ORIGINAL ARTICLE

# Effects of mini-trampoline exercise on neck and knee muscle strength, range of motion, and health-related fitness in sedentary adults

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## ABSTRACT

Sedentary behaviour is increasingly prevalent among young adults and is associated with poorer musculoskeletal health and physical function. Mini-trampoline exercise is low-impact, but its effects on neck and knee function and cardiac autonomic modulation in sedentary adults remain unclear. This study examined the effects of an eight-week mini-trampoline programme. Twenty sedentary adults were randomised to trampoline training or control. The training group completed supervised sessions three times per week for eight weeks; controls maintained usual activities. Outcomes pre/post included knee muscle strength (primary outcome) and neck strength, cervical and knee range of motion, pain, dynamic balance (Star Excursion Balance Test (SEBT)), and heart rate variability (HRV). Neck strength and pain were significantly better than controls, whereas knee strength increased within the training group without a significant between-group difference. Selected measures of knee and cervical range of motion and selected SEBT outcomes favoured training. HRV indices showed favourable between-group differences: root mean square of successive differences (RMSSD), standard deviation of normal-to-normal intervals (SDNN), and high-frequency power (HF) increased and the low-frequency/high-frequency ratio (LF/HF) decreased. An eight-week mini-trampoline exercise programme was associated with improvements in neck strength, balance, pain, and cardiac autonomic modulation in sedentary adults.
**Keywords**: Sport medicine, Physical inactivity, Rebound exercise, Cervical musculature, Joint mobility, Heart rate variability, Dynamic balance.

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## INTRODUCTION

Modern technology has reshaped daily routines, with many adults spending prolonged periods sitting at work, at home, and during transportation. Sedentary behaviour (SB), commonly defined as any waking behaviour with an energy expenditure of ≤1.5 metabolic equivalents (METs) performed in a sitting, reclining, or lying posture (Mansoubi et al., 2015), is now highly prevalent worldwide (Park et al., 2020). A twenty-country study reported that adults aged 18–65 typically sat for 3–8 h/day (median 5 h/day), and 25% sat for ≥8 h/day (Bauman et al., 2011). Sitting for ≥7.5 h/day has been used to indicate a high level of SB (Goyal & Rakhra, 2024), with younger adults tending to report longer sitting times than those aged ≥40 (Bauman et al., 2011).

A growing body of evidence has identified prolonged SB as a major risk factor for all-cause mortality and a wide range of chronic diseases, including cardiovascular disease, type 2 diabetes, hypertension, and several types of cancer (Shibata et al., 2025). Consequently, SB has emerged as a critical public health concern. In response, the World Health Organization has emphasised the importance of reducing sedentary time and increasing physical activity across the lifespan, highlighting the urgent need for feasible and effective interventions targeting the sedentary population (Organization, 2020).

Beyond metabolic and cardiovascular consequences, SB is increasingly recognised as a contributor to musculoskeletal dysfunction. Systematic reviews have shown that prolonged sitting is associated with a higher incidence of musculoskeletal pain, reduced muscle strength, and impaired joint function, particularly affecting the cervical spine and lower extremities (Dzakpasu et al., 2021). Office workers and individuals with prolonged screen exposure report substantially higher prevalences of neck pain, with annual estimates ranging from 42% to 63% (Guduru et al., 2022). Similarly, prolonged sitting has been linked to knee pain, joint stiffness, and an increased risk of knee osteoarthritis (Ehsani et al., 2017). Notably, recent research has demonstrated a strong association between prolonged sitting behaviour and knee osteoarthritis (Ma et al., 2024). Mechanistically, extended sitting may increase intra-articular knee pressure and contribute to muscle atrophy and joint stiffness (Lee et al., 2015).

Exercise-based interventions are widely regarded as a cornerstone strategy for mitigating the adverse effects of SB. Evidence from systematic reviews suggests that regular physical activity can improve musculoskeletal function, reduce pain, and enhance physical performance in sedentary adults (Bull et al., 2020). However, identifying exercise modalities that are safe, engaging, and feasible for individuals with prolonged sitting habits remains challenging.

Among various exercise modalities, trampoline-based exercise has gained increasing attention as a low-impact and accessible form of physical activity. Previous studies have shown that trampoline or rebound exercise can improve cardiorespiratory fitness, enhance balance and motor performance, increase bone density, and promote psychological well-being (Brea-Fernández et al., 2023; Kong et al., 2018; Posch et al., 2019; Schöffl et al., 2021). A recent narrative review further suggests that rebound exercise provides repetitive elastic loading and dynamic postural challenges, which may stimulate neuromuscular activation while minimising joint impact, making it particularly suitable for individuals with limited exercise tolerance (Okemuo et al., 2023).

Mini-trampoline exercise represents a structured, moderately intense form of rebound exercise that may be especially appropriate for sedentary populations (Iannaccone et al., 2020). Despite its potential benefits, existing research has predominantly focused on balance, lower-limb performance, and cardiovascular outcomes, whereas the effects of mini-trampoline exercise on cervical and knee musculoskeletal function in sedentary adults remain largely unexplored. Moreover, high-quality randomised controlled trials specifically addressing these outcomes are scarce.

Therefore, the objective of this randomised controlled trial is to investigate the effects of an eight-week mini-trampoline exercise programme on musculoskeletal and physical fitness outcomes in sedentary adults, with particular focus on neck and knee muscle strength, as well as the knee and cervical joint range of motion.

## MATERIALS AND METHODS

### *Participants*

This study was designed as a pilot randomised controlled trial to investigate the preliminary effects and feasibility of an eight-week mini-trampoline exercise programme in sedentary adults. Participants were recruited through announcements posted on the official platform of Heilongjiang Institute of Technology and included sedentary adults aged 18–35 years. Sedentary behaviour was defined as spending at least six hours per day engaged in sedentary activities (e.g., sitting during work, study, screen use, or transportation) during the previous week, assessed using self-reported daily activity records. Inclusion criteria were: aged between 18 and 35 years; sedentary time ≥6 h/day; and no regular participation in structured aerobic or trampoline-related exercise during the previous three months. Exclusion criteria comprised: recent participation in trampoline exercise within the last week; the presence of cardiovascular, respiratory, neurological, or other severe systemic diseases; pregnancy or breastfeeding; a current diagnosis of severe psychiatric disorders; and the inability to commit to at least three training sessions per week. As this was a pilot trial, no formal a priori sample size calculation was performed, and a total of 20 participants (10 per group) was considered sufficient to assess feasibility, refine measurement procedures, and estimate preliminary effect sizes for future large-scale randomised controlled trials. Participants were randomly allocated in a 1:1 ratio to either the trampoline or control group using a computer-generated random sequence prepared by an independent researcher not involved in recruitment or outcome assessment, with group allocation concealed using sealed, opaque envelopes opened only after completion of baseline assessments. Due to the nature of the intervention, the blinding of participants and exercise instructors was not feasible; however, outcome assessors and data analysts were blinded to group allocation throughout data collection and analysis. The participant recruitment and allocation process is shown in Figure 1.

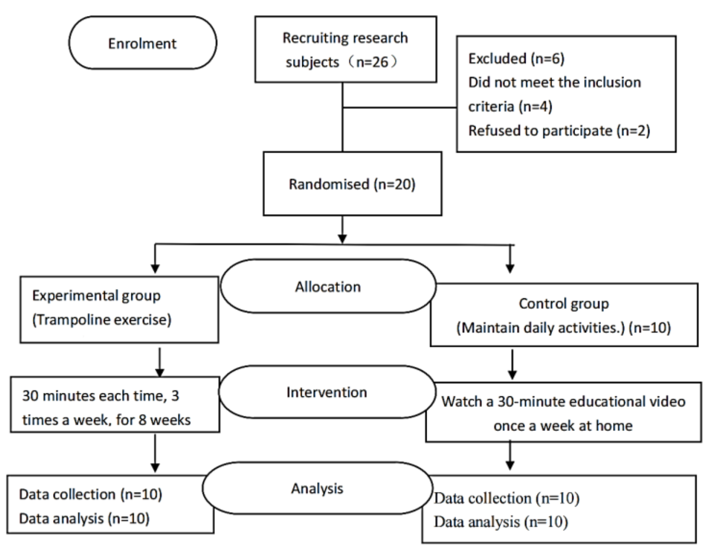


Figure 1. Participant recruitment flowchart.

### *Measures*

The primary outcome of this pilot trial was knee muscle strength. Secondary outcomes included neck muscle strength, joint range of motion, pain intensity, dynamic balance, body composition, flexibility, knee cartilage thickness, handgrip strength, and heart rate variability (HRV). All outcome measures were assessed at the baseline and repeated after the eight-week intervention period. All measurements were conducted by the same trained assessor, who received standardised training and was blinded to group allocation, following standardised procedures in a climate-controlled laboratory maintained at 26 °C. Participants were instructed to rest in a seated position for 10 minutes before baseline assessment.

HRV was assessed using short-term recordings obtained during 3–5 minutes of seated rest, in accordance with established recommendations for resting HRV assessment (Electrophysiology, 1996). RR intervals were recorded using a Polar H10 heart rate sensor chest strap, which has been previously validated for accurate and reliable RR interval acquisition in HRV analysis (Schaffarczyk et al., 2022). Neck flexor and extensor muscle strength was measured during maximal voluntary isometric contractions using a handheld dynamometer (Nscing ES-SH-II, Germany) (Selistre et al., 2021). In contrast, knee muscle strength was assessed using an electronic dynamometer (BCS-400, Beijing Huafu Technology Co., Ltd., China), previously used in studies assessing lower-limb muscle strength using dynamometry (Najiah et al., 2021). Three trials were performed for each muscle strength measurement. The highest value was recorded for analysis.

Cervical range of motion (ROM), including flexion, extension, left and right rotation, and left and right lateral flexion, was assessed using the WE-CAP device, which has demonstrated high reliability and validity for cervical ROM measurement (ICC = 0.89–0.98) (Panngooluema & Eungpinichpong, 2021). Participants were seated upright and performed active movements to the maximum pain-free range; each movement was measured three times, and the mean value was used for analysis. Knee joint ROM, including flexion and extension, was measured using a standard goniometer (Takei 12–1412) following standardised goniometric procedures, with three repetitions recorded for each movement and the mean value used for statistical analysis (Norkin & White, 2016).

Health-related physical fitness was evaluated using standardised field tests. Handgrip strength was assessed using a grip strength dynamometer (GRIP-D, Takei, Japan), with three trials performed for each hand and the maximum value recorded for analysis. Pain intensity was evaluated using a 100-mm visual analogue scale (VAS), and scores were converted to a 0–10 scale for statistical analysis. Dynamic balance was assessed using the Star Excursion Balance Test (SEBT), which has demonstrated good reliability and validity for assessing dynamic postural control (Gribble et al., 2012). Flexibility was assessed using the sit-and-reach test, with the best value from three trials used for analysis. Body composition, including skeletal muscle mass and body fat mass, was measured using a Flycat Body Composition Analyzer 280 (China), based on bioelectrical impedance analysis. Knee cartilage thickness was assessed using a standard ultrasonographic technique with an ultrasound diagnostic instrument (Konted C10, China) in a fully knee-bent, supine position, a method previously validated for the reliable in vivo measurement of femoral cartilage thickness. Three consecutive measurements were obtained for each knee, and the average value was used for analysis (Naredo et al., 2009).

### *Procedures*

This study was reviewed and approved by the Ethics Committee of Khon Kaen University, Thailand (Approval No. HE682018), and conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to the start of the study.

Participants assigned to the trampoline group completed an eight-week supervised mini-trampoline exercise programme, performed three times per week, with each session lasting 30 minutes and at least 48 hours between sessions. All training sessions were conducted in a supervised indoor exercise facility at the School of Physical Education and overseen by trained personnel with a background in sports science to ensure adherence to the correct technique and participant safety. A standard mini-trampoline was used for all sessions (diameter: 100 cm; height: approximately 22 cm). Training was performed individually, with each participant exercising on a separate trampoline within a supervised group setting. Each session consisted of a five-minute warm-up, a 20-minute main exercise phase, and a five-minute cool-down. The main exercise phase included a series of progressive rebound-based movements such as jumping in place, single-leg hopping, forward and backward jumps, and jumping jacks. A detailed description of the exercise content and weekly progression is provided in Table 1. Exercise intensity was prescribed at a moderate level and monitored using heart rate, with the target training intensity maintained at 60–80% of the estimated maximum heart rate. Each exercise bout lasted approximately two minutes, followed by a rest interval of 30 seconds to one minute. Training difficulty was gradually progressed according to individual tolerance and performance to maintain safety and adherence. Training adherence was monitored through attendance records, and participants were regularly asked about fatigue, pain, or discomfort during the intervention period. No serious adverse events were reported.

Table 1. Detailed mini-trampoline exercise programme (Eight-week intervention).

| | | | |
|---|---|---|---|
| Week 1 | Stand on both legs with heels raised<br>Single-leg stance<br>Move forward and backward in small steps<br>Jog<br>Jump in place<br>Single-leg hop | Week 5 | Standing high jump<br>High leg lift<br>Scissors (“paper-scissors”) bounce<br>Single-leg forward and backward jump<br>Jumping jacks<br>Back kick |
| Week 2 | Jump in place<br>Jump forward and backward with a small amplitude<br>Jump left and right<br>Jump on one leg<br>Jog<br>Jumping jacks | Week 6 | Standing high jump<br>Squat jump<br>Run in place<br>Scissors (“paper-scissors”) bounce back and forth<br>Single-leg forward and backward jump<br>Back kick |
| Week 3 | Jump in place (clap legs with both hands)<br>Jump forward and backward (raise arms)<br>Jump left and right<br>Hop on one foot<br>Jumping jacks<br>High leg raises | Week 7 | Standing high jump<br>Squat jump<br>Scissors (“paper-scissors”) bounce<br>Single-leg forward and backward jump<br>High leg lift<br>Jumping jacks |
| Week 4 | Jump in place (cross arms)<br>Jogging<br>Scissors (“paper-scissors”) bounce<br>Single-leg hop<br>Jumping jacks<br>Back kick | Week 8 | Standing high jump<br>High knee lift<br>Scissors bounce back and forth<br>Single-leg forward and backward jump<br>Jumping jacks<br>Back kick |

Participants in the control group were instructed to maintain their usual daily lifestyle and did not engage in any structured exercise programme during the study period. To provide basic health support and reduce attrition, the control group received a weekly 30-minute health education video addressing sedentary behaviour and general physical activity recommendations. After completion of all outcome assessments, participants in the control group were offered access to the same mini-trampoline training protocol in accordance with ethical considerations.

### *Analysis*

Data were analysed using SPSS version 29.0 (SPSS Inc., Chicago, IL, USA). Data normality was assessed using the Shapiro–Wilk test. Normally distributed variables are presented as mean ± standard deviation, and non-normally distributed variables as median (interquartile range). Within-group comparisons were performed using paired t-tests or Wilcoxon signed-rank tests, and between-group comparisons were conducted using independent-samples t-tests or Mann–Whitney U tests, as appropriate. Given the exploratory nature of this pilot study and the relatively small sample size, no formal adjustment for multiple comparisons was applied, and statistical significance was set at $p < .05$; therefore, the results should be interpreted cautiously.

## RESULTS

A total of 20 sedentary adults completed the study. The trampoline group (TG) consisted of seven men and three women with a mean age of 28.25 ± 4.94 years, while the control group (CG) included six men and four women with a mean age of 29.60 ± 4.03 years. No significant between-group differences were observed at the baseline in age, sex distribution, anthropometric variables, or any outcome measures, indicating comparable baseline characteristics between the two groups (all $p > .05$).

For muscle strength outcomes (Table 2), within-group analyses demonstrated significant post-intervention increases in neck flexor, neck extensor, and knee muscle strength in the TG ($p < .001$), whereas no significant changes were observed in the CG ($p > .05$). No significant between-group differences were detected at the baseline for these variables. At post-intervention, neck flexor and extensor muscle strength were significantly greater in the TG compared with the CG (both $p < .001$). Knee muscle strength was also higher in the TG than the CG; however, this between-group difference did not reach statistical significance ($p = .086$).

Table 2. Changes in neck and knee muscle strength before and after the intervention.

| Outcome | Group | Before (Mean ± SD) | After (Mean ± SD) | Within-group t | *p*-value | Between-group t (After) | *p*-value |
|---|---|---|---|---|---|---|---|
| Neck flexor muscle strength (N) | CG | 98.59 ± 3.06 | 99.32 ± 2.60 | −1.05 | .319 | −8.23 | <.001 |
| | TG | 97.37 ± 4.03 | 103.76 ± 4.46 | −9.98 | <.001 | | |
| Neck extensor muscle strength (N) | CG | 122.61 ± 6.59 | 121.61 ± 7.07 | 1.61 | .142 | −4.59 | <.001 |
| | TG | 119.70 ± 3.67 | 134.28 ± 5.12 | −15.65 | <.001 | | |
| Knee muscle strength (N) | CG | 438.1 ± 69.3 | 453.7 ± 81.8 | −1.30 | .227 | −1.82 | .086 |
| | TG | 442.0 ± 48.8 | 515.0 ± 68.6 | −5.97 | <.001 | | |

*Note. Values are presented as mean ± standard deviation. Within-group comparisons were performed using paired t-tests. Between-group comparisons were performed using independent-samples t-tests. Statistical significance was set at p < .05. CG = control group; TG = trampoline group.*

Regarding the knee and cervical range of motion (Table 3), no significant within-group changes were observed in the CG for any knee or cervical range of motion variables (all $p > .05$). In the TG, significant within-group improvements were observed for the knee range of motion, including left knee flexion and extension (both $p < .001$), right knee flexion ($p < .001$), and right knee extension ($p = .027$). Similarly, the cervical range of motion in the TG showed significant within-group increases, with improvements observed in lateral flexion ($p = .002$), rotation ($p < .001$), extension ($p < .001$), and flexion ($p = .015$). Between-group comparisons showed no significant baseline differences in any knee or cervical range of motion measures. After the intervention, the TG demonstrated significantly greater left knee flexion ($p < .001$), left knee extension ($p = .013$), and right knee extension ($p = .001$) than the CG, whereas no significant between-group difference was detected for right knee flexion ($p = .144$). At post-intervention, a significant between-group difference was observed for cervical lateral flexion ($p = .045$); however, no significant differences were detected for other cervical range of motion variables (all $p > .05$).

Table 3. Changes in knee and neck range of motion before and after the intervention.

| Outcome | Group | Before (Mean ± SD) | After (Mean ± SD) | Within-group t | *p*-value | Between-group t (After) | *p*-value |
|---|---|---|---|---|---|---|---|
| Left knee flexion (°) | CG | 122.74 ± 5.69 | 122.32 ± 7.01 | 0.65 | .534 | −4.29 | <.001 |
| | TG | 123.52 ± 8.97 | 139.88 ± 10.89 | −15.73 | <.001 | | |
| Left knee extension (°) | CG | 2.83 ± 1.05 | 2.26 ± 1.36 | 1.75 | .113 | −2.76 | .013 |
| | TG | 3.21 ± 1.70 | 4.32 ± 1.93 | −7.12 | <.001 | | |
| Right knee flexion (°) | CG | 119.87 ± 8.77 | 119.67 ± 9.67 | 0.15 | .883 | −1.53 | .144 |
| | TG | 120.82 ± 11.13 | 127.55 ± 13.15 | −7.66 | <.001 | | |
| Right knee extension (°) | CG | 3.11 ± 0.94 | 2.74 ± 1.51 | 1.32 | .220 | −3.88 | .001 |
| | TG | 3.51 ± 1.11 | 4.70 ± 0.52 | −2.64 | .027 | | |
| Neck lateral flexion (°) | CG | 42.05 ± 4.57 | 41.28 ± 4.19 | 0.84 | .421 | −2.15 | .045 |
| | TG | 42.03 ± 2.92 | 45.33 ± 4.22 | −4.44 | .002 | | |
| Neck rotation (°) | CG | 64.65 ± 6.34 | 65.37 ± 7.02 | -0.96 | .361 | -1.66 | .115 |
| | TG | 65.51 ± 4.94 | 70.08 ± 5.60 | -13.39 | <.001 | | |
| Neck extension (°) | CG | 42.27 ± 11.34 | 42.33 ± 11.90 | −0.08 | .937 | −1.57 | .134 |
| | TG | 44.72 ± 9.17 | 50.11 ± 10.22 | −5.89 | <.001 | | |
| Neck flexion (°) | CG | 54.33 ± 4.15 | 55.73 ± 3.88 | −1.86 | .096 | 1.68 | .110 |
| | TG | 48.05 ± 5.87 | 51.04 ± 7.91 | −3.00 | .015 | | |

*Note. Values are presented as mean ± standard deviation. Within-group comparisons were performed using paired t-tests. Between-group comparisons were performed using independent-samples t-tests. Statistical significance was set at p < .05. CG = control group; TG = trampoline group.*

Table 4. Changes in body composition, knee cartilage thickness, and dynamic balance before and after the intervention.

| Outcome | Group | Before (Mean ± SD) | After (Mean ± SD) | Within-group t | *p*-value | Between-group t (After) | *p*-value |
|---|---|---|---|---|---|---|---|
| Left knee cartilage thickness (mm) | CG | 2.89 ± 0.43 | 2.86 ± 0.40 | 1.41 | .193 | −0.76 | .460 |
| | TG | 2.94 ± 0.32 | 2.98 ± 0.30 | −1.50 | .168 | | |
| Right knee cartilage thickness (mm) | CG | 3.08 ± 0.21 | 3.04 ± 0.25 | 1.07 | .309 | −0.71 | .487 |
| | TG | 3.10 ± 0.20 | 3.11 ± 0.18 | -0.26 | .798 | | |
| Sit-and-reachtest (cm) | CG | 14.70 ± 4.41 | 14.99 ± 5.08 | −0.45 | .666 | −0.43 | .674 |
| | TG | 14.84 ± 5.33 | 16.14 ± 6.81 | −1.40 | .194 | | |
| Skeletal muscle mass (kg) | CG | 26.60 ± 4.37 | 27.37 ± 4.51 | −0.54 | .602 | 0.16 | .871 |
| | TG | 26.67 ± 5.10 | 27.02 ± 4.97 | −2.26 | .050 | | |
| Body fat mass (kg) | CG | 19.85 ± 1.04 | 19.85± 0.88 | −0.00 | 1.000 | -0.83 | .422 |
| | TG | 20.91 ± 2.19 | 20.40 ± 1.90 | 2.63 | .027 | | |
| SEBT Left – Anterior (cm) | CG | 78.20 ± 7.77 | 78.30 ± 7.29 | −0.13 | .899 | −1.33 | .201 |
| | TG | 74.40 ± 8.11 | 82.90 ± 8.20 | −9.22 | <.001 | | |
| SEBT Left – Posteromedial (cm) | CG | 66.60 ± 8.68 | 66.80 ± 9.80 | −0.23 | .820 | −0.94 | .357 |
| | TG | 65.40 ± 9.51 | 71.20 ± 11.00 | −6.41 | <.001 | | |
| SEBT Left – Posterolateral (cm) | CG | 68.00 ± 6.25 | 68.30 ± 7.13 | −0.35 | .734 | 0.00 | 1.000 |
| | TG | 63.40 ± 4.14 | 68.30 ± 5.38 | −7.65 | <.001 | | |
| SEBT Composite score – Left | CG | 0.81 ± 0.05 | 0.82 ± 0.05 | −0.47 | .652 | −1.22 | .236 |
| | TG | 0.78 ± 0.07 | 0.85 ± 0.08 | −14.35 | <.001 | | |
| SEBT Right – Anterior (cm) | CG | 72.80 ± 6.78 | 72.40 ± 7.71 | 0.39 | .705 | −3.51 | .003 |
| | TG | 73.20 ± 4.96 | 83.40 ± 6.24 | −8.25 | <.001 | | |
| SEBT Right – Posteromedial (cm) | CG | 69.20 ± 6.39 | 69.30 ± 7.33 | −0.16 | .876 | −1.60 | .126 |
| | TG | 68.50 ± 8.81 | 76.00 ± 10.99 | −9.15 | <.001 | | |
| SEBT Right – Posterolateral (cm) | CG | 60.90 ± 6.84 | 61.00 ± 6.99 | −0.36 | .726 | −2.58 | .019 |
| | TG | 62.90 ± 3.90 | 67.40 ± 3.57 | −7.73 | <.001 | | |
| SEBT Composite score – Right | CG | 0.78 ± 0.05 | 0.77 ± 0.06 | 0.22 | .831 | −3.77 | .001 |
| | TG | 0.78 ± 0.05 | 0.87 ± 0.05 | −16.72 | <.001 | | |

*Note. Values are presented as mean ± standard deviation. Within-group comparisons were performed using paired t-tests. Between-group comparisons were performed using independent-samples t-tests. Statistical significance was set at p < .05. CG = control group; TG = trampoline group.*

For knee cartilage thickness, body composition, and dynamic balance outcomes (Table 4), no significant within-group or between-group differences were observed for knee cartilage thickness or sit-and-reach performance (all $p > .05$). In terms of body composition, the TG demonstrated a significant reduction in body fat mass ($p = .027$) , whereas the increase in skeletal muscle mass approached but did not reach statistical significance ($p = .050$). No significant changes in body composition variables were observed in the CG (all $p > .05$). However, no significant between-group differences were detected for body composition variables at post-intervention (all $p > .05$). Regarding dynamic balance, significant within-group improvements were observed in all Star Excursion Balance Test (SEBT) directions and composite scores for both limbs in the TG (all $p < .001$), while no significant changes were detected in the CG. Post-intervention between-group comparisons showed significant differences for right anterior reach ($p = .003$), right posterolateral reach ($p = .019$), and right composite score ($p = .001$), whereas other SEBT variables did not differ significantly between groups (all $p > .05$).

Table 5. Changes in pain intensity, handgrip strength, and heart rate variability before and after the intervention.

| Outcome | Group | Baseline | Post-intervention | Within-group Z | *p*-value | Between-group Z (Post) | *p*-value |
|---|---|---|---|---|---|---|---|
| VAS | CG | 7.00 (6.25, 7.00) | 7.00 (7.00, 8.00) | 0.246 | .792 | −2.993 | .003 |
| | TG | 7.00 (7.00, 7.00) | 5.50 (4.25, 6.00) | −2.859 | .004 | | |
| Left handgrip (kg) | CG | 30.97 (30.43, 31.57) | 31.03 (29.33, 31.39) | −1.326 | .185 | −0.605 | .545 |
| | TG | 30.98 (28.89, 31.64) | 30.35 (28.66, 31.38) | −0.700 | .484 | | |
| Right handgrip (kg) | CG | 29.60 (27.56, 31.33) | 29.98 (28.36, 31.39) | 0.949 | .343 | 1.097 | .273 |
| | TG | 31.38 (30.22, 31.47) | 31.33 (31.21, 31.62) | 1.887 | .059 | | |
| RMSSD (ms) | CG | 43.01 (41.27, 45.88) | 43.73 (40.96, 50.78) | 0.459 | .646 | 1.965 | .049 |
| | TG | 39.70 (36.76, 47.63) | 53.19 (50.49, 55.80) | 2.701 | .007 | | |
| LF/HF | CG | 2.13 (1.71, 2.27) | 2.09 (1.71, 2.29) | 0.051 | .959 | −2.043 | .041 |
| | TG | 1.87 (1.67, 2.40) | 1.49 (1.12, 1.86) | −2.805 | .005 | | |
| SDNN (ms) | CG | 45.00 (44.25, 45.75) | 45.00 (44.25, 46.75) | 0.318 | .750 | 3.791 | <.001 |
| | TG | 44.50 (43.00, 45.00) | 63.50 (61.25, 64.75) | 2.807 | .005 | | |
| HF ($ms^2$) | CG | 420.00 (413.25, 421.75) | 406.50 (396.25, 419.50) | −0.867 | .386 | −3.781 | <.001 |
| | TG | 414.50 (400.75, 429.50) | 973.00 (956.75, 984.50) | 2.803 | .005 | | |

*Notes: Values are presented as median (25th – 75th percentiles). Within-group comparisons were performed using the Wilcoxon signed-rank test. Between-group comparisons were performed using the Mann–Whitney U test. Z values correspond to the Wilcoxon signed-rank test (within-group) and the Mann–Whitney U test (between-group). CG = control group; TG = trampoline group.*

Pain intensity, handgrip strength, and autonomic nervous system indices are presented in Table 5. Pain intensity, assessed using the VAS, decreased significantly in the TG after the intervention ($p = .004$), whereas no significant change was observed in the CG (p = .792). A significant between-group difference in VAS scores was observed at post-intervention ($p = .003$). No significant within-group or between-group differences were found for left or right handgrip strength (all $p > .05$). For heart rate variability indices, the TG exhibited significant post-intervention increases in RMSSD, SDNN, and HF, along with a significant reduction in the LF/HF ratio (all $p < .01$), whereas no significant changes were observed in the CG. Between-group comparisons at post-intervention demonstrated significant differences for RMSSD ($p = .049$), LF/HF ratio ($p = .041$), SDNN ($p < .001$), and HF ($p < .001$).

## DISCUSSION

This study evaluates the short-term effects of an eight-week mini-trampoline exercise programme on musculoskeletal function, pain, body composition, dynamic balance, and autonomic regulation in sedentary adults. Overall, the findings suggest an association between the intervention and improvements in neck and knee muscle strength, selected knee and cervical range-of-motion outcomes, reduced pain intensity, and favourable changes in HRV. In contrast, no measurable changes in knee cartilage thickness or sit-and-reach flexibility were observed during the intervention period. These findings support the feasibility and potential functional benefits of mini-trampoline exercise in sedentary adults.

Improvements in neck flexor and extensor strength were among the most consistent findings, with clear between-group differences observed after the intervention. These strength gains are consistent with the postural control demands of rebound exercise, which requires continuous head–trunk stabilisation and may enhance the neuromuscular recruitment of cervical stabilising muscles. This interpretation aligns with previous reports linking sedentary behaviour to altered cervical mechanics and studies indicating that trampoline-based training can improve neck-related function (Jeon et al., 2012; Liu et al., 2015; Mekhora et al., 2000).

Knee muscle strength also increased significantly within the trampoline group. However, the absence of a statistically significant between-group difference at post-intervention suggests that this pilot study may have been underpowered to detect moderate group effects. Given prior evidence supporting the effects of trampoline-based training on knee-related performance (Tay et al., 2019), the observed within-group improvements are biologically plausible and warrant confirmation in larger trials designed to detect between-group differences.

Mini-trampoline training was further associated with improvements in several knee and cervical range of motion measures, whereas no meaningful changes were observed in the control group. Between-group advantages were most evident for left knee flexion and extension, right knee extension, and cervical lateral flexion and rotation, while other range-of-motion outcomes did not differ significantly between groups. These selective improvements suggest that repeated low-impact movement cycles and continuous postural adjustments may preferentially enhance mobility in movement directions most engaged during training, which is consistent with task-specific adaptations reported following balance- and movement-based exercise interventions (Pagan et al., 2024). Given the exploratory nature of this pilot trial, these findings should be interpreted cautiously and hypothesis-generating rather than confirmatory.

Pain intensity decreased significantly following the intervention, with lower post-intervention pain levels observed in the trampoline group compared with controls. This reduction may reflect non-specific exercise-related mechanisms, such as improved neuromuscular control and altered pain modulation, as suggested in previous studies (Rathi et al., 2024; Sarelius & Pohl, 2010; Shiro & Matsubara, 2017). In contrast, consistent with the principle of training specificity, handgrip strength did not change, as the intervention primarily targeted lower-limb loading and balance-related tasks.

With respect to body composition, the trampoline group demonstrated a reduction in body fat mass, whereas the increase in skeletal muscle mass did not reach statistical significance, with no significant between-group differences observed at post-intervention. These findings may indicate early metabolic or compositional adaptations but do not support definitive group-level effects within the constraints of this small pilot sample (Thyfault & Bergouignan, 2020) (Kolnes et al., 2021). Similarly, no changes in knee cartilage thickness were detected. This is plausible given the short intervention duration and the slow structural adaptation of cartilage tissue, which likely requires longer-term mechanical exposure to produce detectable morphological changes (Welhaven et al., 2022).

Dynamic balance improved substantially within the trampoline group across Star Excursion Balance Test outcomes, while between-group differences were limited to selected right-sided measures. Such limb- and direction-specific effects may be influenced by factors such as sample size, limb dominance, and baseline variability and should therefore be interpreted as preliminary. In contrast, sit-and-reach performance did not change, a finding consistent with the training characteristics of mini-trampoline exercise, which emphasise dynamic postural control and functional movement rather than sustained end-range stretching. Without targeted flexibility-oriented stimuli, improvements in static flexibility may be limited, as reported previously (Rathi et al., 2024).

Finally, coordinated improvements were observed in HRV indices, including increases in RMSSD, SDNN, and HF, alongside a reduction in the LF/HF ratio, with significant post-intervention differences in comparison to controls. Collectively, these changes are consistent with enhanced parasympathetic modulation and improved sympathovagal balance, suggesting that mini-trampoline exercise may exert beneficial effects on autonomic regulation in sedentary adults, in line with previous evidence demonstrating improvements in cardiac autonomic modulation following regular exercise interventions.

Importantly, no exercise-related adverse events or safety concerns were reported throughout the intervention period, indicating that the mini-trampoline programme was well tolerated by sedentary participants (Sánchez-Delgado et al., 2023). The present pilot findings support the feasibility and potential multi-domain benefits of mini-trampoline exercise. However, larger, prospectively registered randomised controlled trials with longer intervention and follow-up periods are required to confirm these preliminary observations and to characterise dose–response relationships and adherence effects.

Several limitations should be acknowledged. The small sample size of this pilot study limited its statistical power. Although the eight-week intervention was sufficient to induce functional and physiological adaptations, it may have been insufficient to capture slower structural changes, such as alterations in knee cartilage thickness or more pronounced body composition remodelling. In addition, the findings are limited to sedentary young adults, which may restrict generalisability. Although outcome assessors were blinded to group allocation (single-blinded design), participant blinding was not feasible due to the nature of the exercise intervention, which may have introduced performance or expectation bias.

## CONCLUSIONS

An eight-week mini-trampoline exercise programme was associated with improvements in musculoskeletal function, balance, pain, and autonomic regulation in sedentary adults. These preliminary findings support the feasibility of mini-trampoline exercise and warrant confirmation in larger, long-term randomised controlled trials.

## AUTHOR CONTRIBUTIONS

Yuan Xie conceived the study, coordinated participant recruitment and data collection, delivered the intervention, performed the statistical analyses, and drafted the manuscript. Prof. Dr. Wichai Eungpinichpong supervised the study, contributed to the study design and methodology, guided interpretation of the findings, and critically revised the manuscript for important intellectual content. Asst. Prof. Dr. Nichanun Panyaek contributed to the study design and intervention planning, supported data interpretation, and reviewed and revised the manuscript. All authors approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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