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Relationship between psychological empowerment, physical activity enjoyment, and response to a HIIT Program in physically inactive young women: a prospective multicentre study

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Abstract

Background This study aimed to investigate the relationship of psychological empowerment and enjoyment of physical activity with changes in physical activity levels, sleep quality, and muscular endurance following a high-intensity interval training (HIIT) program in physically inactive young women.

Methods A total of 61 physically inactive young women (age: 20.1 ± 2.7 y) were recruited to participate in a six-month HIIT intervention delivered via a smartphone app. Outcome measures included physical activity levels (MET-min/week), muscular endurance (plank test), and sleep quality through the Pittsburgh Sleep Quality Index (PSQI). The Healthy Lifestyle and Personal Control Questionnaire (HLPCQ) and the Physical Activity Enjoyment Scale (PACES) were used to assess psychological empowerment and enjoyment, respectively. Repeated measures ANOVA and covariate analyses were performed to evaluate the impact of the intervention and the role of psychological empowerment and enjoyment.

Results At 6 months, significant improvements in physical activity ($p < 0.001$; $\eta_p^2 = 0.336$) and muscular endurance ($p = 0.005$; $\eta_p^2 = 0.085$) were observed, with large and moderate effect sizes, respectively. The PACES showed a significant interaction with time for MET-min/week ($F = 11.67$, $p = 0.001$, $\eta_p^2 = 0.129$), suggesting that enjoyment influenced the increase in physical activity. No significant differences in sleep quality were observed ($p > 0.05$).

Conclusion Enjoyment plays a crucial role in the response to HIIT programs among physically inactive young women, particularly in improving weekly physical activity levels. Psychological training showed no significant relationship with the outcomes studied.

Keywords Psychological empowerment, Physical activity enjoyment, HIIT, Physically inactive young women, Physical activity, Sleep quality, Muscular endurance

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Introduction

Physical inactivity is a major global health concern, particularly among young women [1]. The World Health Organization estimates that over five million deaths annually could be prevented through increased physical activity [2]. The global cost of physical inactivity is estimated at $54 billion in healthcare expenses, accounting for 1–3% of national health expenditure [3]. Despite established guidelines recommending 150–300 min of moderate-intensity activity or 75–150 min of vigorous-intensity activity per week [4], according to the European Commission's Report on Sport and Physical Activity nearly 45% of individuals in the EU aged 15 years and older report never doing any physical activity, with women less likely than men to engage in regular physical activity [5].

While exercise is an effective tool for combating sedentary lifestyles, many individuals, especially women, struggle to maintain exercise routines [5, 6]. Psychological factors such as enjoyment and psychological empowerment play crucial roles in perception and engagement with physical activity [7, 8]. Psychological empowerment is a multifaceted construct that includes intrapersonal components (perceptions of control, self-efficacy, and social support), interactional components (critical awareness of one's environment) and behavioural components (actions taken to influence outcomes and exert control in a given context) [9, 10]. This sense of empowerment may be particularly important for young women, who may experience societal pressures or self-doubt that can hinder their participation in physical activity [11, 12]. Moreover, enjoyment of physical activity is not only a motivational factor but also an essential component of psychological empowerment [13]. Similarly, enjoyment of physical activity is critical for long-term engagement and integration into daily routines [14, 15]. Self-Determination Theory emphasizes autonomy, competence, and relatedness as essential psychological needs that foster intrinsic motivation [16]. When exercise is perceived as enjoyable, it is more likely to be integrated into one's daily routine, thereby contributing to sustained physical activity levels [17]. Enjoyment can also enhance the psychological benefits of exercise, such as improved mood and reduced stress, which may further encourage continued participation [14, 15]. Despite the recognized importance of both psychological empowerment and enjoyment in promoting sustained physical activity, few studies have explored their combined effects within structured exercise programs for young women.

High-Intensity Interval Training (HIIT), defined as short bursts of intense exercise alternated with periods of rest or low-intensity activity, has emerged as a popular and efficient exercise option, offering significant benefits in short 20–30 min sessions [18]. Studies suggest HIIT is more enjoyable and motivating than traditional exercise programs [19], improving cardiorespiratory fitness and health markers in various populations [20, 21].

Moreover, while technological advancements have revolutionized exercise accessibility and engagement, the interplay between these technologies, psychological factors, and physical outcomes in young women is not well understood. Devices like smartwatches provide accurate activity tracking and personalized goal-setting [22, 23], but their impact on psychological empowerment and enjoyment in the context of a structured exercise program has not been thoroughly examined.

This study aims to address these knowledge gaps by investigating the relationship between psychological empowerment, physical activity enjoyment, and changes in physical activity levels, sleep quality, and muscular endurance following a smartphone-based HIIT program among physically inactive young women. Our novel approach combines cutting-edge technology with psychologically-informed exercise interventions, potentially offering new insights into effective strategies for promoting long-term physical activity adherence in this underserved population.

Materials and methods

Study design

The Women's Involvement in Steady Exercise (WISE) protocol, which involves an unsupervised exercise intervention with virtual guidance for young physically inactive women, has been previously published [24].

A prospective multicentre study was conducted at three centers with a 6-month intervention period using a smartphone app (WISE RCT), including (i) a remote HIIT program with video sessions, (ii) an interface including health information, and (iii) an activity tracking tool (Protocol registration number: NCT05467280, date: July 15, 2022). Recruitment and data collection were managed by the University of Valencia (Spain), Nikola Tesla University (Serbia), and SPORTLAB (Italy), respectively. The study protocol was approved by the Ethics Committee of the University of Valencia in accordance with the Declaration of Helsinki. For an overview of the study design, see Supplementary Material Figure S1.

Participants

Eligible participants were young women who met the following inclusion criteria: (1) aged between 15 and 24 years; and (2) classified as insufficiently active, defined as not meeting WHO recommendations for physical activity [4] and having a score of less than 3 on the International Physical Activity Questionnaire (IPAQ) [25].

Exclusion criteria were: (1) a diagnosis of diabetes, (2) cardiac issues that would make exercise unsafe such as unstable angina, acute myocardial infarction,

uncontrolled arrhythmias, severe heart valve disease, and uncontrolled hypertension, (3) unwillingness to wear the smartwatch throughout the intervention, and (4) a history of severe COVID-19 [26]. Participants were recruited from local schools and universities through emails and posters, with the cooperation of local authorities. Each center was responsible for recruitment in their respective locations.

Recruitment

A total of 282 participants were recruited from three countries, of whom 167 were assigned to the intervention group. The recruitment breakdown included 62 participants from Spain, 52 from Italy, and 53 from Serbia, all of whom were young women. The project was publicized through emails and posters. Interested candidates contacted the researchers and were provided with detailed study information before being scheduled for a personal interview to verify eligibility. After confirming their qualification and obtaining written consent, participants received a wearable Xiaomi Mi Band 5 device and were officially enrolled.

Intervention

Procedure

The study lasted from August 2022 to February 2023 and consisted of four participant visits: a selection visit followed by three assessment visits at baseline (T0), mid-program (T1, three months), and post-intervention (T2, six months) (see Supplementary Material Table S1). Assessment sessions were conducted consistently to ensure accurate data comparison. During the initial selection visit, eligible participants signed the informed consent form and underwent a preliminary assessment. Baseline measurements were performed during the T0 visit, while the T1 and T2 visits assessed mid-program and postintervention outcomes, respectively.

The WISE intervention is composed of four main features:

1. Exercise videos: participants received two weekly high-intensity interval training (HIIT) video sessions via the WISE app (Fig. 1A). Each session was structured to be completed at home without the need for exercise equipment, ensuring accessibility. The sessions, designed by certified exercise professionals, included four exercises that focused on a combination of strength, cardio, and flexibility.

The HIIT protocol used in this study consisted of two weekly sessions, each lasting approximately 25–30 min. Each session included a 5-minute warm-up, a 15–20 min core HIIT workout, and a 5-minute cooldown. The core HIIT workout involved four exercises performed in intervals of 40 s of high-intensity activity followed by 20 s of rest. The intensity of the sessions was progressively increased each week, with two intensity options (standard and advanced) introduced from the 10th session onwards.

The videos were divided into three main segments:

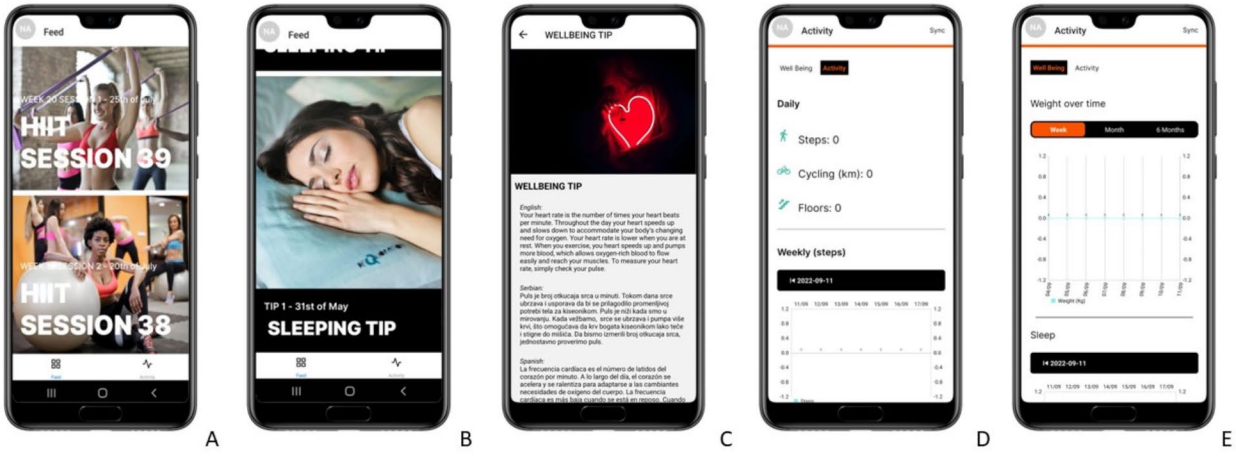

Fig. 1 Screenshots examples of the WISE application. (**A**) HIIT video sessions. (**B**) Sleeping tips. (**c**) Well-being tips. (**D**) The activity monitoring tool. (**E**) Weight and sleep monitoring tool

- A 5-minute warm-up featuring low-intensity dynamic stretches and light cardio to prepare the body for more intense activity.
- A core HIIT workout lasting approximately 15–20 min, including exercises such as squats, lunges, burpees, and planks. Exercises were performed in intervals (e.g., 40 s of activity followed by 20 s of rest) with modifications demonstrated for different fitness levels.
- A 5-minute cooldown consisting of static stretches targeting major muscle groups to aid in recovery and prevent stiffness.

As mentioned before the intensity of the sessions was progressively increased to adapt to the participants' improved physical fitness. From the 10th session onwards, two intensity options were introduced, allowing participants to choose a level appropriate to their abilities. The second weekly session was designed to be more demanding than the first, providing variation and a gradual adaptive stimulus.

2. Education in healthy habits: once a week, participants received a brief reading (2 to 5 min) on general advice regarding nutrition, sleep (Fig. 1B), and well-being (Fig. 1C), written by experts in these fields. Dietary guidelines were created by a team of nutrition professionals, providing participants with basic instructions on proper eating behavior. These readings were delivered through the WISE app.
3. Activity tracking: the participants monitored their physical activity using the Xiaomi Mi Band 5 smartwatch. The app displayed weekly data, enabling participants to track their progress. The smartwatch recorded activity levels, sleep patterns, heart rate, and body weight over time, providing real-time feedback to encourage adherence and self-monitoring (Fig. 1D and E).
4. Motivational activities: to motivate participants to engage with the exercise videos, various communication channels such as social media, email, WhatsApp groups, and/or other popular platforms like Viber (depending on the country) were utilized. Regular motivational messages, reminders, and updates on new video releases were distributed through these channels to keep participants interested and engaged. In addition, "Open Days" were held in each participating country, offering both in-person and virtual participation options to maximize accessibility. These events featured interactive talks by experts on nutrition and the benefits of physical activity. Participants also had the opportunity to take part in live exercise sessions, fostering a sense of community and shared commitment to health goals. Recordings of these sessions were made available for those who could not attend live. Furthermore, these events served as a platform for participants to share their experiences, challenges, and progress, enhancing peer support and motivation.

Table 1 BCT implementation in the intervention group following Michie et al.'s taxonomy [58]

BCT	Implementation in the WISE RCT
Goal setting behaviour	Set monthly step goal
Feedback on behaviour	Feedback on daily steps via the activity monitoring tool included in the application with weekly graphs
Self-monitoring of behaviour	Weekly diary to record, whether they have done the exercise video
Feedback on outcome(s) of behaviour	Bioimpedance sheet with all the information of the changes in their body composition after 3 and 6 months of exercise
Social support (practical)	Social days created so the participants can exercise together in real life
Social support (emotional)	Promote social interaction through social media groups
Instruction on how to perform a behaviour Behavioural practice/ rehearsal Demonstration of the behaviour	Exercise videos
Information about health consequences	Tips and information about the benefits of exercise and a healthy life-style given through the application
Prompts/cues	Push notification through the application
Graded tasks	Exercise program with increased difficulty

BCTs, behaviour change techniques; WISE, Women's Involvement in Steady Exercise; RCT, randomized controlled trial

Table 1 summarizes the behaviour change techniques applied in the intervention group.

Outcome measures

Physical activity

To evaluate physical activity, self-reported behaviours were recorded using the International Physical Activity Questionnaire (IPAQ). The IPAQ assesses walking and activities of moderate and vigorous intensity that are performed continuously for at least 10 min in all domains of everyday life in the last 7 days. The resulting data are expressed in MET-minutes per week (MET-min/week). The IPAQ demonstrates acceptable levels of test-retest reliability and fair to moderate associations with accelerometer measures [27, 28].

Muscular endurance

Muscular endurance was measured using the plank test, which records the duration (in seconds) that participants can maintain the position. The plank test protocol requires participants to maintain a static prone position with only forearms and toes touching the ground. Proper form requires feet together with toes curled under the feet, elbows forearm distance apart, and hands clasped together against the floor mat. Participants maintain eye contact with their hands, a neutral spine, and a straight line from head to ankles. The test begins when the participant demonstrates the correct position. Participants are allowed to deviate from the correct position once and can continue the test if they immediately resume the correct starting position. The test is terminated on the second deviation from the correct position or if the participant does not return to the correct position after the first warning [29]. The plank test protocol is a reliable test [30] and has been used with children [29] and young adults [30].

Quality of sleep

Quality of sleep was assessed using the Pittsburgh Sleep Quality Index (PSQI), a widely utilized questionnaire comprising 19 items that generate a global score ranging from 0 to 21 [31]. Higher scores denote poorer sleep quality, while lower scores indicate better sleep quality. For this multicenter study, validated versions of the PSQI were used for each participating country: The Spanish version demonstrated acceptable internal consistency (Cronbach's alpha = 0.73) in a study involving an adolescent population [32]. The Italian version demonstrated good internal consistency (Cronbach's alpha = 0.719) in a study involving healthy children [33]. The Serbian translation of the PSQI questionnaire has also been validated. This version demonstrated good internal consistency (Cronbach's alpha = 0.791) and can be utilized as a reliable screening tool for assessing sleep quality in diverse populations [34].

Covariates

Psychological empowerment

Psychological empowerment was evaluated using the Healthy Lifestyle and Personal Control Questionnaire (HLPCQ). The HLPCQ is a 26-item scale that assesses lifestyle habits and aspects of personal control. It measures five dimensions: healthy eating, physical activity, interpersonal relationships, stress management, and self-care. The scale evaluates both the frequency of health-promoting behaviors and the perceived control over these behaviors, operationalizing psychological empowerment through measures of self-efficacy and perceived behavioral control [35]. Respondents indicate the frequency of adopting positively stated lifestyle habits using a Likert-type scale (1 = Never or rarely, 2 = Sometimes, 3 = Often, and 4 = Always) [35]. The HLPCQ provides a total score ranging from 26 to 104 points, with higher scores indicating a healthier lifestyle [35].In terms of reliability, the internal consistency of the Polish version and its domains is excellent, with Cronbach's alpha for each of the domains of the scale ranging between 0.6 and 0.9 [36]. For this study, the HLPCQ was translated into Spanish, Italian, and Serbian using a rigorous translation and back-translation process.

Enjoyment of physical activity

Enjoyment of physical activity was assessed using the Physical Activity Enjoyment Scale (PACES). We used the 16-item version of PACES, originally developed and validated by Motl et al. (2001) [37] for adolescent girls. Participants rated the question "When I am active." using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (totally agree) [37, 38]. This version has demonstrated good psychometric properties and has been further validated in various populations [39, 40]. The 16- items PACES shows a very high internal consistency (Cronbach's alpha = 0.908), and the test-retest reliability indicates a good temporal agreement (Spearman rho = 0.815, $p < 0.001$) in adolescents with overweight and obesity [41]. The Spanish version of PACES has been validated in previous studies [42], while the Italian version was adapted from the validated 18-item version [43] to the 16-item format used in this study. A Serbian version was translated using a rigorous translation and back-translation process.

Statistical analysis

All statistical analyses were performed in SPSS, version 22.0 (IBM Corporation, Armonk, New York). The normality of the data distribution was evaluated using the Shapiro-Wilk test. To evaluate the results of the intervention, a repeated measures analysis of variance (ANOVA) was applied, considering three time points (T0, T1 and T2). Age, BMI and the PACES and HLPCQ scales were used as covariates. If the assumption of sphericity, as checked by the Mauchly test, was violated, the Greenhouse-Geisser correction was applied. In cases where the repeated measures analysis was significant, a covariate model was used to determine if these covariates explained part of the change. If a significant iteration was found, the correlation between the covariate and the outcome was assessed using Pearson's correlation coefficient to determine both the magnitude and direction of the association. Post hoc tests with Bonferroni correction were performed for multiple comparisons. Data are expressed as mean and 95% confidence interval (CI). Statistical significance was set at a p-value of 0.05. Partial eta squared (η_p^2) values were estimated as a measure

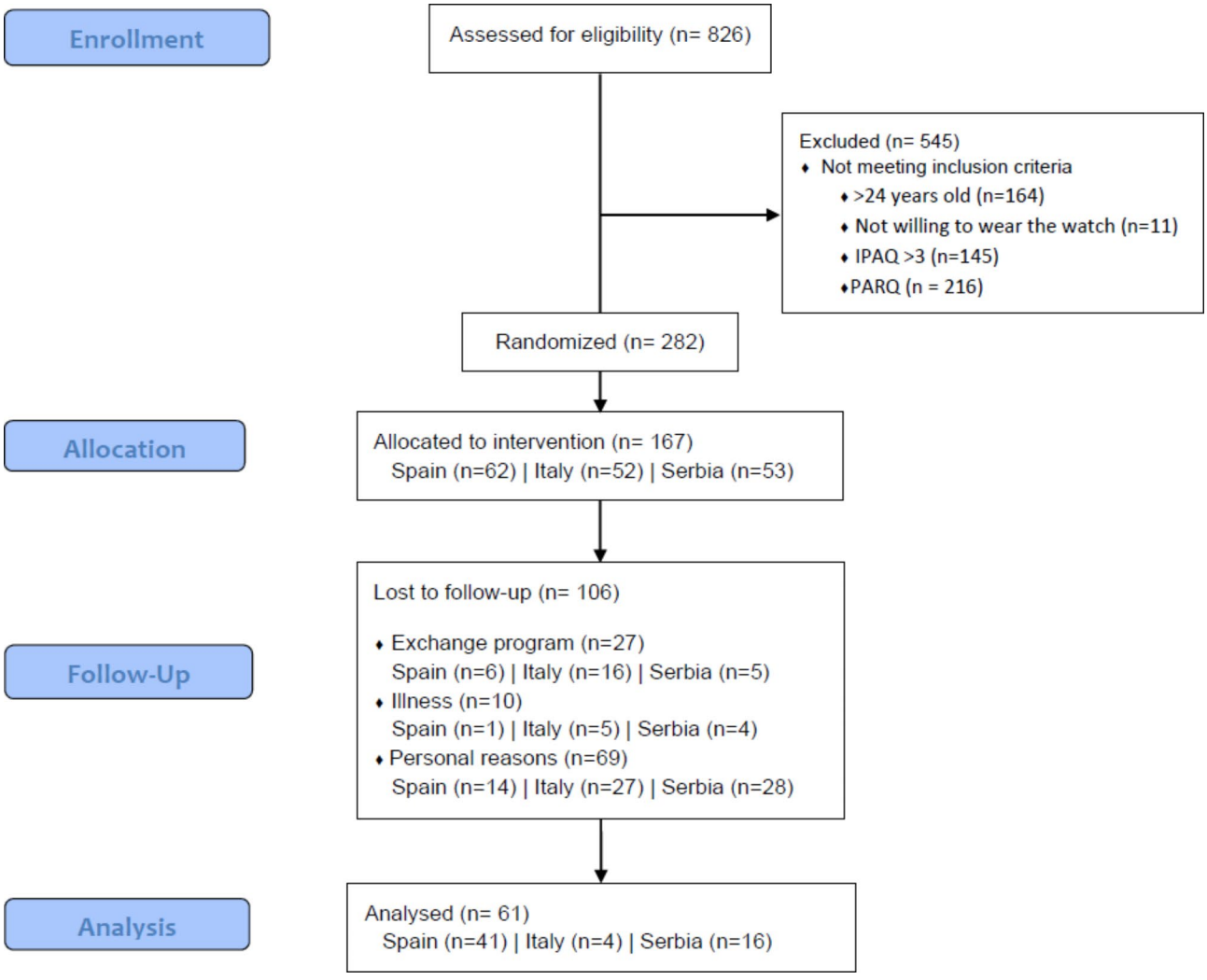

Fig. 2 CONSORT flow diagram illustrating the recruitment, follow-up of participants across the study, and final numbers of people included in the analysis from the three countries

Table 2 Characterization of participants at the beginning of the study ($n=61$)

Characteristic	Mean ± SD
Age (years)	20.1 ± 2.7
BMI (kg/m^2)	22.9 ± 3.8
PACES (16–112)	45.9 ± 5.2
HLPCQ (26–104)	59.6 ± 9.7
PSQI (0–21)	6.9 ± 3.3
Plank test (seconds)	69.7 ± 36.1
MET-min/week	1030.2 ± 878.2

Data are expressed as mean ± SD

PACES: Physical Activity Enjoyment Scale HLPCQ: Healthy Lifestyle and Personal Control Questionnaire PSQI: The Pittsburgh Sleep Quality Index

of effect size and these were interpreted as small (> 0.01), medium (> 0.06) and large (> 0.14). Taking into account possible losses during monitoring, a post-hoc power calculation was performed in G*Power software (version 3.1, Universit¨at Düsseldorf, Germany), assuming an α err prob = 0.05.

Results

A total of 167 women were initially recruited for the WISE program from three countries: 62 from Spain, 52 from Italy, and 53 from Serbia. However, 106 participants dropped out during the study, with their reasons detailed in Fig. 2. After attrition, the final sample consisted of 61 participants across the three countries (Spain: $n=41$, Serbia: $n=16$, Italy: $n=4$). The baseline characteristics of the sample are presented in Table 2.

No adverse events were reported during the experimental test and intervention.

Physical activity

Repeated measures ANOVA without covariates showed a significant improvement in MET-min/week over time

Table 3 Changes in physical activity, sleep quality, and muscular endurance over time ($n=61$)

			Repeated measures ANOVA		
Outcome	**Follow-up**	**Mean ± SD**	**F**	***p*-value**	**ηp^2**
	T0	1030.2 ± 878.2			
MET-min/wek	T1	2872.1 ± 1605.4	28.8	< 0.001**	0.336
	T2	2604.5 ± 2004.4			
	T0	6.9 ± 3.3			
PSQI	T1	8.8 ± 2.7	16.5	0.428	0.210
	T2	8.8 ± 2.8			
	T0	65.9 ± 34.3			
Plank test	T1	68.5 ± 33.5	5.56	0.005*	0.085
	T2	75.3 ± 35.9			

Abbreviations: PSQI: The Pittsburgh Sleep Quality Index

*Statistically significant difference ($p<0.05$); **Statistically significant difference ($p<0.01$);

($p<0.001$; $\eta_p^2=0.336$), with large effect sizes. (Table 3). Post-hoc analysis showed an improvement of 1841.9 MET-min/week [95%CI: 1309.6 to 2374.1; $p<0.001$] at 3 months and 1574.3 MET-min/week [95%CI: 873.5 to 2275.1; $p<0.001$] at 6 months compared to baseline. Furthermore, the PACES was included as a covariate, demonstrating a significant interaction for the time factor in the MET-min/week ($F=11.67$, $p=0.001$, $\eta_p^2=0.129$). A small but significant positive correlation was observed between a higher perceived enjoyment of physical activity (PACES score) and the level of physical activity (MET-min/week) achieved after the end of the program ($r=0.320$, $p=0.03$). This suggests that the level of enjoyment experienced during physical activity explains part of the increase in MET-min/week over time. Other possible covariates (i.e., HLPCQ) were also evaluated, but showed no significant interactions. The post-hoc statistical power (1-β err prob) for the physical activity ANOVA was 0.99.

Quality of sleep

The PSQI showed an increase in scores from T0 (6.9 ± 3.3) to T1 and T2 (8.8 ± 2.7 and 8.8 ± 2.8), but repeated measures ANOVA showed a non-significant change in PSQI scores over time ($p=0.428$, $\eta_p^2=0.210$) (Table 3).

Muscular endurance

The plank test showed an increase in endurance time from T0 (65.9 ± 34.3 s) to T1 (68.5 ± 33.5 s) and T2 (75.3 ± 35.9 s). Repeated measures ANOVA showed a significant improvement in the plank test duration over time ($p=0.005$; $\eta_p^2=0.085$), with a moderate effect size (Table 3). Post-hoc analysis showed an improvement of 2.5 Sect. [95% CI: -8.8 to 3.7; $p=0.954$] at 3 months and 9.4 Sect. [95% CI: 1.1 to 17.4; $p=0.22$] at 6 months compared to baseline. No significant interaction was observed with the study covariates ($p>0.05$). The post-hoc statistical power (1-β err prob) for the plank test ANOVA was 0.99.

Discussion

This study investigated the relationship between psychological empowerment, physical activity enjoyment, and the response to a high-intensity interval training (HIIT) program in physically inactive young women, focusing on changes in physical activity, muscular endurance, and sleep quality.

Our results demonstrated significant improvements in MET-min/week and plank test performance following the HIIT program, indicating positive impacts on physical activity levels and core muscle strength. These findings highlight the potential effectiveness of HIIT in promoting health-related outcomes among physically inactive young women.

While the direct impact of enjoyment on specific outcomes is not extensively addressed in existing literature, our findings suggest that this factor may be related to overall exercise program outcomes. The affective and motivational aspects of exercise, shaped by individual experiences including enjoyment and psychological empowerment, play a crucial role in program effectiveness [44].

Phychological-empowerment

Psychological empowerment is a multifaceted construct that encompasses individual, interpersonal, and community levels [9]. The individual level includes personal perceptions of control and self-efficacy [45], while the interpersonal dimension focuses on social support and relationship dynamics [46]. The community level addresses broader systemic influences on personal agency [46].

Our study unexpectedly found a complex relationship between psychological empowerment and the response to the HIIT program. This result was surprising given the theoretical importance of psychological empowerment in behaviour change models and its documented role in exercise adherence [47, 48]. While traditionally viewed as key factor in behaviour change, our results suggest that the role of empowerment in exercise adherence may be more nuanced than previously thought. The structure of our smartphone-based HIIT program may have interacted with various dimensions of empowerment, including psychological, social, and economic factors. Stork et al. observed that young adults experienced negative affect during a HIIT classes but reported a preference for HIIT over moderate-intensity continuous training (MICT) post-activity [49]. This suggests that enjoyment may overshadow psychological empowerment in determining program adherence psychological empowerment. Similarly, Fernández-Lasa et al. (2024) highlighted that young

women's motivations for leisure-time physical activity were primarily intrapersonal (related to health and enjoyment) and interpersonal (social support and group belonging) [50]. The multidimensional nature of empowerment includes economic, familial, legal, psychological, political and socio-cultural aspects. While psychological empowerment may drive initial engagement, social and cultural dimensions may play a more important role in long-term adherence. The economic dimension, related to access to resources and time management, may have been particularly relevant in our study population of young women. These findings highlight the need for a more comprehensive approach to understanding empowerment in exercise interventions. Future research should consider how different dimensions of empowerment interact with program design and individual characteristics to influence exercise adherence and outcomes.

Enjoyment of physical activity

Our findings highlight the significant role of enjoyment in increasing physical activity levels over time. The observed interaction between enjoyment and increased MET-min/week over time underscores its importance in sustaining physical activity among young, physically inactive women. While our results indicate that perceived enjoyment of physical activity significantly influenced physical activity levels, the psychological empowerment did not demonstrate significant interactions in this study.

The role of enjoyment in promoting physical activity is well-documented. Liu et al. (2023) [51] found that perceived enjoyment predicted increased physical activity in children and adolescents, while Lewis et al. (2016) [52] demonstrated that greater physical activity enjoyment influenced self-efficacy in low-active adults. Our results align with Dishman et al. (2005) [53], who found that higher levels of enjoyment were associated with greater increases in physical activity among adolescents. However, enjoyment is not the sole determinant of physical activity levels. Factors such as social support, self-efficacy, and environmental influences also play critical roles in maintaining regular physical activity [54, 55].

It is important to note that much of the existing literature emphasizes the significance of in-task responses, particularly affective valence, during exercise as critical predictors of future exercise behavior and adherence [56, 57]. In our study, enjoyment was measured post-exercise, which may not fully capture the immediate affective experiences that occur during the HIIT sessions. Future research should consider incorporating real-time measures of enjoyment to better understand how these in-task responses influence long-term adherence to physical activity.

Our study adds to the growing evidence that enjoyment is pivotal in increasing physical activity levels. HIIT programs can be more effective in promoting long-term adherence among young, physically inactive women by incorporating strategies to enhance enjoyment, such as varying exercises, incorporating social elements, and providing positive feedback. Future research should consider these multifaceted influences to develop more comprehensive interventions for sustained physical activity.

Sleep quality

Our study showed no significant change in PSQI scores over time following the 6-month HIIT program. The baseline sleep quality of participants was relatively good (mean PSQI score of 6.9 ± 3.3) [58, 59] and this could explain this result.

These findings align with Bullock et al. (2020) [60] and Adams et al. (2018) [61], who found no improvements in sleep quality after HIIT interventions in different populations. However, they contrast with some studies reporting beneficial effects of HIIT on sleep quality, particularly in interventions exceeding eight weeks [62]. The discrepancy could be attributed to our focus on young, physically inactive women, insufficient program duration or intensity, and moderating factors such as age, sex, and baseline physical activity levels [63].

These results suggest complex relationships between HIIT training and sleep quality that our current model may not fully capture. Future research should explore potential moderating factors and consider more comprehensive measures of sleep quality or longer intervention periods to better understand the dynamics at play in this specific population.

Strengths and limitations

Our findings highlight the significant role of enjoyment in the response to HIIT among physically inactive young women. This insight can help tailor exercise interventions to enhance motivation, adherence, and overall program effectiveness. While we explored the relationship between psychological empowerment and exercise outcomes, our results did not provide strong evidence to support its direct influence in this context.

However, this study has limitations. The uneven sample sizes across countries, particularly the small samples in Italy and Serbia, limit the generalizability and international representation of our findings. These imbalances stemmed from logistical challenges and recruitment difficulties exacerbated by the COVID-19 pandemic. Additionally, the lack of a formal power calculation prior to the study is a recognized limitation. As a result, the study's uneven distribution hampers country-specific conclusions and its representation as a truly international multicenter investigation. Despite these constraints, the data provide valuable insights into general patterns, though the findings are limited in their applicability

across diverse cultural contexts. Self-report measures for physical activity and sleep quality are subject to recall bias; objective measures could enhance validity. The study focused short-term effects, and long-term follow-ups would be beneficial to assess the sustainability of improvements. Furthermore, the use of questionnaires that have not been fully validated in all study languages (HLPCQ and PACES) may affect the reliability of our findings across cultural contexts. Lastly, the lack of a control group limits causal inferences.

Future research should explore the mechanisms linking physical empowerment, enjoyment, and exercise outcomes to optimize intervention strategies. In particular, studies should investigate how psychological empowerment interacts with enjoyment and other factors to influence program adherence and outcomes. Researchers should aim for larger and more balanced samples across participating countries to strengthen the international and multicentre aspects of such research. Prioritizing validation of instruments such as the HLPCQ and PACES in multiple languages will also enhance the reliability and validity of cross-cultural studies in this area. Furthermore, including objective measures, long-term follow-up, and control groups would provide stronger evidence of the effectiveness of HIIT programs for physically inactive young women. Strategies to sustain long-term engagement and benefits should also be developed while addressing potential effects on sleep quality and investigating country-specific factors that may influence program adherence and outcomes.

Conclusion

This study provides compelling evidence for the significant role of enjoyment in enhancing the effectiveness of HIIT programs among physically inactive young women. Our findings demonstrate that higher levels of physical activity enjoyment are associated with increased engagement and improved outcomes, particularly in terms of physical activity levels and muscular endurance. Although we explored the relationship between psychological empowerment and exercise outcomes, our results did not provide strong evidence to support its direct influence in this context. By focusing on creating enjoyable exercise experiences and considering the multifaceted influences on engagement, we can develop more effective interventions to combat physical inactivity and promote better health outcomes in this important demographic. Future research should further investigate the interactions between enjoyment and psychological empowerment, as well as other factors that may influence adherence to exercise programs.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12905-025-03576-8.

Supplementary Material 1

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Author contributions

Conceptualization, R.N.-C., I.P., and L.D.; methodology, I.F.-T., R.N.-C., E.A., and L.D; formal Analysis, I.F.-T.; investigation, I.F.-T, J.C., J.C.-G., and L.L.-B.; resources, I.F.-T. and R.N.-C.; data curation, I.F.-T., L.D. and R.N.-C.; writing—original draft preparation, I.F.-T.; writing—review and editing, R.N.-C., L.L.-B., E.A., J.C., J.C.-G., I.P., and L.D.; visualization, I.F.-T.; supervision, L.D. and R.N.-C.; project administration, I.P., and L.D. All authors have read and agreed to the published version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of University of Valencia (1944476, 5 May 2022). The trial protocol has been registered on the Clinical Trials Registry (NCT05467280). Informed consent was obtained from all subjects involved in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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