvements in BP following Pilates training in individuals with hypertension (Martins-Meneses et al. 2015; Batista et al. 2022; Barbosa et al. 2025), though some studies have shown more modest or inconsistent results (González-Devesa et al. 2024). These improvements may be related to physiological mechanisms typically observed with exercise training, including enhanced endothelial function, reduced sympathetic activity, and improved arterial compliance (Zhou et al. 2022; Li et al. 2025). It is noteworthy that all participants maintained their use of antihypertensive medication, reinforcing that the observed benefits resulted from the PM intervention in addition to pharmacological treatment. This highlights the potential role of PM as a non-pharmacological adjunct without the risk of drug interaction.

Despite the promising outcomes, this study has some limitations. The relatively small sample size and short duration of the intervention may limit the generalizability of the findings. Although the *a priori* calculation indicated that 11 participants per group would be sufficient, a substantially larger number of women ( $n = 63$ ) was intentionally recruited to ensure robustness and compensate for anticipated attrition. This conservative approach was adopted considering the long duration of the supervised intervention, the known challenges in maintaining adherence among hypertensive women, and the additional uncertainties imposed by the COVID-19 pandemic. Even with this strategy, retention proved difficult, leading to higher-than-expected dropout and exclusion rates, mainly due to unavoidable external factors related to the pandemic (e.g., isolation, diagnosis, caregiving responsibilities, employment changes). These factors were not directly related to the intervention itself.

In addition, we did not apply an intention-to-treat analysis, opting instead for a per-protocol approach. Although this strategy enabled us to determine the efficacy of the intervention among adherent participants, it may limit the generalizability of the findings. Another limitation of this study is that participants who had antihypertensive medication adjustments prior to enrollment were not excluded. Although all participants were clinically stable at baseline, these pre-trial pharmacological changes may have introduced baseline

variability, potentially influencing BP responses. However, medication regimens remained stable during the intervention period, which likely minimized this effect. Moreover, the physiological mechanisms underlying the observed improvements were not directly assessed. Future studies should include measures of autonomic function, inflammatory markers, and neuroendocrine responses to clarify the mechanisms involved. Finally, although a WhatsApp group was created for the CG to maintain engagement, which may have introduced minor information bias, the content was limited to general educational information and did not include exercise instruction.

## Conclusion

A 13-week PM training program significantly improved symptoms of anxiety, depression, stress, mood, attention, sleep quality, and HRQoL in women with hypertension using antihypertensive medications. Additionally, it promoted significant reductions in BP. Therefore, PM can be considered a valuable complementary tool for the treatment and management of hypertension.

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1007/s00421-025-06055-y>.

**Author contributions** DTR and AM conceived and designed the research. DTR conducted the experiments. HKMA and AM contributed with analytical tools. DTR, HKMA and AM analyzed the data. DTR, HKMA and AM wrote the manuscript. All authors read and approved the manuscript.

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**Data Availability** The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of interest** The authors have no competing interests to declare that are relevant to the content of this article.

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