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RESEARCH

Comparison of physiological and psychological outcomes between mineral panning dance exercise and traditional aerobic exercise among sedentary young adults

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Abstract

Purpose Physical inactivity increases health risks, and enjoyable, culturally rooted activities may help promote movement among sedentary young adults. However, the acute physiological and psychological responses to Applied Mineral Panning Dance (AMPD) have not been compared with traditional aerobic exercise. In this study, we examined the acute effects of AMPD versus treadmill walking (TW) on activity energy expenditure, heart rate, flexibility, enjoyment, and perceived exertion.

Methods Twenty participants (aged 23.45 ± 5.09 years) completed AMPD and TW sessions in a counterbalanced, crossover design with a washout period. Flexibility was assessed at baseline and after each activity. Paired t tests were used to compare activity energy expenditure, heart rate, enjoyment, and rating of perceived exertion between conditions. One-way repeated-measures analysis of variance was conducted to assess changes in flexibility, with Bonferroni corrections for post hoc comparisons.

Results The dance activity resulted in greater post-session improvements in right-sided back-scratch test scores, compared with TW. Sit-and-reach and back-scratch scores improved from baseline following the dance session, with no such changes after walking. Dance elicited higher heart rates, enjoyment, and ratings of perceived exertion than walking did. Nonetheless, activity energy expenditure did not differ between exercise forms.

Conclusion AMPD produced greater short-term improvements in flexibility, heart rate, and enjoyment than TW did, supporting its value as a culturally relevant and engaging exercise alternative.

Keywords Applied mineral panning dance · Treadmill walking · Flexibility · Activity energy expenditure · Enjoyment

Introduction

Sedentary behavior in adults is related to elevated risks of cardiovascular disease, stroke, hypertension, certain cancers, musculoskeletal conditions, cognitive decline, sleep disturbances, and metabolic disorders, such as obesity and type 2 diabetes mellitus [1–6]. It also contributes to functional impairments, including poor balance, impaired coordination, and decreased muscle strength [3, 7]. This behavioral pattern is particularly prevalent among young adults, driven by academic demands, prolonged screen exposure, and social interactions via digital platforms. This demographic is especially vulnerable, as excessive sedentary time is associated with adverse physical and psychological health outcomes [8, 9].

Given these concerns, movement-based activities such as dancing are common. Dancing integrates movements and music and is enjoyed across all age groups, promoting physiological homeostasis by enhancing metabolic and muscular endurance, strength, body composition, coordination, balance, and joint function [10–12]. As a complementary

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therapy, dancing may benefit physical and psychological conditions, including anxiety, depression, cardiovascular disease, and cancer [13, 14]. Recent research demonstrated that a single, culturally relevant session of Brazilian recreational dance reduced systolic blood pressure by approximately 10 mmHg within 30–60 min post-exercise in women with overweight/obesity, highlighting the potential of dance-based interventions to improve cardiovascular health in at-risk populations [15].

An example of a culturally rooted dance-based activity in Thailand is "mineral panning dance," which evolved from a cultural practice in which local communities developed specialized skills tied to their occupations. Mineral panning, once a widespread livelihood, gradually declined following the closure of mining operations in Phuket, Ranong, and other coastal provinces of the Andaman Sea in southern Thailand. Mineral panning dance movements reflect occupational tasks, such as shoulder carrying, stomping, digging, scooping, panning, and shaking of minerals using the *Liang*, a pan-shaped apparatus (Fig. 1).

Highlighting its cultural and historical importance, mineral panning dance has potential physical benefits, including full-body movement, rotation, and static and dynamic balance. Therefore, applied mineral panning dance (AMPD), a form of mineral panning dance, may help younger generations recall traditional practices while enjoying physical activity.

Fig. 1 An individual holding the original ancient *Liang* apparatus

Culturally inspired exercises, such as AMPD, promote health and help preserve aspects of heritage; however, comparisons with more commonly practiced physical activities can help establish evidence of health benefits. Among these, walking—including treadmill walking (TW)—is recommended for its simplicity, affordability, and widespread acceptance, essentially boosting energy and positively impacting health. Moreover, walking is a safe and effective lifestyle activity for managing abdominal obesity [16]. The American College of Sports Medicine (ACSM) recommends engaging in a 30-min brisk walk 5 days a week [17]. Walking minimizes stress on the musculoskeletal system, compared with activities such as running.

Nevertheless, traditional forms of physical activity may not appeal to all individuals, particularly those seeking more stimulating and enjoyable exercise experiences. This is often the case among adults who aim to enhance well-being and avoid detrimental health consequences associated with physical inactivity. Consequently, there has been growing interest in interactive forms of physical activity that enhance motivation and engagement. In recent years, such modalities have gained attention for their potential to sustain participation, especially among younger populations [18–21].

To contextualize the focus of the current study on a dance-based intervention, prior research on interactive exercise formats, such as exergaming, can serve as a useful point of reference for physiological and psychological comparisons. Exergaming involves digital games that require physical movement in response to visual stimuli [22], with common tasks including dance or sport-like movements. A previous study on the effects of exergaming on energy expenditure (EE), rating of perceived exertion (RPE), and enjoyment experienced by college students compared these with traditional treadmill exercises [20]. TW produced a higher mean EE than that of exergaming sessions. Nevertheless, exergaming is more enjoyable, producing lower RPEs than that of treadmill sessions.

Energy expenditure was also among the variables [19] used to compare dance-based exergaming with instructor-led aerobic dance. They observed similar EE, as well as higher enjoyment and self-efficacy among their college student participants. The findings indicate that college students achieve comparable EE to that of traditional aerobic dance sessions, while reporting higher levels of enjoyment. Another study examined the caloric expenditure of college students during two activities (folk dancing and walking) and revealed no notable differences in energy output [23]. Collectively, these findings indicate that dance-based or rhythm-based activities can generate EE levels comparable to those of traditional aerobic exercise while often producing more positive psychological responses.

Flexibility is an essential component of physical fitness. Prior studies have shown that dance training enhances joint range of motion and flexibility across various populations [24, 25]. Given that AMPD incorporates rhythmic upper and lower body movements, it may similarly improve flexibility.

To the best of our knowledge, the acute effects of AMPD, involving the *Liang* apparatus, compared with TW, on physiological and psychological responses in young adults have not been examined. The same rhythmic beats can be used to control intensity in AMPD and TW exercises, allowing direct comparisons between the two modalities. Consequently, we aimed to compare these exercises based on activity energy expenditure (AEE), heart rate (HR), flexibility, and enjoyment, while minimizing RPE.

Methods

Ethical approval and informed consent

This study was approved by the appropriate Human Research Ethics Committee (approval no. PKRU2566/22) on December 4, 2023, and conducted in accordance with the principles of the Declaration of Helsinki and the Consolidated Standards of Reporting Trials guidelines. After a detailed explanation of the exercise protocols and experimental procedures, all participants provided written consent to participate in this study.

Study design

Participants were recruited from a university in Asia. The inclusion criteria were as follows: (1) age of 20–40 years; (2) no exercise > twice a week for at least 6 months prior to study participation; (3) no smoking; (4) no issues with vision, hearing, or vestibular function; (5) no tranquilizer or antidepressant use affecting balance; (6) no unstable or ongoing respiratory or cardiovascular disorders; (7) no musculoskeletal or neurological diseases or impairments; and (8) no history of injury within the previous year. These criteria focused on healthy young adults whose activity patterns were consistent with a sedentary lifestyle.

The sample size for the analysis was determined using G*power software (Heinrich Heine University Düsseldorf, Germany), specifically by conducting t tests to assess differences between two dependent means (matched pairs). An effect size (ES) of 0.99 was derived from a previous study by McDonough et al. [20]. This prior comparison was used, because AMPD shares rhythmic and interactive features with exergaming, making it a relevant proxy for estimating effect size in our crossover design.

An a priori sample size calculation indicated that at least 13 participants were required to detect observed differences with 90% power. To account for potential withdrawals, the sample size was increased by 7, bringing the total number to 20 participants. None of the participants withdrew from the study. Participants were categorized as sedentary adults based on their average physical activity level (PAL) values, which fell within the sedentary range (PAL = 1.0–1.39) [26]. The participants' PAL data are presented in Table 1.

Before the exercise sessions began, the Physical Activity Readiness Questionnaire Plus (PAR-Q+) [27] was administered to assess participants' health and readiness. The PAR-Q+ was used to identify any health condition that could be aggravated by increased activity. All participants were deemed eligible to participate in the exercise sessions.

In the crossover design of the current study, we evaluated the effects of two aerobic exercises on AEE, HR, flexibility, enjoyment, and RPE. Participants were randomly assigned to complete either AMPD followed by TW, or TW followed by AMPD, within a 5-week program. A 1-week washout period separated the two conditions to minimize carryover effects. A detailed overview of the session structure, crossover sequence, and timeline is provided in Fig. 2.

Preliminary testing

Approximately 48 h after completing the flexibility assessment, each participant received instructions and a brochure on using the Actiheart 5 device (CamNtech Ltd., Cambridge, UK) and then recorded their daily AEE for 4 consecutive days, which served to monitor their free-living physical activity levels and obtain PAL values in this preliminary phase.

Biometric data

Biometric data included body weight, height, body mass index, body fat percentage, resting blood pressure, and resting HR. Body weight and fat percentage were measured using a body composition analyzer (Tanita MC-780 MA,

Table 1 Baseline characteristics of the participants

Biometric characteristics (*N* = 20; female = 18)	Mean ± SD
Age (years)	23.45 ± 5.09
Body weight (kg)	66.91 ± 21.60
Height (cm)	160.50 ± 6.54
Body mass index (kg/m^2)	27.65 ± 10.18
Body fat percentage (%)	35.47 ± 7.70
Resting heart rate (bpm)	86.90 ± 16.96
Daily energy expenditure (cal)	2,039.45 ± 559.37
PAL	1.38 ± 0.15

SD, standard deviation; bpm, beats per minute; cal, calories; PAL, physical activity level

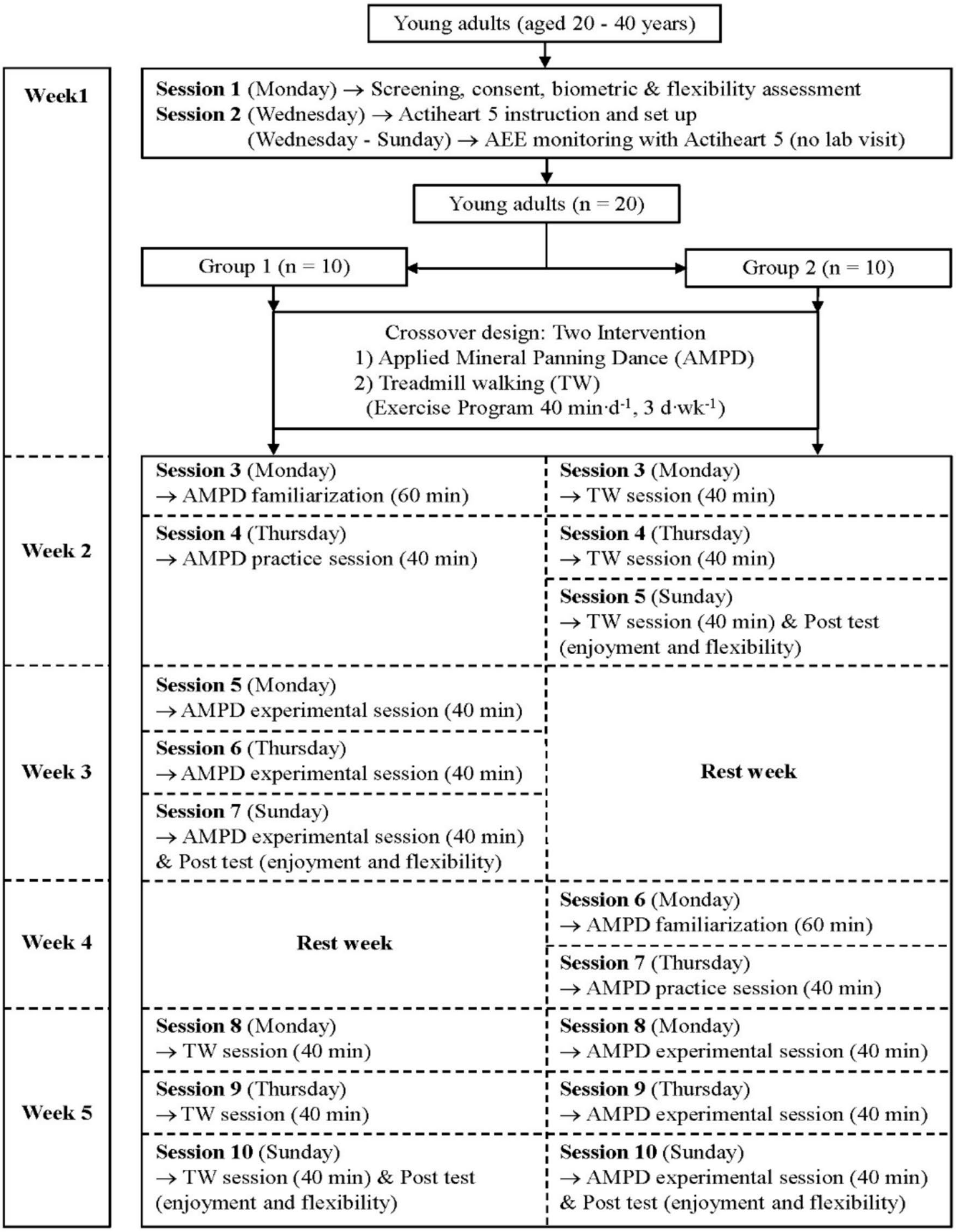

Fig. 2 Flowchart of the experimental procedures. AEE, activity energy expenditure

Tanita Corp., Tokyo, Japan). Each participant rested by sitting for approximately 5 min before blood pressure measurement, and resting HR was measured using an OMRON HEM-7120 monitor (Omron Healthcare Corp., Kyoto, Japan).

Flexibility assessment

Flexibility was assessed using the sit-and-reach and back-scratch tests. Baseline measurements for all participants were obtained during week 1 (Fig. 2, day 1). The assessments were subsequently repeated after the third session for each experimental condition. Participants assigned to the AMPD-first sequence were reassessed on week 3, day 7 (AMPD) and again on week 5, day 10 (TW), whereas those allocated to the TW-first sequence were reassessed on week 2, day 5 (TW) and week 5, day 10 (AMPD). The sit-and-reach box test (FBT 69302, Football Thai Factory Sporting Goods Corp., Bangkok, Thailand) was employed to assess hip and lower back flexibility as per the ACSM guidelines [28]. The better result of the two trials was recorded.

The back-scratch test, using a stainless-steel ruler (Orca 29,411, Orca Corp., Bangkok, Thailand), was used to assess bilateral shoulder flexibility, as per procedures previously described by Fukuda [29]. The better result of the two trials was recorded.

Exercise testing protocol

During the exercise testing week, participants engaged in AMPD or TW sessions on 3 separate days, with a 72-h interval between sessions to allow for adequate recovery time. To ensure accurate AEE results, participants were instructed to eat a meal 2 h before each session, avoid caffeine and alcohol consumption for 24 h prior, and refrain from exercise for 24–48 h before testing [30]. Furthermore, participants were instructed to ensure adequate sleep before each exercise session. All AMPD sessions were conducted in a mirrored exercise studio (approximately 50 m^2), whereas TW sessions took place in a climate-controlled fitness center. Both rooms were maintained at 25 °C and 45–55% relative humidity.

On the first, second, and third days of AMPD and TW sessions, AEE and HR were recorded. RPE was assessed after each session. AEE, HR, and RPE data collected over the 3 measurement days were aggregated to obtain a single mean value. Evaluation of enjoyment was conducted only on the third day after completing AMPD and TW.

AMPD condition

AMPD postures were developed by a university department specializing in performing arts. AMPD program validity was assessed using the Item Objective Congruence Index [31], supported by item analysis from four external experts in kinesiology, physiology, and dance exercise. Each 40-min exercise session included three phases: a 10-min warm-up, 20-min workout, and 10-min cool-down. The warm-up included 5 min of basic dance movements without the *Liang* apparatus, performed to music at 125 beats per minute (bpm), followed by 5 min of general stretching.

To control for extraneous variables affecting AEE, HR, and flexibility, AMPD and TW warmups were conducted at 125 bpm during light aerobic activity. Moreover, both conditions utilized the same stretching postures during the warm-up and cool-down phases. The cool-down mirrored the warm-up: 5 min of basic dance movements without the *Liang* apparatus at 125 bpm, followed by 5 min of general stretching.

The AMPD session included nine postures, presented in Fig. 3. During the workout phase, music was played at 130 bpm and followed a consistent 32-beat structure, divided into four phases of eight beats each. Steps for each posture were choreographed to synchronize with these eight-beat segments. This tempo was selected for its suitability for novices and compatibility with movements involving the *Liang* apparatus, falling within the typical range for dance exercises [32]. The 130 bpm value indicates the music/metronome tempo used to standardize movement cadence in AMPD and TW. This tempo falls within the typical range used in aerobic dance programs [32] and was not intended to reflect physiological intensity; actual intensity was assessed using measured heart-rate responses.

The ring-shaped *Liang* apparatus employed in this study was made of stainless steel, as shown in Fig. 4, which depicts a participant using the modern device during an AMPD session. In contrast, Fig. 1 illustrates the original ancient version.

TW condition

Each 40-min TW exercise session included three phases: a 10-min warm-up, 20-min workout, and 10-min cool-down. The warm-up phase included 5 min of TW at 125 bpm and 5 min of general stretching. Subsequently, the workout phase consisted of TW for 20 min at 130 bpm set by a metronome. Consistent with the AMPD protocol, the 130 bpm value reflected cadence rather than physiological intensity, and actual exercise intensity was determined from measured heart-rate responses. Finally, the cool-down phase included 5 min of TW at 125 bpm, followed by 5 min of general stretching. All TW sessions were performed at a zero-degree incline.

Evaluation of AEE

The Actiheart 5, a single, lightweight, wearable device, was used to estimate the AEE by combining accelerometric and HR data. Participants wore the device during AMPD and TW sessions. The Actiheart device estimates AEE (kcal·min^{-1}) using branched-chain algorithms based on HR and triaxial accelerometry, as detailed in the Actiheart® user manual (UK version; Cambridge Neurotechnology, 2020), and has been validated for use in laboratory settings [33].

HR and activity levels were recorded in 15-s epochs to estimate the AEE during AMPD and TW sessions. After each session, the device was promptly removed, and the data were downloaded for analysis.

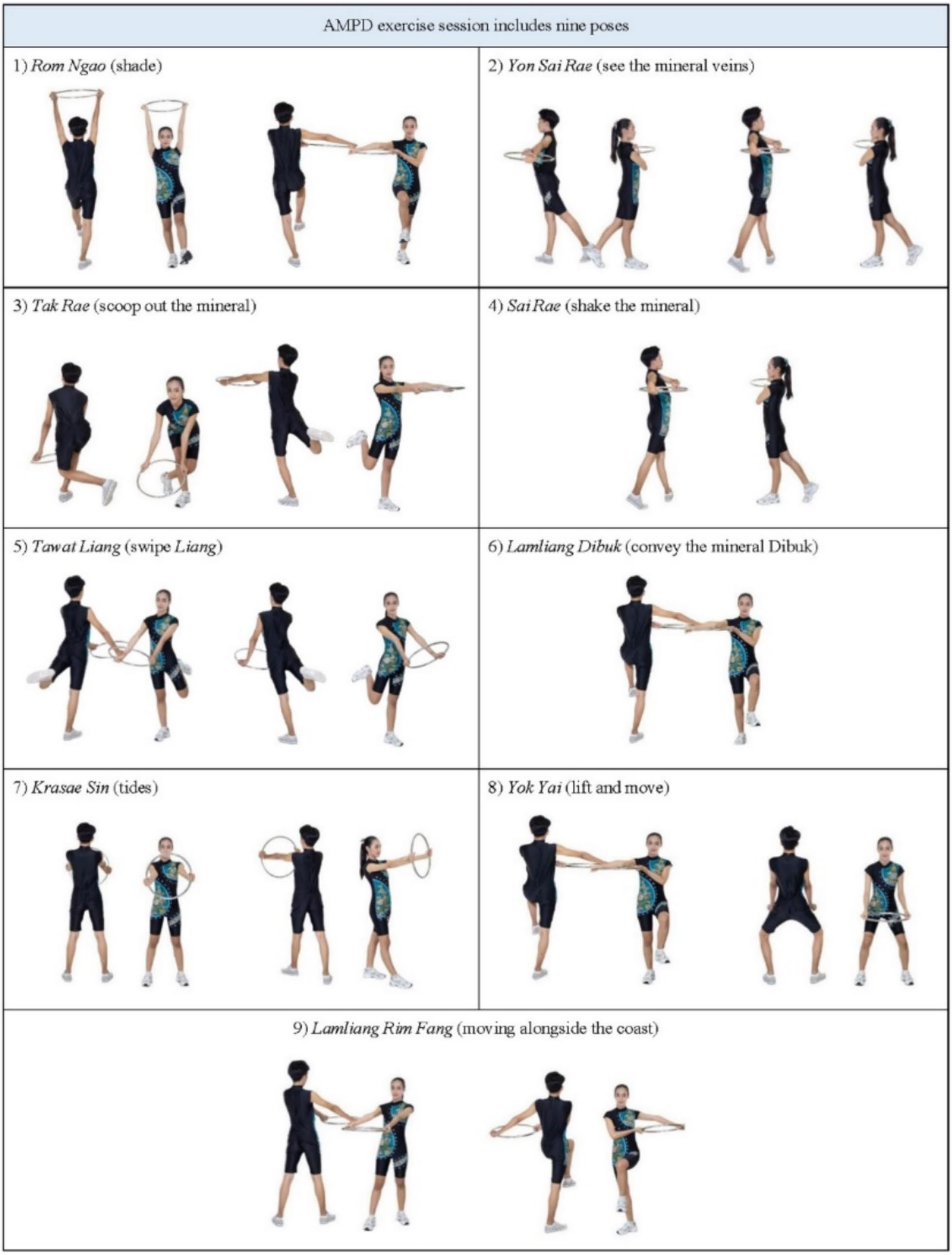

Fig. 3 Postures performed during the applied mineral panning dance (AMPD) exercise session

Fig. 4 A participant holding the *Liang* apparatus used in the applied mineral panning dance sessions

Perceptual enjoyment

After the third session of AMPD or TW, participants completed the Physical Activity Enjoyment Scale (PACES) questionnaire [34, 35]. This instrument has been validated across cultural contexts, including a German version that showed high internal consistency ($\alpha = 0.89$) and measurement invariance [36]. A European Portuguese adaptation of the full 18-item PACES also showed good composite reliability, convergent and concurrent validity, and measurement invariance across sex groups [37].

A total enjoyment score was computed by summing all 18 items, yielding a possible score range of 18–126, with higher scores indicating greater enjoyment.

RPE assessment

After completing each AMPD or TW session, participants were prompted to self-evaluate their perceived exertion using Borg's 6–20 Scale [38]. The RPE scale has shown reliability in most populations with a reliability range of 0.8–0.9 and has been validated against various physiological outcomes, such as blood lactate concentrations and HR [39].

Statistical analysis

Effect sizes (ESs) in the current study were calculated using Cohen's d_{av} method [40] for all dependent variables across baseline, TW, and AMPD conditions. Values were classified as trivial (< 0.50), small (0.50–1.25), moderate (1.25–1.9), or large (> 2.0) [41].

Prior to inferential analyses, potential period and carryover (sequence) effects associated with the randomized crossover design were formally assessed. The subsequent use of paired *t* tests and one-way repeated-measures ANOVA was considered appropriate, because no significant period effects or intervention × period interactions were observed (all $p > 0.05$).

Dependent variables for each exercise form are reported as means ± standard deviations (SDs). Paired t tests were conducted to compare AEE, HR, RPE, and enjoyment between AMPD and TW. Moreover, percentage differences were calculated for both conditions using the following formula:

$$\text{Percentage difference} = (\text{AMPD} - \text{TW}) \times 100/\text{TW}. \quad (1)$$

A one-way repeated-measures ANOVA was employed to compare flexibility across three within-subject conditions (Baseline, Post-AMPD, and Post-TW). Bonferroni multiple comparison tests were applied, where necessary, to identify statistically significant pairwise differences. All analyses were performed using IBM SPSS Statistics for Windows version 29.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at $p \leq 0.05$.

Supplementary methods

Details regarding PACES translation and validation, effect size reference for sample size estimation, Actiheart 5 setup and placement, PAL calculation, *Liang* apparatus specification, and musical instruments used for AMPD are provided in Online Resource 1.

Results

Twenty participants completed the study, of whom 18 were female. Table 1 presents the participants' baseline characteristics; the means of the variables under investigation are shown in Figs. 5, 6, 7, and 8.

Paired *t* tests revealed no significant differences in AEE between AMPD (mean = 86.35; SD = 34.80) and TW

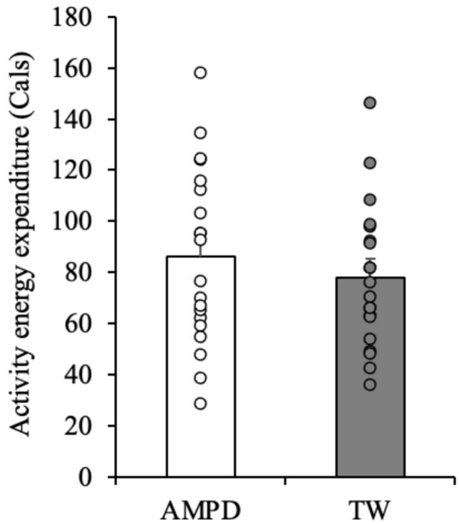

Fig. 5 Mean activity energy expenditure during the workout periods of the applied mineral panning dance (AMPD) and treadmill walking (TW) conditions

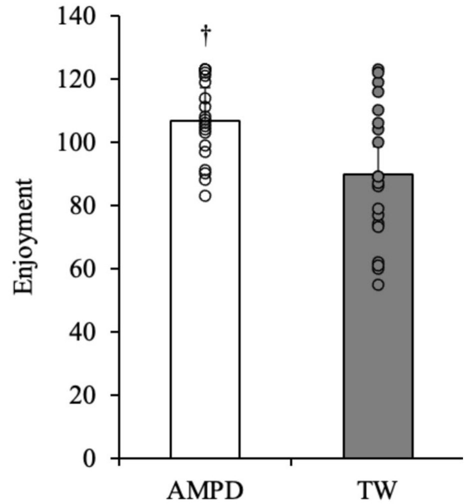

Fig. 7 Mean enjoyment scores for the applied mineral panning dance (AMPD) and treadmill walking (TW) conditions. †$p < 0.05$ indicates a significant difference between the two conditions

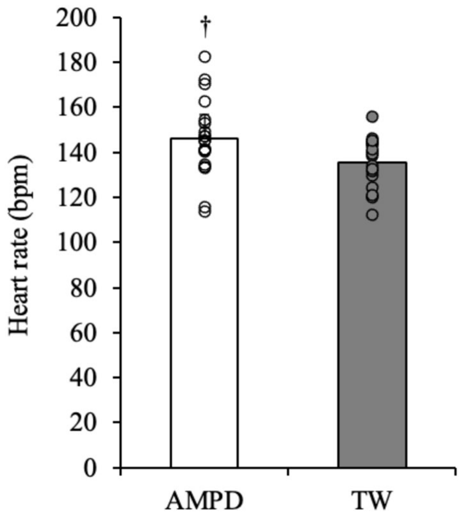

Fig. 6 Mean heart rate during the workout periods of the applied mineral panning dance (AMPD) and treadmill walking (TW) conditions. †$p < 0.05$ indicates a significant difference between the two conditions

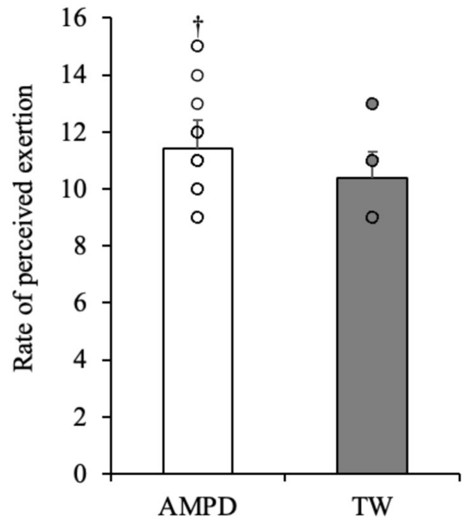

Fig. 8 Mean ratings of perceived exertion for the applied mineral panning dance (AMPD) and treadmill walking (TW) conditions. †$p < 0.05$ indicates a significant difference between the two conditions

(mean = 77.82; SD = 28.08) conditions, with a mean difference of 8.53 (95% CI −2.38 to 19.43) [t (19) = 1.64; $p = 0.118$] (Fig. 5). Nevertheless, the difference in HR between AMPD (mean = 146.18; SD = 17.05) and TW (mean = 135.41; SD = 11.26) conditions was significant, and the mean difference was 10.78 (95% CI: 5.21 to 16.34) [t (19) = 4.051; $p = 0.001$] (Fig. 6). A significant difference in enjoyment was observed between AMPD (mean = 106.85; SD = 12.72) and TW (mean = 89.60; SD = 21.99) conditions, with a mean difference of 17.25 (95% CI: 7.75 to 26.75) [t (19) = 3.801; $p = 0.001$] (Fig. 7), as was the difference in the RPE between AMPD (mean = 11.40; SD = 1.79) and TW (mean = 10.40; SD = 1.47) conditions, showing a mean difference of 1.30 (95% CI: 0.48 to 2.12) [t (19) = 2.179; $p = 0.042$] (Fig. 8). The percentage changes and ESs for all variables are shown in Tables 2 and 3, respectively.

Furthermore, flexibility scores from the back-scratch test markedly improved after AMPD sessions compared with those after TW sessions (Table 4). Post-AMPD scores notably exceeded baseline scores for the sit-and-reach and back-scratch tests. In contrast, flexibility scores after TW exercise

Table 2 Percentage changes in energy expenditure, heart rate, rate of perceived exertion, and enjoyment between applied mineral panning dance and treadmill walking conditions

Dependent variable	Percentage change TW to AMPD
Activity energy expenditure (cal)	10.96
Heart rate (bpm)	7.95
Enjoyment (score: 18–126)	19.25
Rate of perceived exertion (score: 6–20)	9.62

bpm, beats per minute; cal, calories; TW, treadmill walking; AMPD, applied mineral panning dance

Table 3 Effect sizes for exercise responses comparing applied mineral panning dance (AMPD) and treadmill walking (TW) conditions

Dependent variable	Effect size AMPD and TW
Activity energy expenditure (cal)	0.27
Heart rate (bpm)	0.76
Rate of perceived exertion (score: 6–20)	0.61
Enjoyment (score: 18–126)	0.99

bpm, beats per minute; cal, calories

did not differ substantially from baseline for any measure on either side. Percentage changes and ESs for flexibility variables are presented in Tables 5 and 6. As shown in Table 7, absolute mean differences indicated greater improvements in flexibility following AMPD than with TW, particularly for the back-scratch test, whereas differences between AMPD and TW for the sit-and-reach test were modest.

Discussion

In this study, we compared the effects of two exercise modalities, a culturally relevant form of dance, AMPD, and TW, on physiological indicators, including HR and AEE, in addition to psychological variables, such as enjoyment and RPE, in young adults. The primary outcome from this study was that flexibility scores improved after the AMPD session compared with pre-exercise values. Furthermore, post-AMPD scores for the right-sided back-scratch were notably higher than those post-TW. However, flexibility scores did not differ markedly between pre- and post-TW. Moreover, the findings indicate that AMPD produced greater enjoyment and higher RPE than TW did. AEE was similar between the two exercise modalities, with AMPD condition

Table 4 Comparison of flexibility assessments before exercise and after applied mineral panning dance and treadmill walking sessions ($N = 20$)

Flexibility assessments	Baseline	AMPD		TW		*p* value‡
	Mean ± SD	Mean ± SD	*p* value†	Mean ± SD	*p* value†	
Sit-and-reach test (cm)	6.60 ± 9.76	9.70 ± 8.18	0.004*	8.55 ± 8.43	0.145	0.118
Back-scratch test: right-sided (cm)	2.00 ± 5.97	4.85 ± 6.94	0.010*	3.00 ± 6.97	0.625	< 0.001*
Back-scratch test: left-sided (cm)	− 3.95 ± 7.77	− 0.82 ± 7.75	0.008*	− 2.17 ± 8.52	0.100	0.325

p value corresponds to Bonferroni test

†compared with baseline; ‡compared between applied mineral panning dance and treadmill walking

AMPD, applied mineral panning dance; BL, baseline; TW, treadmill walking

Table 5 Percentage changes in flexibility variables from baseline to post-exercise conditions for applied mineral panning dance and treadmill walking

Dependent variable	Percentage change		
	BL to TW	BL to AMPD	TW to AMPD
Sit-and-reach test (cm)	29.55	46.97	13.45
Back-scratch test: right-sided (cm)	50.00	142.50	61.67
Back-scratch test: left-sided (cm)	45.06	79.24	62.21

BL, baseline; TW, treadmill walking; AMPD, applied mineral panning dance

Table 6 Effect sizes for flexibility variables at baseline and after applied mineral panning dance and treadmill walking sessions

Dependent variable	Effect size		
	TW and BL	AMPD and BL	AMPD and TW
Sit-and-reach test (cm)	0.21	0.35	0.14
Back-scratch test: right-sided (cm)	0.15	0.44	0.27
Back-scratch test: left-sided (cm)	0.22	0.40	0.17

BL, baseline; TW, treadmill walking; AMPD, applied mineral panning dance

Table 7 Absolute mean differences (95% CI) in flexibility variables from baseline to post-exercise conditions following applied mineral panning dance and treadmill walking

Flexibility assessments	Mean difference (95%CI)		
	AMPD and BL	TW and BL	AMPD and TW
Sit-and-reach test (cm)	3.10 (0.96–5.25)	1.95 (− 0.48 to 4.38)	1.15 (− 0.21 to 2.51)
Back-scratch test: right-sided (cm)	2.85 (0.63–5.07)	1.00 (− 1.02 to 3.02)	1.85 (1.09–2.61)
Back-scratch test: left-sided (cm)	3.13 (0.75–5.50)	1.78 (− 0.26 to 3.81)	1.35 (− 0.75 to 3.45)

AMPD, applied mineral panning dance; BL, baseline; TW, treadmill walking

showing higher values that did not reach statistical significance. Furthermore, AMPD condition resulted in a notably higher average HR than that of the TW, even though the activities were similarly paced rhythmically at 130 bpm.

We conclude that AMPD can enhance flexibility, elevate HR, and boost enjoyment, compared with traditional exercise, such as TW, despite similar AEE between these modalities. Walking provides consistent cardiovascular stimulation, whereas AMPD appears to offer additional benefits in dynamic flexibility and participant enjoyment, both of which may support long-term adherence. This comparison shows that AMPD can be used as an alternative and a complement to walking for enhancing physical activity engagement in young adults to optimize health benefits.

The current study demonstrates cardiovascular benefits that parallel those reported for other dance forms, such as Brazilian recreational dance, thereby reinforcing the value of culturally grounded dance modalities for cardiovascular health [15] and the potential of dance-based interventions for cardiovascular health promotion.

AEE comparison between AMPD and TW

Mean AEE did not differ significantly between exercise modes ($p = 0.118$), yet AMPD generated 10.9% more kcal·min^{-1} than TW did. A similar, albeit smaller, advantage for dance-type activity was reported by Çakir-Atabek et al. [18], who observed approximately 6% greater EE during active video-gaming compared with brisk walking. Ribeiro-Nunes et al. [23] detected no EE difference between folk dancing and walking, explaining that higher effort by less-skilled dancers was counterbalanced by the greater movement efficiency of experienced dancers. At the opposite extreme, McDonough et al. [20] recorded 72% higher AEE for TW when a higher treadmill speed (6.4 km·h^{-1}) and an intermittent game format were used. These were considerably faster than the speeds reported by Ribeiro-Nunes et al. [23] (5.97 km·h^{-1}) and in the present study (5.24 km·h^{-1}). Collectively, the findings suggest that continuous dance formats, such as AMPD, can match, and under certain loading conditions, modestly exceed the energy cost of walking when cadence and session structure are comparable.

Another contributing factor to the differences in energy expenditure outcomes between studies may be the intermittent format of the exergaming sessions in the study by McDonough et al. [20], which included rest periods. By comparison, both the study by Ribeiro-Nunes et al. [23] and the present study implemented continuous dance-based activity sessions. The absence of a marked difference in average AEE between AMPD and TW conditions suggests that both activities can elicit comparable levels of physical exertion among sedentary young adults. This similarity in exertion highlights AMPD's potential as a viable alternative to traditional aerobic exercise, such as TW. Furthermore, considering that AMPD was rated as considerably more enjoyable than TW in this study, it may offer additional motivational benefits, potentially enhancing long-term exercise adherence and engagement. Despite the different formats, the lack of a significant difference in AEE between the two conditions indicates that AMPD—a culturally grounded, rhythm-based activity—can elicit physical exertion comparable to TW. This finding is especially relevant for individuals who are less inclined to engage in conventional exercise, highlighting AMPD's potential to enhance adherence while delivering comparable physiological benefits.

HR responses to AMPD and TW

The HR was notably higher in AMPD condition than in TW condition, with a percentage increase of 7.95%. These findings align with those of Grant et al. [42], who demonstrated that aerobic dance elicited a greater mean %HR$_{max}$ response than walking did, with a percentage increase of 23.33%. This can be attributed to the dynamic nature of dancing, which encompasses high-impact full-body movements performed to music. Furthermore, in the present study, participants used the *Liang* apparatus during AMPD sessions, requiring additional upper body engagement to generate and control movement.

The present study revealed a dissociation between HR and AEE, in which AMPD elicited a greater HR response despite similar AEE compared to TW. This dissociation may be interpreted using the framework of motor economy. TW is an economical and automated gait pattern, whereas AMPD requires greater neuromuscular coordination and postural control. According to principles outlined by Sparrow and Newell [43], tasks with higher coordination demands may reduce movement economy, explaining why AMPD elicited a greater HR response without a corresponding increase in AEE.

Enjoyment responses to AMPD and TW

AMPD was rated as more enjoyable than TW, with a percentage increase of 19.25% in the enjoyment response. Mealey et al. [21] also demonstrated that music-based video game dancing elicits greater enjoyment than walking-based video routines do, showing a percentage change of 11.21%. As demonstrated in the current study, the increased enjoyment and motivation may stem from music, rhythm, and opportunities for social interaction, which are typically present in dance-based activities. Conversely, the repetitive nature of walking may be less engaging for participants.

RPE between AMPD and TW

The RPE was higher (by 9.62%) for the AMPD condition than for the TW condition. These findings are consistent with those reported by Grant et al. [42], who noted a 10.00% increase in RPE during aerobic dance than during walking. This elevation likely results from the complex coordination required in dance movements and the higher HR observed during aerobic dance in both studies. Additionally, the use of the *Liang* apparatus during AMPD sessions in the current study may have increased the perceived intensity due to upper body involvement. Importantly, despite perceptions of high intensity, the enjoyable nature of dancing may help moderate perceived exertion.

AMPD elicited higher RPE than TW; nonetheless, enjoyment scores were consistently greater. This pattern may be explained by rhythmic entrainment and distraction mechanisms. While TW was performed using a metronome to maintain cadence, AMPD relied on musical beats, which provide richer rhythmic, affective, and motivational cues. According to the physiological entrainment framework [44], musical rhythms can synchronize motor and neural activity, enhance affective valence, and promote attentional diversion from internal fatigue cues. Together, these mechanisms explain how participants could experience greater exertion yet simultaneously report higher pleasure during AMPD.

Flexibility improvements following AMPD and TW

This study revealed that post-exercise flexibility scores in the sit-and-reach and back-scratch tests were higher after AMPD sessions than those after TW sessions. These field-based flexibility tests are widely used due to their simplicity, non-invasive nature, and minimal equipment requirements, making them accessible tools for monitoring physical fitness in various settings [45, 46]. Moreover, flexibility scores following AMPD sessions exceeded baseline values for both flexibility measures. This crucial finding demonstrates that relatively short sessions with low intensity can produce such results with rather simple measures. Arfanda et al. [24] noted similar benefits from a 6-week program of 30-min sessions of low-impact aerobic dance. There were notable improvements in flexibility, as measured by the sit-and-reach test. Furthermore, our results are consistent with those of Douka et al. [25], who reported improved flexibility in older adult participants after 32 weeks of twice-weekly Greek traditional dance sessions, assessed using sit-and-reach and back-scratch tests.

In contrast, post-TW flexibility scores did not differ significantly from baseline in any bilateral measure. This observation may result from the repetitive and mechanically constrained nature of TW, primarily engaging a limited set of muscle groups in a linear movement pattern. Such a limited range and direction of motion may not be sufficient to produce acute improvements in flexibility over a short intervention period.

Conversely, in support of this distinction, AMPD sessions involve dynamic, full-body movements that engage multiple muscle groups and joints simultaneously. These diverse movements, combined with the use of the *Liang* apparatus, likely promoted greater joint mobility and range of motion, thereby enhancing flexibility outcomes. This conceptual distinction between the two modalities—AMPD's multidirectional, rhythm-based structure versus TW's repetitive linearity—helps explain the differential effects observed.

Nevertheless, the acute flexibility outcomes in our study differ from the long-term effects reported by Campos et al. [47], who reported that a 16-week, outdoor walking intervention, consisting of 32 training sessions conducted biweekly, resulted in improved flexibility in older adults, as determined by the sit-and-reach test.

Study limitations and scope for future studies

This study has some limitations. First, we examined only the acute effects of AMPD exercises on AEE, HR, flexibility, enjoyment, and RPE, compared with TW, in adults. Additionally, although the results show some promise, the long-term benefits of employing the *Liang* apparatus during AMPD exercises require further evaluation, particularly regarding flexibility, balance, muscular endurance and strength, and agility. Future studies should also incorporate vascular assessments, as recent work has shown that specific exercise modalities can induce acute vascular function improvements [48]. Investigating whether AMPD produces similar vascular benefits would further clarify its cardiovascular value.

Second, all participants were dance novices and generally sedentary, which may have affected AEE outcomes. Individuals with intermediate or advanced dance experience may adapt more quickly to new movements and generate higher AEE during AMPD exercises. Our study findings revealed greater enjoyment, higher HR, and improved flexibility during AMPD sessions than with TW sessions, whereas AEE remained similar between the two exercise modalities among novice adult dancers. Future studies could assess the acute effects of AMPD and TW conditions in participants with more dance experience, as faster motor learning may enable higher energy output. Consequently, this could result in measurable differences in AEE between the two modalities.

Third, although a standardized tempo of 130 bpm ensured consistent movement cadence across participants, individual physiological intensity may not be solely represented by cadence. Standardizing tempo provides consistent movement pacing but may not precisely reflect physiological load. Future studies should incorporate objective measures, such as %HRmax, %HRR, or VO_2max, to achieve more accurate intensity matching across exercise modalities.

Fourth, the sample was predominantly female (18/20), which limits the generalizability of the findings. Because physiological and psychological responses to exercise may differ between men and women, future studies should include more balanced or male-specific samples to examine whether the effects of AMPD and TW observed here also apply to both sexes.

Fifth, assessor blinding was not feasible, because AMPD and TW were visually distinct, which may have introduced measurement bias. Independent assessors or automated measurement tools should be considered in future studies to minimize this risk.

Conclusions

AMPD exercises produced a greater HR, improved flexibility, and enhanced enjoyment than TW did among sedentary young adults with limited exercise-dance experience. Our findings highlight the benefits of dance with a hand-held apparatus as a practical, enjoyable option for improving flexibility and overall fitness. In addition to its physiological and psychological benefits, AMPD's roots in local cultural traditions highlight its potential as a meaningful and engaging form of physical activity.

Given its accessibility and cultural relevance, university recreation centers or community fitness programs could incorporate AMPD into their offerings to promote physical activity engagement among inactive young adults. Future research should explore how culturally grounded exercises can foster stronger community ties and promote sustained participation in physical activity.

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Author contributions All authors were involved in the conception and design of the study. Postures performed during the applied mineral panning dance (AMPD) exercise were created by Wikrom Krungkaeo and Supansa Suwan. All authors contributed to gathering data and performing analyses. All authors reviewed and approved the final manuscript.

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Data availability The datasets generated and/or analyzed during the current study are not publicly available due to participant privacy and ethical restrictions. However, anonymized data are available from the corresponding author on reasonable request and with institutional approval.

Declarations

Conflict of interest The authors declare no competing interests.

Ethics approval This study was approved by the appropriate Human Research Ethics Committee (Approval No. PKRU2566/22) on December 4, 2023, and conducted in accordance with the principles of the Declaration of Helsinki and the Consolidated Standards of Reporting Trials guidelines.

Consent to participate Informed consent was obtained from all individual participants included in this study.

Consent to publish Not applicable.

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