



The role of physical activity avoidance and loneliness in physical activity participation among adolescents: A cross-lagged mediation analysis

Jian Yi¹ · Chuan-Yin Fang² · I-Hua Chen³ · Yi-Ching Lin⁴ · Wen-Li Hou⁵ · Musheer A. Aljaberi^{6,7} · Yu-Chen Lai² · Jung-Sheng Chen⁸ · I-Ching Lin^{9,10,11} · Mark D. Griffiths¹² · Chung-Ying Lin^{5,13,14,15} · Po-Ching Huang¹⁶

Accepted: 27 July 2025

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2025

Abstract

Insufficient physical activity (PA) is a significant global concern among adolescents. The relationship between PA avoidance and loneliness has not been thoroughly investigated, nor have these variables been examined concurrently. The present longitudinal study utilized cross-lagged mediation analysis with sex, age, and weight status controlled to explore the associations between PA avoidance, loneliness, and various levels of PA (including total PA, vigorous PA, moderate PA, and walking) among adolescents. An online survey was administered at three time points (from September 2023 to February 2024), yielding responses from 1,024 students at the first time point (T1), 972 at the second time point (T2), and 978 at the third time point (T3). A reciprocal interaction between PA avoidance and loneliness was found over time (standardized coefficients [β]=0.08 to 0.17). More specifically, PA avoidance at T1 negatively predicted both vigorous and moderate PA at T2 (β =−0.11 for both measures). Moreover, loneliness at T1 was negatively associated with walking at T2 (β =−0.10), and loneliness at T2 was negatively associated with vigorous PA at T3 (β =−0.13). Additionally, PA avoidance at T1 was indirectly related to vigorous PA at T3 through the mediation of loneliness at T2 (b =−0.020, SE =0.010, t =2.00, p =0.046). These findings contribute to the existing literature by elucidating the dynamic interplay between PA avoidance, loneliness, and PA levels, thereby showing a novel mechanism through which loneliness may lead to decreased PA. Interventions aimed at enhancing psychological well-being, social skills, or enjoyment of PA may prove beneficial in alleviating PA avoidance and loneliness, ultimately fostering a more active lifestyle among adolescents.

Introduction

Insufficient physical activity (PA) has emerged as a significant global health concern. Reports indicate that globally 81% of adolescents and 30% of adults are physically inactive (Guthold et al., 2020; Strain et al., 2024), which may elevate the risks of various physical conditions, such as cardiometabolic diseases (Kallio et al., 2021), as well as mental health disorders, including depression (Kandola et al., 2020). This inactivity consequently increases the potential medical burden on healthcare systems (World Health Organization, 2022). For instance, low PA levels increase the risk of obesity and depression, consequently leading to a greater economic burden on the healthcare system (McLoughlin et al., 2021; Tapias et al., 2021). Such concerns highlight the need for further research into the factors that influence individuals' PA engagement.

Motivation for participation in PA is a critical determinant of individuals' levels of engagement

in such activities, as elucidated by self-determination theory (SDT) and social cognitive theory (SCT) (Bandura, 2001; Teixeira et al., 2012). According to SDT, intrinsic motivation—characterized by enjoyment or personal satisfaction—facilitates sustained participation in PA (Teixeira et al., 2012). More specifically, SDT posits that individuals are more inclined to engage in PA when their fundamental psychological needs, including autonomy, competence, and relatedness, are satisfied (Teixeira et al., 2012). In contrast, SCT conceptualizes PA behavior as a product of the interplay between personal, behavioral, and environmental factors (Bandura, 2001). Variables such as individuals' self-efficacy, perceived benefits and barriers to PA, and social support can significantly influence an individual's decision to participate in PA (Hamilton et al., 2017; Roth et al., 2019). Collectively, these theories offer a comprehensive framework encompassing intrinsic and extrinsic factors influencing participation in PA.

PA avoidance, as an intrinsic factor, has been proposed in several contexts such as weight stigma (Bevan et al., 2022), problematic social media use (Huang et al., 2024) or exercise psychology (Mason et al., 2019), and illustrates how it can influence individuals' PA participation. Studies have reported that perceived weight stigma, nomophobia and exercise anxiety can foster the development of PA avoidance (Bevan et al., 2022; Huang et al., 2024; Mason et al., 2019). Consequently, a new psychometric measure was developed (Bevan et al., 2022) and has recently been utilized in several studies, all of which reported a negative association between PA avoidance and individuals' levels of PA (Huang et al., 2024; Saffari et al., 2025; Yi et al., 2024).

Loneliness is another significant intrinsic factor that may affect individuals' levels of PA (Ahn et al., 2024). It is characterized as a state of solitude that often emerges when an individual's perceived interpersonal relationships do not meet their expectations (Zhang et al., 2022). Numerous studies have documented a consistent negative association between loneliness and PA (Ahn et al., 2024; Pinto et al., 2021; Zhao et al., 2024). This relationship may be attributed to the strong connection between loneliness and social support (Solomon et al., 2015; Zhang et al., 2022). As previously noted, social support is critical for engagement in PA (Hamilton et al., 2017), thereby potentially linking loneliness

to participation in PA (Zhao et al., 2024). A systematic review conducted by Pels et al. (2016) examined the relationship between loneliness and PA. They reported that four out of seven longitudinal studies identified a direct negative impact of loneliness on PA. Moreover, five out of seven studies indicated that PA interventions could alleviate feelings of loneliness. This suggests a potential reciprocal relationship between PA and loneliness. However, a recent systematic review by Ahn et al. (2024) concluded that the existing evidence was inadequate regarding the bidirectional relationship between PA and loneliness. Consequently, employing a cross-lagged model with a longitudinal design to assess PA and loneliness may contribute empirical evidence to the extant literature regarding such a reciprocal relationship.

The psychological processes underlying the relationship between PA avoidance and loneliness can be bidirectional. The link between loneliness and PA avoidance can be explained by emotional regulation difficulties, social anxiety, stigmatization and self-efficacy. Loneliness has been reported to be associated with avoidant behaviors (Rokach et al., 1998). Individuals with emotional regulation difficulties may experience higher levels of loneliness, turning to behaviors such as internet use as an emotional coping strategy (Ang et al., 2018). In addition, loneliness has been reported to have a reciprocal relationship with social anxiety (Maes et al., 2019), which may prevent lonely individuals from participating in group activities (such as PA) to avoid social interaction. Moreover, adolescence has been reported to be a critical period where the individuals may experience high levels of loneliness and stigma in their lifetime (Flaherty, 2015). Individuals who tend to avoid PA may be stigmatized as ‘lazy’ or ‘weak’ by the general public, subsequently leading to a greater feeling of loneliness. Lower self-efficacy has also been reported to be associated with motivation to participate in PA (Bauman et al., 2012), subsequently affecting the individuals’ PA participation and resulting in loneliness.

To the authors’ knowledge, no prior research has ever investigated the association between PA avoidance and loneliness, nor has any previous study concurrently explored how the interaction of these two variables affects engagement in PA. Given the aforementioned intricate relationship between PA and loneliness, the avoidance of PA may function as a potential mediator that requires

further examination. In addition, this area has been much less investigated in Eastern cultures compared to Western ones. However, cultural differences such as attitudes toward sport (Zhu et al., 2024) or motivation for PA (Guo et al., 2023) may influence how PA promotion strategies are adopted. Moreover, the transition from adolescence to adulthood represents a critical period for establishing an active lifestyle because studies have reported a significant decline in vigorous-intensity PA and an increase in sedentary behavior during this period of development (Vanhelst et al., 2023). Investigating such issue may help uncover the underlying mechanisms affecting this specific cohort, thereby informing more culturally sensitive and effective strategies for promoting PA. Consequently, utilizing a longitudinal design and cross-lagged mediation analysis, the present study focused on Chinese adolescents to investigate the temporal relationships and mediating effects among PA avoidance, loneliness, and PA engagement. The study findings may provide evidence to inform school-based intervention programs targeting adolescent PA and psychosocial health. Therefore, it was hypothesized that:

- (i) PA avoidance would be negatively associated with total PA (H₁), vigorous PA (H₂), moderate PA (H₃), and walking (H₄) over time;
- (ii) loneliness would be negatively associated with total PA (H₅), vigorous PA (H₆), moderate PA (H₇), and walking (H₈) over time;
- (iii) PA avoidance would be positively associated with loneliness (H₉);
- (iv) PA avoidance would negatively mediate the association between loneliness and total PA (H₁₀), vigorous PA (H₁₁), moderate PA (H₁₂) and walking (H₁₃);
- (v) loneliness would negatively mediate the association between PA avoidance and total PA (H₁₄), vigorous PA (H₁₅), moderate PA (H₁₆) and walking (H₁₇).

Methods

Participants and recruitment procedure

The present study utilized a longitudinal design encompassing all Grade 11 students from two senior

high schools in central China. The research protocol received approval from the Institutional Review Board of **BLIND FOR REVIEW**. Prior to the commencement of the study, the research team collaborated with school principals to organize an online information session for the students' legal guardians. This session provided comprehensive details regarding the study's objectives, participants' rights, data protection measures, and withdrawal options. Only those students whose guardians and the students themselves provided explicit consent were included in the study.

The study employed a longitudinal panel design. The online survey included measures assessing PA avoidance, loneliness, and PA engagement. The survey was created using *Wenjuanxing* (a Chinese online survey platform) and distributed in supervised computer laboratories at three distinct time points for data collection. In accordance with the planned missing data by wave-missing design, all Grade 11 students from both schools were invited to participate at each time point, irrespective of their prior participation status. Participants did not receive any financial compensation or incentives for their participation. The initial survey (T1) was administered during the first week of September 2023, wherein participants reported their experiences from the preceding summer vacation (July 1 - August 31, 2023). The second survey (T2) took place in November 2023, focusing on participants' experiences during the current semester. The final survey (T3) was completed in February 2024, evaluating participants' experiences during the winter vacation period (January 22 - February 24, 2024). The study successfully collected responses from 1,024 students at T1, 972 students at T2, and 978 students at T3, maintaining substantial sample sizes throughout the data collection phases. Detailed background information is provided in the 'Results section' of the main paper.

Measures

Demographics

Self-reported demographic information such as gender, weight, height, and the number of siblings was collected. The weight status classification was determined based on the age- and sex-specific Body Mass Index (BMI) cutoff points established by the National Health Commission of China

(National Health Commission of the People's Republic of China, 2018). For the classification of being underweight, the BMI thresholds were defined as follows: $< 17.3 \text{ kg/m}^2$ for 16-year-old males and $< 17.0 \text{ kg/m}^2$ for 16-year-old females; $< 17.7 \text{ kg/m}^2$ for 17-year-old males and $< 17.2 \text{ kg/m}^2$ for 17-year-old females; and $< 17.9 \text{ kg/m}^2$ for 18-year-old males and $< 17.3 \text{ kg/m}^2$ for 18-year-old females. The classification of being overweight was established using the following BMI thresholds: $\geq 23.3 \text{ kg/m}^2$ for 16-year-old males and $\geq 23.6 \text{ kg/m}^2$ for 16-year-old females; $\geq 23.5 \text{ kg/m}^2$ for 16.5-year-old males and $\geq 23.7 \text{ kg/m}^2$ for 16.5-year-old females; $\geq 23.7 \text{ kg/m}^2$ for 17-year-old males and $\geq 23.8 \text{ kg/m}^2$ for 17-year-old females; $\geq 23.8 \text{ kg/m}^2$ for 17.5-year-old males and $\geq 23.9 \text{ kg/m}^2$ for 17.5-year-old females; and $\geq 24.0 \text{ kg/m}^2$ for both 18-year-old males and females. Participants with BMI values falling between the underweight and overweight thresholds were classified as having an average weight.

2.2.2 *The Tendency to Avoid Physical Activity and Sport Scale (TAPAS)*

The TAPAS is a 10-item instrument specifically designed to evaluate individuals' tendencies to avoid PA and sports participation, with a particular emphasis on weight-related and appearance-based concerns (Bevan et al., 2022). Each item is assessed using a five-point Likert scale, where responses range from 1 (*strongly disagree*) to 5 (*strongly agree*). Higher aggregate scores indicate a greater tendency to avoid PA and sports participation. Originally developed in English, the scale has been translated and validated for Chinese populations (Fan et al., 2023; Saffari et al., 2023). Both language versions have exhibited strong psychometric properties, including robust factorial validity (unidimensionality), criterion validity, and internal reliability (Bevan et al., 2022; Fan et al., 2023; Saffari et al., 2023). In the present study, the TAPAS demonstrated excellent internal consistency reliability across the three timepoints, yielding McDonald's omega coefficients (ω) of 0.96, 0.97, and 0.97, respectively.

2.2.3 *UCLA Loneliness Scale Version 3 (three-item version)*

The UCLA-3 is a validated instrument designed to assess perceived loneliness and social isolation (Russell, 1996). Hughes et al. (2004) proposed the abbreviated version comprising three

items from the full scale: “*How often do you feel that you lack companionship?*” (Item 2), “*How often do you feel left out?*” (Item 11), and “*How often do you feel isolated from others?*” (Item 14). Liu et al. (2020) subsequently validated a Chinese version of this abbreviated scale, where each item is rated on a four-point Likert scale ranging from 1 (*never*) to 4 (*always*), with higher scores indicating greater perceived loneliness. Their study demonstrated robust psychometric properties, including satisfactory internal consistency (Liu et al., 2020). Further validation studies involving participants diagnosed with schizophrenia and schizoaffective disorder showed that both the three-item version and alternative (original and eight-item) versions demonstrated satisfactory concurrent validity, internal consistency, and test-retest reliability (Lin et al., 2022). For the present three-wave study, the three-item version was selected to minimize potential missing data and showed very good internal consistency reliability across all three timepoints ($\omega = 0.83, 0.86, \text{ and } 0.83$, respectively).

2.2.4 The International Physical Activity Questionnaire Short Form (IPAQ- SF)

The IPAQ-SF is a seven-item instrument designed to quantify individuals’ PA levels by comprehensively assessing both activity duration and intensity (Huang et al., 2022). Following the guidelines established by the IPAQ Research Committee (2005) physical activities are converted into metabolic equivalent of task (MET) values, with a standardized truncation at 180 minutes per day. The instrument assigns specific MET values to various activity intensities: walking (3.3 METs), moderate activities such as jogging (4.0 METs), and vigorous activities like swimming (8.0 METs). Total PA is calculated by multiplying these MET values by the duration of the activity, resulting in MET-minutes for each category. The Chinese version of the IPAQ-SF has undergone extensive psychometric validation, demonstrating robust measurement properties across multiple studies. These validations have confirmed its strong content validity and test-retest reliability (Fung et al., 2019; Saffari et al., 2022)..

Data analysis

The analysis adhered to a systematic three-stage implementation process. In the initial stage, the participants’ background characteristics were thoroughly examined at each timepoint. This was

complemented by descriptive statistical analyses that included both the scores from the TAPAS and the various levels of PA across all timepoints. Additionally, a comparison of the distinct PA levels at each timepoint was performed using repeated measures ANOVA, along with an evaluation of their interrelationships through Pearson's correlation coefficients.

The second stage comprised a comprehensive assessment of measurement quality through the implementation of three confirmatory factor analyses (CFAs). The measurement models were designed to include two latent variables—loneliness and PA avoidance—alongside three observed variables representing distinct levels of PA (i.e., vigorous intensity, moderate intensity, and walking). The observed variables were treated as manifest variables, assuming no measurement error. In this stage, maximum likelihood estimation with robust standard errors (MLR) was utilized because it is particularly advantageous due to its reduced sensitivity to violations of multivariate normality assumptions.

Following the establishment of measurement quality, the third stage involved testing four cross-lagged mediation models using multiple indicators for loneliness and PA avoidance. These models included control variables: sex (male as the reference group), age (in years), and BMI group (being non-overweight as the reference group versus being overweight). PA avoidance was designated as the exogenous variable, with loneliness as the endogenous variable. Four distinct levels of PA served as mediators in separate models: total amount, vigorous intensity, moderate intensity, and walking. The models incorporated autoregressive coefficients to assess measurement stability over time and cross-lagged coefficients to investigate temporal relationships. To ensure methodological consistency, MLR estimation was employed across all mediation models.

Full Information Maximum Likelihood (FIML) estimation was employed in both the CFAs and the cross-lagged mediation models to address the issue of missing data. The assessment of model fit for both CFA and structural equation modeling (SEM) analyses adhered to established criteria (Kline, 2023), which stipulate that the root mean square error of approximation (RMSEA) and standardized root mean square residual (SRMR) values should be below 0.10, while the comparative fit index (CFI)

and non-normed fit index (NNFI) values should exceed 0.90. All statistical analyses were executed using SPSS (Version 27.0) and Jamovi (Version 2.6.23).

Results

At T1, the sample consisted of 1,024 participants with a balanced gender distribution, comprising 514 males (50.2%) and 510 females (49.8%). The mean age of the participants was 16.6 years ($SD = 0.7$), with an average height of 165.62 cm ($SD = 9.68$) and an average weight of 73.08 kg ($SD = 21.86$). A significant majority of participants (94.1%) reported having siblings ($n = 947$). In terms of weight status, 46.2% of the participants were classified as being average weight ($n = 465$), 46.9% as being overweight ($n = 472$), and 6.9% as being underweight ($n = 69$). The means and standard deviations for each level of PA, PA avoidance, and loneliness are also presented in Table 1, with significant differences found across time. Additionally, baseline differences in gender, weight, and vigorous PA participation were observed across weight status. These findings are detailed in Supplementary Materials (S1) and Table (S1).

(Insert Table 1 here)

Pearson correlation analyses indicated negative associations between total PA and the three distinct types of PA with both PA avoidance and loneliness at each measurement point ($r = -0.08$ to -0.21 , $p < 0.05$). Importantly, PA avoidance consistently demonstrated positive correlations with loneliness across all timepoints, with correlation coefficients of $r = 0.42$, 0.46 , and 0.46 for T1, T2, and T3, respectively ($p < 0.01$). Several significant cross-lagged associations were identified: moderate PA at T1 was negatively associated with PA avoidance at T2 ($r = -0.07$, $p < 0.05$); vigorous PA and walking PA at T1 were negatively associated with loneliness at T2 ($r = -0.11$ and -0.08 , respectively, $p < 0.05$); and vigorous PA at T2 was negatively associated with PA avoidance at T3 ($r = -0.11$, $p < 0.05$).

(Insert Table 2 here)

The CFAs demonstrated satisfactory model fit indices across all three timepoints (see Table 3).

The model showed adequate and similar fit at T1 and T2, and exhibited a slight improvement at T3. All fit indices consistently met conventional standards for acceptable model fit (i.e., CFI and NNFI > 0.90, SRMR and RMSEA < 0.10), with T3 demonstrating the best overall fit, indicating good factorial validity. Additionally, the standardized factor loadings for both TAPAS and UCLA-3 across the three timepoints ranged from 0.67 to 0.95, demonstrating satisfactory convergent validity for both latent constructs. Additionally, the cross-lagged mediation analyses yielded acceptable fit indices across all models.

(Insert Table 3 here)

The comprehensive model coefficients, detailed in Supplementary Tables (S2) to (S5), delineate distinct PA levels' mediating effects. Significant autoregressive coefficients emerged across all variables between consecutive timepoints (T1 to T2, and T2 to T3), demonstrating robust temporal stability in the measurement of constructs (illustrated in Figures 1). After controlling for sex, age, and weight status (non-overweight and overweight), the analysis of cross-lagged coefficients showed several significant temporal relationships. PA avoidance at T1 exhibited negative predictive effects on both vigorous PA and moderate PA at T2 (standardized coefficient $[\beta] = -0.11$ for both indices). Moreover, PA avoidance demonstrated consistent positive predictive effects on subsequent loneliness ($\beta = 0.11$ for T1 to T2; $\beta = 0.17-0.18$ for T2 to T3). A bidirectional relationship emerged, wherein loneliness significantly predicted subsequent PA avoidance from T1 to T2 ($\beta = 0.08$), and T2 to T3 ($\beta = 0.11$). Additional temporal associations indicated that loneliness at T2 negatively predicted vigorous PA at T3 ($\beta = -0.13$), while loneliness at T1 demonstrated a negative predictive effect on walking PA at T2 ($\beta = -0.09$). Importantly, no significant predictive relationships were observed from any PA level to subsequent PA avoidance or loneliness across the three timepoints. The analysis also showed a significant cross-lagged mediation effect, wherein PA avoidance at T1 indirectly influenced vigorous PA at T3 through loneliness at T2 ($b = -0.020$, $SE = 0.010$, $t = 2.00$, $p = 0.046$).

(Insert Figure 1 here)

Discussion

The present study conducted a longitudinal investigation into the temporal relationships and mediating effects between PA avoidance, loneliness, and various levels of PA (specifically, total PA, vigorous intensity, moderate intensity, and walking) among Chinese adolescents. The results indicated significant cross-lagged associations between PA avoidance and loneliness across different timepoints, indicating that earlier measurements of each variable predicted subsequent changes in the other over time. In addition, PA avoidance at T1 was significantly associated with both vigorous and moderate PA at T2. Loneliness at T1 was significantly associated with walking at T2, while loneliness at T2 was significantly associated with vigorous PA at T3. Moreover, PA avoidance at T1 showed an indirect association with vigorous PA at T3 through the mediating effect of loneliness at T2. These results suggest that the interrelationship between PA avoidance and loneliness over time may dynamically influence PA participation among adolescents. These results indicated that H₅ to H₉, as well as H₁₄ to H₁₇, were supported, H₂ and H₃ were partially supported, and H₁, H₄, as well as H₁₀ to H₁₃ were not supported.

The present study's findings support the negative association between PA avoidance and both total and distinct levels of PA, consistent with previous research (Huang et al., 2024; Saffari et al., 2025; Yi et al., 2024). However, prior studies have predominantly investigated this association within the contexts of weight stigma or problematic technology use. The present study is the first to incorporate loneliness as a variable in examining the relationship between PA avoidance and PA levels, and found that loneliness significantly mediated the association between PA avoidance and vigorous PA. Additionally, PA avoidance and loneliness were identified as distinct predictors of varying levels of PA. Although some of the effect sizes observed in the present study were small (e.g., $\beta = -0.011$), they may still hold practical significance. As previous literature has noted, small effects can have a substantial cumulative impact among larger populations (Carey et al., 2023), particularly in psychological contexts (Funder et al., 2019). In addition, small effects can be meaningful in the context based on appropriate empirical data and theory (Primbs et al., 2023). Given the high

prevalence of physical inactivity and psychosocial challenges among adolescents (Guthold et al., 2020; Haugen et al., 2013; Pinto et al., 2021; Rangul et al., 2024; Strain et al., 2024), even modest associations may inform the development of early intervention strategies and prevention programs.

During the first transition period (i.e., T1 to T2), PA avoidance was found to have a detrimental effect on both vigorous and moderate PA, while feelings of loneliness adversely influenced walking behavior. However, the impact of PA avoidance diminished during the subsequent transition period (i.e., T2 to T3), whereas the effect of loneliness continued to negatively affect vigorous PA. A cross-sectional study conducted by Chen et al. (2023) found that adolescents who engaged in higher levels of moderate-to-vigorous PA reported lower levels of social anxiety. This aligns with previous proposed notions that individuals experiencing social anxiety often encounter difficulties in participating in PA, with tendencies to avoid PA being more pronounced among those exhibiting anxiety-related traits (Levinson et al., 2013). In alignment with these findings, the present study found that PA avoidance adversely affected both vigorous and moderate PA levels. This relationship highlights a conceptual similarity, emphasizing the significance of psychological barriers in influencing PA behaviors.

Previous research examining the relationship between loneliness and participation in PA has primarily concentrated on middle-aged and older populations. Findings indicated that loneliness may predict decreased levels of PA (Hawkey et al., 2009), while walking significantly mitigated perceived loneliness (Mizuta et al., 2023; Shellito et al., 2019). In studies focusing on adolescents, a decline in PA levels coupled with an increase in loneliness has been documented from early to late adolescence (Rangul et al., 2024). Moreover, engagement in sports has been associated with lower levels of loneliness (Haugen et al., 2013). Building upon these findings, the present study contributes to the extant literature by elucidating the impact of loneliness on varying levels of PA among adolescents. Future research should further investigate how different types of PA, particularly those characterized by varying degrees of social interaction, may influence loneliness within this population.

The cross-lagged associations between PA avoidance and loneliness over time indicated a

reciprocal relationship between these variables, thereby elucidating a novel mechanism through which they affect individuals' levels of PA. A plausible explanation for this relationship can be derived from both psychological mechanisms and social dynamics. For example, PA avoidance may stem from psychological barriers such as concerns regarding physical appearance (Bevan et al., 2022) or social anxiety (Levinson et al., 2013). Individuals exhibiting a higher tendency to avoid PA may consequently participate less frequently in public activities, which can exacerbate feelings of loneliness. In turn, loneliness has been reported to be associated with psychological distress (Konno et al., 2021), which may further contribute to PA avoidance (Bevan et al., 2023; Mason et al., 2019). Additionally, the psychological distress associated with anxiety has been shown to moderate the relationship between intention and PA behaviors (Galli et al., 2022), thereby impacting individuals' participation in PA (Gucciardi et al., 2020; Milas et al., 2019). Consequently, this intricate interaction fosters a vicious cycle that progressively influences individuals' engagement in PA.

SDT emphasizes that intrinsic motivation for PA is driven by the fulfillment of three psychological needs: autonomy, competence, and relatedness (Teixeira et al., 2012). Based on the present study's findings, loneliness can be viewed as a failure to satisfy the relatedness need in the SDT. With the reciprocal relationship between PA avoidance and loneliness, it is possible that low relatedness resulted from loneliness leading to avoidance behaviors, further reducing motivation for PA and consequent low PA engagement. SCT posits that PA behavior is shaped by the interplay of personal, behavioral, and environmental factors, including self-efficacy and social support (Bandura, 2001; Hamilton et al., 2017). The present study's findings that loneliness predicted particular levels of PA suggests that low social support may deter PA among adolescents. Moreover, The mediation effect of loneliness aligns with SCT's emphasis on reciprocal determinism (Bandura, 2001), where social and emotional factors (loneliness) impact behavior (PA avoidance), which in turn shapes future behavior (lower PA levels).

Other variables such as sex, cultural context or socioeconomic status may also have had an influence on the present study's findings. In particular, the associations between loneliness and

adverse health outcomes may vary depending on cultural context (e.g., individualism vs. collectivism) or sex (Beller et al., 2020; Holt-Lunstad, 2018). Moreover, global surveys have shown that patterns of PA participation—including frequency and types of PA—differ across countries and regions (Guthold et al., 2020; Hulteen et al., 2017). Additionally, weight stigmatization also has been reported to be associated to individuals' PA avoidance and subsequent PA engagement (Huang et al., 2025). Taken together, these findings highlight the importance of considering cultural and socioeconomic influences. Future studies may consider adopting Hofstede's (2011) Cultural Dimensions framework to further examine the mechanisms underlying these associations in diverse sociocultural contexts.

The present study has several limitations. Firstly, relying on self-reported demographics (e.g., weight and height) and measures may introduce potential biases, including social desirability and recall biases. These biases may have led to either underreport or overreport of participants' behaviors, particularly in sensitive domains such as PA avoidance or PA participation. Moreover, participants may have reported their weight and/or height inaccurately. As a result, the data accuracy may be compromised, potentially influencing the strength or direction of observed associations. Future studies could take objective measurements in future studies to mitigate some of these biases. Secondly, recruiting participants from only two senior high schools may limit the diversity of participants' socioeconomic background or academic pressure. Such an approach may cause sampling bias, restricting the representativeness of the findings. More specifically, adolescents in different types of schools (e.g., vocational schools or rural schools) may show different patterns of PA engagement and psychosocial experiences, which were not captured in the present study. Future studies may explore the mechanisms by considering characteristic differences (such as cultural context or socioeconomic status) or extend to subtypes of PA avoidance (such as body image concerns or performance anxiety), to provide more comprehensive evidence. Thirdly, the exclusive focus on Chinese adolescents may limit the generalizability and applicability of the results to other groups with particular demographic, such as younger or older adults, or populations with contextual differences, such as Western populations. Cross-cultural replication and age-comparative studies are necessary to evaluate the

robustness and applicability of the present study's findings.

Despite these limitations, the study emphasizes the importance of individuals transitioning from adolescence to adulthood, a critical period for developing an active lifestyle. The present study's findings could be integrated into school-based interventions. For example, school counselors and teachers may consider incorporating structured social skills training into health education curricula, helping adolescents strengthen their interpersonal relationships, thereby alleviating feelings of loneliness during puberty. Moreover, physical education teachers can design group-based PA sessions that emphasize enjoyment, cooperation, and peer support, or incorporate goal-setting and self-monitoring strategies during regular classroom activities to promote positive attitudes and experiences toward PA. These interventions not only encourage social interaction during PA participation but also reduce tendencies to avoid PA, thereby directly and indirectly promoting PA among adolescents. Collectively, these strategies may contribute to increased levels of engagement in PA.

Conclusion

The present study utilized a longitudinal design and cross-lagged mediation analysis to investigate the relationships between PA avoidance, loneliness, and varying levels of PA among adolescents. The results showed that PA avoidance was a predictor of vigorous PA through the mediating role of loneliness. Moreover, the study identified reciprocal relationships between PA avoidance and loneliness over time. Additionally, PA avoidance was shown to have a detrimental effect on both vigorous and moderate PA, while loneliness was linked to a reduction in walking and vigorous PA. These findings contribute to the extant literature by providing a novel perspective on how loneliness may lead to decreased levels of PA. Moreover, the distinct impacts of PA avoidance and loneliness on different forms of PA were emphasized. To encourage sustained participation in PA, interventions designed to enhance psychological well-being and social skills may prove effective in mitigating the adverse effects of PA avoidance and loneliness.

References

- Ahn, J., Falk, E. B., & Kang, Y., (2024). Relationships between physical activity and loneliness: A systematic review of intervention studies. *Current Research in Behavioral Sciences*, 6, 100141. <https://doi.org/10.1016/j.crbeha.2023.100141>
- Ang, C. S., Chan, N. N., & Lee, C. S., (2018). Shyness, loneliness avoidance, and Internet addiction: What are the relationships? *Journal of Psychology*, 152(1), 25-35. <https://doi.org/10.1080/00223980.2017.1399854>
- Bandura, A., (2001). Social cognitive theory: An agentic perspective. *Annual Review of Psychology*, 52, 1-26. <https://doi.org/10.1146/annurev.psych.52.1.1>
- Bauman, A. E., Reis, R. S., Sallis, J. F., Wells, J. C., Loos, R. J., & Martin, B. W. (2012). Correlates of physical activity: Why are some people physically active and others not? *The Lancet*, 380(9838), 258-271. [https://doi.org/10.1016/S0140-6736\(12\)60735-1](https://doi.org/10.1016/S0140-6736(12)60735-1)
- Beller, J., & Wagner, A., (2020). Loneliness and health: The moderating effect of cross-cultural individualism/collectivism. *Journal of Aging and Health*, 32(10), 1516-1527. <https://doi.org/10.1177/0898264320943336>
- Bevan, N., Latner, J. D., Vandenberg, B., Jeanes, R., & Lin, C. Y., (2023). The relationship between weight stigmatization, avoidance, enjoyment and participation in physical activity and sport, and psychological distress. *American Journal of Health Behavior*, 47(2), 360-368. <https://doi.org/10.5993/AJHB.47.2.15>
- Bevan, N., O'Brien, K. S., Latner, J. D., Lin, C. Y., Vandenberg, B., Jeanes, R., & Fung, X. C. C., (2022). Weight stigma and avoidance of physical activity and sport: Development of a scale and establishment of correlates. *International Journal of Environmental Research and Public Health*, 19(23), 16370. <https://doi.org/10.3390/ijerph192316370>
- Carey, E. G., Ridler, I., Ford, T. J., & Stringaris, A., (2023). Editorial perspective: When is a 'small effect' actually large and impactful? *Journal of Child Psychology and Psychiatry*, 64(11), 1643-1647. <https://doi.org/10.1111/jcpp.13817>
- Chen, S., Jing, L., Li, C., & Wang, H., (2023). Exploring the nexus between moderate-to-vigorous physical activity, self-disclosure, social anxiety, and adolescent social avoidance: Insights from a cross-sectional study in central China. *Children*, 11(1), 56. <https://doi.org/10.3390/children11010056>
- Fan, C. W., Chang, Y. L., Huang, P. C., Fung, X. C. C., Chen, J. K., Bevan, N., O'Brien, K. S., Yeh, Y. C., Chen, H. P., Chen, I. H., Lin, I. C., Griffiths, M. D., & Lin, C. Y., (2023). The Tendency to Avoid Physical Activity and Sport Scale (TAPAS): Rasch analysis with differential item functioning testing among a Chinese sample. *BMC Psychology*, 11(1), 369. <https://doi.org/10.1186/s40359-023-01377-y>
- Flaherty, L., T (2015). Sleeplessness, loneliness and stigma: Under-recognized problems in adolescent psychiatry. *Adolescent Psychiatry*, 5(3), 143-145. <https://doi.org/10.2174/221067660503151204111213>
- Funder, D. C., & Ozer, D. J., (2019). Evaluating effect size in psychological research: Sense and nonsense. *Advances in Methods and Practices in Psychological Science*, 2(2), 156-168. <https://doi.org/10.1177/2515245919847202>
- Fung, X. C. C., Pakpour, A. H., Wu, Y. K., Fan, C. W., Lin, C. Y., & Tsang, H. W. H., (2019). Psychosocial variables related to weight-related self-stigma in physical activity among young adults across weight status. *International Journal of Environmental Research and Public Health*, 17(1), 64. <https://doi.org/10.3390/ijerph17010064>
- Galli, F., Giancamilli, F., Palombi, T., Vitale, J. A., Borghi, S., De Maria, A., Cavicchiolo, E., Diotaiuti, P., La Torre, A., Zelli, A., Lucidi, F., Codella, R., & Chirico, A., (2022). Anxiety, motives, and intention for physical activity during the Italian COVID-19 lockdown: An observational longitudinal study. *International Journal of Environmental Research and Public Health*, 19(8), 4689. <https://doi.org/10.3390/ijerph19084689>
- Gucciardi, D. F., Law, K. H., Guerrero, M. D., Qusted, E., Thøgersen-Ntoumani, C., Ntoumanis, N.,

- & Jackson, B., (2020). Longitudinal relations between psychological distress and moderate-to-vigorous physical activity: A latent change score approach. *Psychology of Sport and Exercise*, 47, 101490. <https://doi.org/10.1016/j.psychsport.2019.02.005>
- Guo, S., Izydorczyk, B., Lipowska, M., Kamionka, A., Lizinczyk, S., Sajewicz-Radtke, U., Radtke, B. M., Liu, T., & Lipowski, M., (2023). Socio-cultural attitudes toward the body as a predictor of motivation for physical activity in young people brought up in Asian and European culture - Chinese - Polish comparison. *BMC Sports Science, Medicine and Rehabilitation*, 15(1), 52. <https://doi.org/10.1186/s13102-023-00662-y>
- Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C., (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *Lancet Child and Adolescent Health*, 4(1), 23-35. [https://doi.org/10.1016/S2352-4642\(19\)30323-2](https://doi.org/10.1016/S2352-4642(19)30323-2)
- Hamilton, K., Warner, L. M., & Schwarzer, R., (2017). The role of self-efficacy and friend support on adolescent vigorous physical activity. *Health Education & Behavior*, 44(1), 175-181. <https://doi.org/10.1177/1090198116648266>
- Haugen, T., Säfvenbom, R., & Ommundsen, Y., (2013). Sport participation and loneliness in adolescents: The mediating role of perceived social competence. *Current Psychology*, 32, 203-216. <https://doi.org/10.1007/s12144-013-9174-5>
- Hawkley, L. C., Thisted, R. A., & Cacioppo, J. T., (2009). Loneliness predicts reduced physical activity: Cross-sectional & longitudinal analyses. *Health Psychology*, 28(3), 354-363. <https://doi.org/10.1037/a0014400>
- Hofstede, G., (2011). Dimensionalizing cultures: The Hofstede model in context. *Online Readings in Psychology and Culture*, 2(1), 8. <https://doi.org/10.9707/2307-0919.1014>
- Holt-Lunstad, J., (2018). Why social relationships are important for physical health: A systems approach to understanding and modifying risk and protection. *Annual Review of Psychology*, 69, 437-458. <https://doi.org/10.1146/annurev-psych-122216-011902>
- Huang, P. C., Wu, H. C., Chen, J. K., Fung, X. C. C., Bevan, N., Ahorsu, D. K., Griffiths, M. D., Chen, J. S., Lee, K. H., & Pakpour, A. H., (2025). The mediating role of physical activity avoidance in the association between weight stigma and physical activity. *Acta Psychologica*, 257, 105107. <https://doi.org/10.1016/j.actpsy.2025.105107>
- Huang, P. C., Chen, J. S., Potenza, M. N., Griffiths, M. D., Pakpour, A. H., Chen, J. K., Lin, Y. C., Hung, C. H., O'Brien, K. S., & Lin, C. Y., (2022). Temporal associations between physical activity and three types of problematic use of the internet: A six-month longitudinal study. *Journal of Behavioral Addictions*, 11(4), 1055-1067. <https://doi.org/10.1556/2006.2022.00084>
- Huang, P. C., Geusens, F., Tu, H. F., Fung, X. C. C., & Chen, C. Y., (2024). Association between problematic social media use and physical activity: The mediating roles of nomophobia and the tendency to avoid physical activity. *Journal of Social Media Research*, 1(1), 14-24. <https://doi.org/10.29329/jsomer.4>
- Hughes, M. E., Waite, L. J., Hawkley, L. C., & Cacioppo, J. T., (2004). A short scale for measuring loneliness in large surveys: Results from two population-based studies. *Research on Aging*, 26(6), 655-672. <https://doi.org/10.1177/0164027504268574>
- Hulteen, R. M., Smith, J. J., Morgan, P. J., Barnett, L. M., Hallal, P. C., Colyvas, K., & Lubans, D. R., (2017). Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. *Preventive Medicine*, 95, 14-25. <https://doi.org/10.1016/j.ypmed.2016.11.027>
- IPAQ Research Committee. (2005). *Guidelines for data processing analysis of the International Physical Activity Questionnaire (IPAQ) - Short and long forms*. <https://drive.google.com/file/d/1gehdaq1-04eSWfbxscwtzXa1MUID8Mffa/view>
- Kallio, P., Pahkala, K., Heinonen, O. J., Tammelin, T. H., Palve, K., Hirvensalo, M., Juonala, M., Loo, B. M., Magnussen, C. G., Rovio, S., Helajarvi, H., Laitinen, T. P., Jokinen, E., Tossavainen, P., Hutri-Kahonen, N., Viikari, J., & Raitakari, O. T., (2021). Physical inactivity from youth

- to adulthood and adult cardiometabolic risk profile. *Preventive Medicine*, 145, 106433. <https://doi.org/10.1016/j.ypmed.2021.106433>
- Kandola, A., Lewis, G., Osborn, D. P. J., Stubbs, B., & Hayes, J. F., (2020). Depressive symptoms and objectively measured physical activity and sedentary behaviour throughout adolescence: A prospective cohort study. *Lancet Psychiatry*, 7(3), 262-271. [https://doi.org/10.1016/S2215-0366\(20\)30034-1](https://doi.org/10.1016/S2215-0366(20)30034-1)
- Kline, R. B. (2023). *Principles and practice of structural equation modeling* (5th ed.). Guilford publications.
- Konno, Y., Nagata, M., Hino, A., Tateishi, S., Tsuji, M., Ogami, A., Yoshimura, R., Matsuda, S., & Fujino, Y., (2021). Association between loneliness and psychological distress: A cross-sectional study among Japanese workers during the COVID-19 pandemic. *Preventive Medicine Reports*, 24, 101621. <https://doi.org/10.1016/j.pmedr.2021.101621>
- Levinson, C. A., Rodebaugh, T. L., Menatti, A. R., & Weeks, J. W., (2013). Validation of the Social Exercise and Anxiety Measure (SEAM): Assessing fears, avoidance, and importance of social exercise. *Journal of Psychopathology and Behavioral Assessment*, 35, 244-253. <https://doi.org/10.1007/s10862-012-9326-1>
- Lin, C. Y., Tsai, C. S., Fan, C. W., Griffiths, M. D., Chang, C. C., Yen, C. F., & Pakpour, A. H., (2022). Psychometric evaluation of three versions of the UCLA Loneliness Scale (full, eight-item, and three-item versions) among sexual minority men in Taiwan. *International Journal of Environmental Research and Public Health*, 19(13), 8095. <https://doi.org/10.3390/ijerph19138095>
- Liu, T., Lu, S., Leung, D. K., Sze, L. C., Kwok, W. W., Tang, J. Y., Luo, H., Lum, T. Y., & Wong, G. H., (2020). Adapting the UCLA 3-item loneliness scale for community-based depressive symptoms screening interview among older Chinese: A cross-sectional study. *BMJ Open*, 10(12), e041921. <https://doi.org/10.1136/bmjopen-2020-041921>
- Maes, M., Nelemans, S. A., Danneel, S., Fernandez-Castilla, B., Van den Noortgate, W., Goossens, L., & Vanhalst, J., (2019). Loneliness and social anxiety across childhood and adolescence: Multilevel meta-analyses of cross-sectional and longitudinal associations. *Developmental Psychology*, 55(7), 1548-1565. <https://doi.org/10.1037/dev0000719>
- Mason, J. E., Faller, Y. N., LeBouthillier, D. M., & Asmundson, G. J., (2019). Exercise anxiety: A qualitative analysis of the barriers, facilitators, and psychological processes underlying exercise participation for people with anxiety-related disorders. *Mental Health and Physical Activity*, 16, 128-139. <https://doi.org/10.1016/j.mhpa.2018.11.003>
- McLoughlin, R. F., & McDonald, V. M., (2021). The management of extrapulmonary comorbidities and treatable traits; Obesity, physical inactivity, anxiety, and depression, in adults with asthma. *Frontiers in Allergy*, 2, 735030. <https://doi.org/10.3389/falgy.2021.735030>
- Milas, G., Klarić, I. M., Malnar, A., Šupe-Domić, D., & Slavich, G. M., (2019). Socioeconomic status, social-cultural values, life stress, and health behaviors in a national sample of adolescents. *Stress and Health*, 35(2), 217-224. <https://doi.org/10.1002/smi.2854>
- Mizuta, S., Uchida, K., Sawa, R., Nakamura, J., Encho, H., Akisue, T., & Ono, R., (2023). Context of walking and loneliness among community-dwelling older adults: A cross-sectional study. *BMC Geriatrics*, 23(1), 326. <https://doi.org/10.1186/s12877-023-04043-5>
- National Health Commission of the People's Republic of China. (2018, March 30). *Screening for overweight and obesity in school-age children and adolescents*. Retrieved June 22 2025 from <http://www.nhc.gov.cn/wjw/pqt/201803/a7962d1ac01647b9837110bfd2d69b26.shtml>
- Pels, F., & Kleinert, J., (2016). Loneliness and physical activity: A systematic review. *International Review of Sport and Exercise Psychology*, 9(1), 231-260. <https://doi.org/10.1080/1750984X.2016.1177849>
- Pinto, A. A., Oppong Asante, K., Puga Barbosa, R., Nahas, M. V., Dias, D. T., & Pelegri, A., (2021). Association between loneliness, physical activity, and participation in physical education among adolescents in Amazonas, Brazil. *Journal of Health Psychology*, 26(5), 650-658. <https://doi.org/10.1177/1359105319833741>

- Primbs, M. A., Pennington, C. R., Lakens, D., Silan, M. A. A., Lieck, D. S. N., Forscher, P. S., Buchanan, E. M., & Westwood, S. J., (2023). Are small effects the indispensable foundation for a cumulative psychological science? A reply to Gotz et al. (2022). *Perspectives on Psychological Science*, 18(2), 508-512. <https://doi.org/10.1177/17456916221100420>
- Rangul, V., Sund, E. R., Ingul, J. M., Rimehaug, T., Pape, K., & Kvaloy, K., (2024). Exploring the link between physical activity, sports participation, and loneliness in adolescents before and into the COVID-19 pandemic: The HUNT study, Norway. *International Journal of Environmental Research and Public Health*, 21(11), 1417. <https://doi.org/10.3390/ijerph21111417>
- Rokach, A., & Brock, H., (1998). Coping with loneliness. *Journal of Psychology*, 132(1), 107-127. <https://doi.org/10.1080/00223989809599269>
- Roth, S. E., Gill, M., Chan-Golston, A. M., Rice, L. N., Crespi, C. M., Koniak-Griffin, D., Cole, B. L., Upchurch, D. M., & Prelip, M. L., (2019). Physical activity correlates in middle school adolescents: Perceived benefits and barriers and their determinants. *The Journal of School Nursing*, 35(5), 348-358. <https://doi.org/10.1177/1059840518780300>
- Russell, D. W., (1996). UCLA Loneliness Scale (Version 3): Reliability, validity, and factor structure. *Journal of Personality Assessment*, 66(1), 20-40. https://doi.org/10.1207/s15327752jpa6601_2
- Saffari, M., Chen, I. H., Huang P. C., O'Brien, K. S., Hsieh, Y. P., Chen, J. K., Chang, Y. H., Jiang, X., Bevan, N., Chang, Y. L., Griffiths, M. D., & Lin, C. Y., (2023). Measurement invariance and psychometric evaluation of the Tendency to Avoid Physical Activity and Sport Scale (TAPAS) among mainland Chinese university students. *Psychology Research and Behavior Management*, 16, 3821-3836. <https://doi.org/10.2147/PRBM.S425804>
- Saffari, M., Chen, J. S., Wu, H. C., Fung, X. C. C., Chang, C. C., Chang, Y. L., Kamolthip, R., Potenza, M. N., Lin, I. C., & Lin, C. Y., (2022). Effects of weight-related self-stigma and smartphone addiction on female university students' physical activity levels. *International Journal of Environmental Research and Public Health*, 19(5), 2631. <https://doi.org/10.3390/ijerph19052631>
- Saffari, M., Huang, C. H., Huang, P. C., Chang, Y. H., Chen, J. S., Poon, W. C., Potenza, M. N., Griffiths, M. D., & Lin, C. Y., (2025). Mediating roles of weight stigma and physical activity avoidance in the associations between severity of gaming disorder and levels of physical activity among young adults. *Journal of Behavioral Addictions*, 14(1), 289-303. <https://doi.org/10.1556/2006.2024.00083>
- Shellito, N., & Roldan, N. V., (2019). Walking away from loneliness: The mediating role of social isolation. *Innovation in Aging*, 3(Suppl 1), S836. <https://doi.org/10.1093/geroni/igz038.3082>
- Solomon, Z., Bensimon, M., Greene, T., Horesh, D., & Ein-Dor, T., (2015). Loneliness trajectories: The role of posttraumatic symptoms and social support. *Journal of Loss and Trauma*, 20(1), 1-21. <https://doi.org/10.1080/15325024.2013.815055>
- Strain, T., Flaxman, S., Guthold, R., Semenova, E., Cowan, M., Riley, L. M., Bull, F. C., Stevens, G. A., & Group, C. D. A., (2024). National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: A pooled analysis of 507 population-based surveys with 5.7 million participants. *Lancet Global Health*, 12(8), e1232-e1243. [https://doi.org/10.1016/S2214-109X\(24\)00150-5](https://doi.org/10.1016/S2214-109X(24)00150-5)
- Tapias, F. S., Otani, V. H. O., Vasques, D. A. C., Otani, T. Z. S., & Uchida, R. R., (2021). Costs associated with depression and obesity among cardiovascular patients: Medical expenditure panel survey analysis. *BMC Health Services Research*, 21(1), 433. <https://doi.org/10.1186/s12913-021-06428-x>
- Teixeira, P. J., Carraca, E. V., Markland, D., Silva, M. N., & Ryan, R. M., (2012). Exercise, physical activity, and self-determination theory: A systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, 9, 78. <https://doi.org/10.1186/1479-5868-9-78>
- Vanhelst, J., Beghin, L., Drumez, E., Labreuche, J., Polito, A., De Ruyter, T., Censi, L., Ferrari, M., Miguel-Berges, M. L., Michels, N., De Henauw, S., Moreno, L. A., & Gottrand, F., (2023).

Changes in physical activity patterns from adolescence to young adulthood: The BELINDA study. *European Journal of Pediatrics*, 182(6), 2891-2902. <https://doi.org/10.1007/s00431-023-04948-8>

- World Health Organization. (2022, October 19). *WHO highlights high cost of physical inactivity in first-ever global report*. Retrieved June 22 2025 from <https://www.who.int/news/item/19-10-2022-who-highlights-high-cost-of-physical-inactivity-in-first-ever-global-report>
- Yi, J., Chen, I. H., Chen, H. P., Lin, I. C., Chen, J. S., Huang, P. C., O'Brien, K. S., Griffiths, M. D., & Lin, C. Y., (2024). Tendency to avoid physical activity mediates the association between perceived weight stigma and physical activity levels among university students. *Mental Health and Physical Activity*, 26, 100584. <https://doi.org/10.1016/j.mhpa.2024.100584>
- Zhang, X., & Dong, S., (2022). The relationships between social support and loneliness: A meta-analysis and review. *Acta Psychologica*, 227, 103616. <https://doi.org/10.1016/j.actpsy.2022.103616>
- Zhao, G., Sun, K., Xue, Y., & Dong, D., (2024). A chain-mediated model of the effect of physical exercise on loneliness. *Scientific Reports*, 14(1), 30798. <https://doi.org/10.1038/s41598-024-81059-w>
- Zhu, Y., & Du, R., (2024). Chinese and Western sports philosophy and their differences. *Trans/Form/Ação*, 47(5), e02400188. <https://doi.org/10.1590/0101-3173.2024.v47.n5.e02400188>

Figures

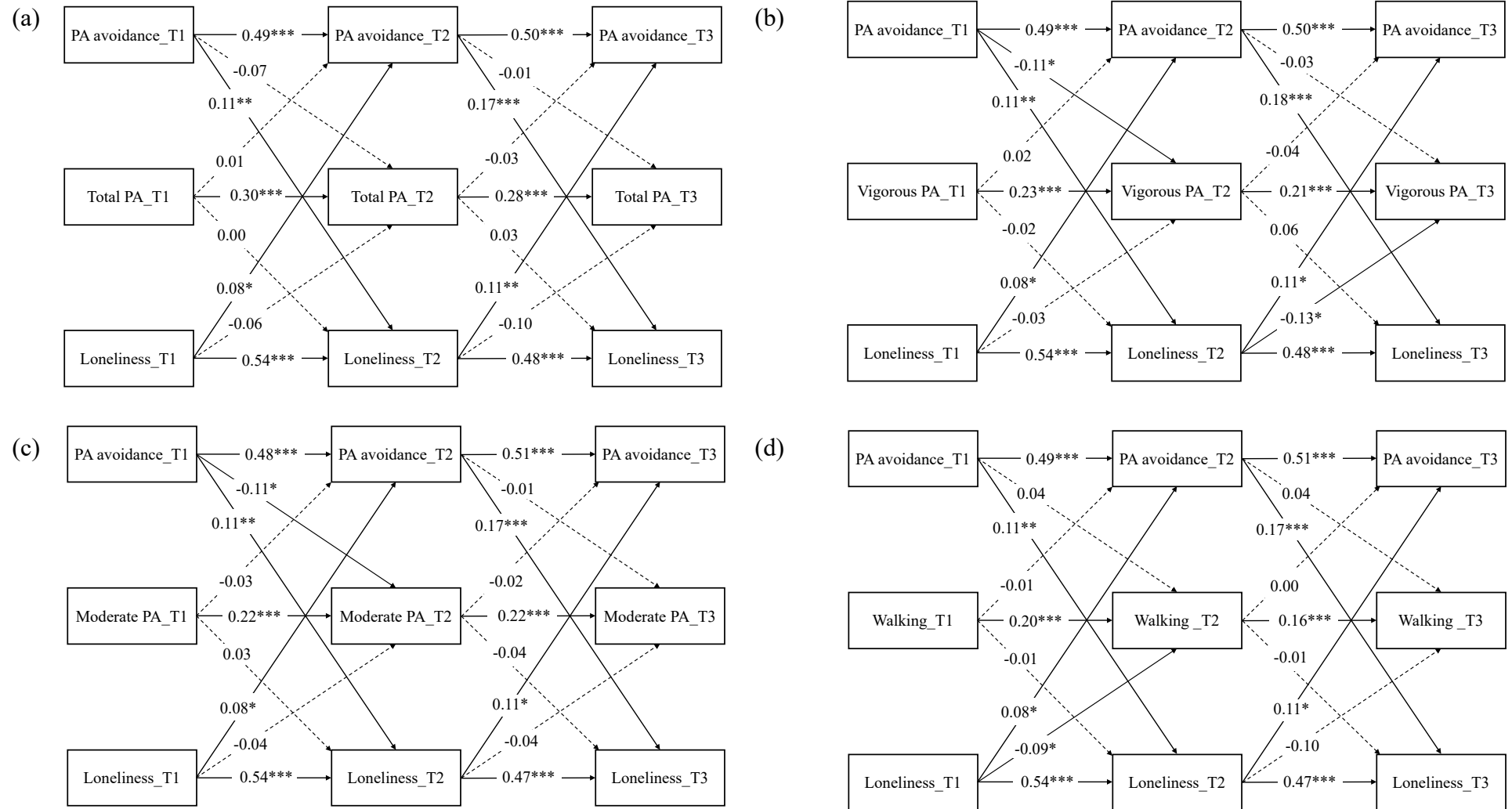


Figure 1. Results of cross-lagged mediation models with mediators using (a) total PA, (b) vigorous intensity PA, (c) moderate intensity PA and (d) walking.

T1 = Timepoint 1; T2 = Timepoint 2; T3 = Timepoint 3. PA = physical activity. Solid lines indicate significant associations. Dash lines indicate non-

significant associations.

Tables

Table 1. Characteristics of the participants at Time 1 (n=1024)

Variables	Mean (SD) or n (%)	Comparison across time
Age (in years)	16.57 (0.69)	
Gender		
Male	514 (50.2)	
Female	510 (49.8)	
Height ^a	165.62 (9.68)	
Weight ^a	73.08 (21.86)	
Weight status ^a		
Underweight	69 (6.9)	
Average weight	465 (46.2)	
Overweight	472 (46.9)	
Siblings ^a		
No	59 (5.9)	
Yes	947 (94.1)	
Physical activity – Total amount		
T1	3548.52 (4086.77)	
T2	2143.47 (2943.72)	
T3	2902.31 (3672.68)	
Physical activity – Vigorous intensity		T1 > T3 > T2
T1	1626.21 (2500.68)	
T2	811.05 (1712.14)	
T3	1245.51 (2144.29)	
Physical activity – Moderate intensity		T1 > T3 > T2
T1	813.43 (1226.49)	
T2	406.69 (857.83)	
T3	619.27 (1058.63)	
Physical activity – Walking		T1 > T2
T1	1108.88 (1245.37)	
T2	925.74 (1206.54)	
T3	1037.53 (1192.74)	
PA avoidance (ranged from 10 to 50)		T1 > T2
T1	22.40 (9.60)	
T2	20.89 (9.53)	

T3	20.58 (8.97)	
Loneliness (ranged from 3 to 12)		T1 > T2 > T3
T1	6.16 (2.38)	
T2	5.97 (2.32)	
T3	5.45 (2.08)	

^a18 participants did not respond their height, weight, and sibling information.

T1 = Timepoint 1; T2 = Timepoint 2; T3 = Timepoint 3.

Table 2. Pearson correlations among study variables (N = 972-1024).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Total PA_T1	-																	
2 VPA_T1	0.91	-																
3 MPA_T1	0.77	0.56	-															
4 Walking_T1	0.69	0.43	0.43	-														
5 PA avoidance_T1	-0.18	-0.18	-0.11	-0.11	-													
6 Loneliness_T1	-0.15	-0.13	-0.10	-0.13	0.42	-												
7 Total PA_T2	0.27	0.23	0.19	0.24	-0.14	-0.15	-											
8 VPA_T2	0.23	0.22	0.17	0.16	-0.15	-0.12	0.86	-										
9 MPA_T2	0.26	0.22	0.19	0.22	-0.14	-0.12	0.75	0.51	-									
10 Walking_T2	0.14	0.10	0.08	0.20	-0.02	-0.09	0.70	0.30	0.38	-								
11 PA avoidance_T2	-0.08	-0.07	-0.07	-0.05	0.51	0.27	-0.11	-0.14	-0.08	-0.02	-							
12 Loneliness_T2	-0.10	-0.11	-0.05	-0.08	0.31	0.48	-0.10	-0.11	-0.03	-0.06	0.46	-						
13 Total PA_T3	0.37	0.31	0.30	0.28	-0.12	-0.14	0.23	0.18	0.20	0.15	-0.07	-0.10	-					
14 VPA_T3	0.35	0.32	0.30	0.22	-0.14	-0.13	0.20	0.17	0.21	0.09	-0.10	-0.12	0.91	-				
15 MPA_T3	0.28	0.23	0.24	0.20	-0.10	-0.08	0.21	0.17	0.19	0.13	-0.03	-0.04	0.81	0.62	-			
16 Walking_T3	0.26	0.20	0.19	0.29	-0.04	-0.12	0.15	0.11	0.08	0.15	-0.03	-0.06	0.73	0.45	0.49	-		
17 PA avoidance_T3	-0.12	-0.11	-0.09	-0.08	0.47	0.27	-0.09	-0.11	-0.06	0.00	0.55	0.32	-0.17	-0.21	-0.12	-0.06	-	
18 Loneliness_T3	-0.11	-0.11	-0.04	-0.11	0.26	0.35	-0.04	-0.03	-0.07	-0.03	0.36	0.46	-0.16	-0.18	-0.13	-0.06	0.46	-

T1 = Timepoint 1; T2 = Timepoint 2; T3 = Timepoint 3; PA = physical activity; VPA = vigorous physical activity; MPA = moderate physical activity; PA avoidance = physical activity avoidance tendency. Significance ($p < 0.05$) are shown in **bold**.

Table 3. Model fit indices for confirmatory factor analyses (CFAs) at three timepoints and cross-lagged mediation models.

	$\chi^2 (df)$	CFI	NNFI	SRMR	RMSEA (90% CI)
CFA T1	694.84 (97)	0.917	0.908	0.041	0.078 (0.073-0.082)
CFA T2	635.91 (97)	0.914	0.908	0.030	0.076 (0.071-0.080)
CFA T3	449.44 (97)	0.941	0.927	0.024	0.061 (0.057-0.065)
Cross-lagged mediation model A	3199.09 (912)	0.912	0.904	0.054	0.041 (0.040-0.042)
Cross-lagged mediation model B	3176.74 (912)	0.913	0.905	0.054	0.041 (0.039-0.042)
Cross-lagged mediation model C	3156.60 (912)	0.913	0.906	0.053	0.041 (0.039-0.042)
Cross-lagged mediation model D	3148.31 (912)	0.917	0.910	0.053	0.041 (0.039-0.042)

T1 = Timepoint 1; T2 = Timepoint 2; T3 = Timepoint 3; CFI = comparative fit index; TLI = Tucker-Lewis index; NNFI = non-normed fit index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation. CI = confidence interval.

Note. Cross-lagged mediation model A used total physical activity [PA] as mediator; model B used vigorous PA as mediator; model C used moderate PA as mediator; model D used walking as mediator.