

Perceived physical literacy, sports team participation, and regular physical activity among university students: a national survey study

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Abstract

Background Insufficient physical activity in young adults is a persistent global public health concern, associated with noncommunicable disease and poorer mental health. University students are a critical life-course group whose activity is shaped by individual capacities and institutional environments. Physical literacy, spanning motivation, confidence, and health-related understanding, may support activity, but evidence from large university populations is limited. We examined whether perceived physical literacy was associated with regular physical activity, and whether sports team participation statistically accounted for part of this association.

Methods We analyzed the Student Sports Participation Survey, a nationally representative survey administered by the Sports Administration, Ministry of Education, Taiwan. The analytic sample comprised 8,981 undergraduates surveyed in 2023; 2020 data were analyzed for comparison during the COVID-19 pandemic. Perceived physical literacy was measured with the Ministry's standardized self-report scale, adapted from a validated instrument; sports team participation and regular physical activity used standardized survey items. Regular physical activity followed the Ministry standard, at least three weekly sessions of 30 min or longer at an intensity inducing sweating and breathlessness; a WHO-aligned threshold (≥ 150 min/week) was examined in sensitivity analysis. Structural equation modeling tested direct and indirect associations.

Results 28.6% of students met the regular-activity criterion. Higher perceived physical literacy was associated with greater regular physical activity and with sports team participation, which in turn statistically accounted for part of the perceived physical literacy and activity association (standardized indirect $\beta = 0.25$; 95% CI, 0.22–0.30). This indirect association was weaker in the 2020 sample than in 2023. Findings were robust to a WHO-aligned threshold and supported by full measurement invariance (configural, metric, scalar) across periods.

Conclusions Among university students, perceived physical literacy was positively associated with regular physical activity, with sports team participation accounting for part of this association. The weaker 2020 association, when opportunities for organized sport were likely more limited, suggests that the contribution of structured participation may depend on opportunity availability; because contextual variables were not measured, it cannot be attributed to pandemic restrictions. Universities could pair physical-literacy development with low-barrier, structured participation opportunities to support regular physical activity.

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Keywords Young adults · Higher education · Health promotion · Structural equation modeling · COVID-19

Introduction

Insufficient physical activity has been recognized not merely as a behavioral risk factor but as an upstream determinant associated with multiple chronic diseases across the life course, representing a persistent global public health challenge and a major contributor to the burden of noncommunicable diseases [1, 2]. Physical inactivity is estimated to be associated with approximately 9% of premature mortality worldwide and has been linked to cardiovascular disease, type 2 diabetes, and several cancers [1]. Recent Global Burden of Disease estimates further indicate that low physical activity was associated with approximately 0.83 million deaths and 15.74 million disability-adjusted life-years in 2019 alone [3, 4]. Conversely, meeting recommended activity levels, including combinations of aerobic and muscle-strengthening activity, is prospectively associated with substantially lower all-cause, cardiovascular, and cancer mortality [5]. Despite sustained public health investment, population-level physical activity has not improved substantially, with particularly pronounced declines observed during young adulthood [6].

Young adulthood represents a critical life-course transition during which health behaviors become increasingly self-directed and tend to track into later adulthood, with important implications for long-term morbidity risk and future health system demand. Longitudinal studies have reported associations between lower physical activity in late adolescence, steeper declines across young adulthood, and higher risks of premature cardiovascular events later in life [7–9]. University students comprise a large and policy-relevant segment of the young adult population; however, even in settings characterized by relatively high educational attainment and access to health information, levels of regular physical activity remain persistently suboptimal [10, 11].

These patterns are shaped by context-specific factors. In Taiwan, as in several East Asian societies, a strong academic-achievement orientation, examination pressure, and long study and commuting hours can crowd out leisure-time physical activity among young adults, while the de-prioritization of structured physical education after senior high school removes a previously institutionalized source of activity. The transition to relatively autonomous university life further reduces external mandates for activity at precisely the stage when habits consolidate. National efforts to promote campus physical activity have continued, yet sustained regular activity among university students remains limited. Understanding the individual capacities and institutional opportunities that support activity in this context is therefore a public health priority and motivates attention to perceived physical literacy as an integrative behavioral capacity.

Although numerous interventions have sought to promote physical activity within university settings, their effectiveness in sustaining regular participation has generally been modest [11, 12]. Many approaches emphasize knowledge acquisition, motivational enhancement, or environmental availability, yet such strategies incompletely explain why some individuals maintain regular physical activity whereas others do not under similar conditions [13, 14]. This limitation underscores the importance of examining individual-level capacities that may be associated with sustained engagement beyond opportunity and intention alone.

Physical literacy has been proposed as an integrative behavioral construct encompassing motivation, confidence, perceived competence, and health-related understanding that together may support engagement in physical activity across diverse contexts [15, 16]. Emerging evidence suggests that higher perceived physical literacy is associated with greater physical activity participation among adolescents and young adults [17, 18]. However, most existing studies rely on small or convenience samples and conceptualize physical activity primarily as an individual behavior, with limited attention to the social and organizational contexts in which individual capacities are expressed. Among university students, physical activity is often embedded within institutional environments such as sports teams and clubs, which provide structured schedules, peer support, and social reinforcement, and may represent contextual factors associated with both individual capacities and population-level behavior

[19–21]. Nevertheless, few large-scale studies have empirically examined whether sports team participation statistically accounts for part of the association between perceived physical literacy and regular physical activity in university populations.

Environmental disruptions may further shape these associations. The COVID-19 pandemic constituted one such disruption, imposing pandemic-related social and institutional constraints—campus closures, suspension of organized sport, and limits on group gatherings—that curtailed the structured opportunities through which individual capacities are often enacted. During the COVID-19 pandemic, university students experienced marked reductions in physical activity across multiple countries [22, 23]. Rather than estimating the causal impact of the pandemic itself, cross-sectional comparisons across periods of differing social and institutional constraint may provide contextual insight into whether observed associations vary with the availability of social and institutional opportunity structures [24, 25].

To address these gaps, we used nationally representative survey data from university students in Taiwan to examine the associations between perceived physical literacy and regular physical activity, with sports team participation evaluated as a potential statistical mediator in cross-sectional analysis. Specifically, this study aimed to determine whether perceived physical literacy was associated with regular physical activity, and whether sports team participation statistically accounted for part of this association; a secondary aim was to compare these association patterns between a pandemic-constrained period (2020) and a post-pandemic period (2023). Using structural equation modeling, we assessed both direct and indirect associations and compared association patterns across periods characterized by differing social constraints. By examining the associations among individual behavioral capacities, organized social participation, and regular physical activity, this study provides evidence relevant to population-level physical activity promotion strategies in higher-education settings and informs public health policy aimed at supporting physical activity during young adulthood.

Methods

Study design and data source

This cross-sectional survey study analyzed data from the Student Sports Participation Survey, a nationally representative survey administered annually by the Sports Administration, Ministry of Education, Taiwan, as part of a long-standing national surveillance program designed to monitor student sport participation and physical activity-related health indicators. The survey has been conducted continuously for more than 20 years using standardized sampling procedures and core measures. Assessment of perceived physical literacy has been incorporated into the survey for the past six years as part of an expanded monitoring framework addressing behavioral and psychosocial correlates of physical activity.

Following completion of each annual survey cycle, deidentified data are archived in the Survey Research Data Archive (SRDA) maintained by Academia Sinica and are made available for academic research use in accordance with established data governance and ethical regulations. For the present analysis, data from the 2023 academic year were used as the primary analytic sample. We contrasted the 2020 and 2023 cycles as the two end points of the pandemic period. The 2023 cycle was the most recent fully post-pandemic cycle, fielded after campus and community restrictions had been lifted, whereas the transitional 2021 and 2022 cycles were collected while restrictions were being progressively and unevenly relaxed; using the two end points therefore provided the clearest contrast between socially constrained and unconstrained conditions.

The survey employed a stratified multistage sampling design based on the national population of day-division (daytime) undergraduate students. Sampling probabilities were proportional to each institution's enrollment size, with stratification by sex and academic year to reflect the distribution of university students in Taiwan for the survey year. The analytic sample comprised 8,981 university students from the 2023 academic year. The 2023 survey achieved a response rate of 96.7%, consistent with representativeness of the target population. The 2020 survey

achieved a comparable response rate of 97.1%. As a long-standing national policy survey administered and collected through institutions according to the sampled allocation, the survey consistently attains high response rates and representativeness across cycles. To provide contextual comparison across periods characterized by differing pandemic-related social and institutional constraints, data collected during the COVID-19 pandemic period (academic year 2020) were analyzed using identical measures, variable definitions, and analytic procedures.

The study protocol for the present analysis was reviewed and approved with exemption from full review by the Institutional Review Board of E-DA Hospital (IRB No. 2025013). All data were fully deidentified prior to archiving and analysis; therefore, the requirement for informed consent was waived. The study was conducted in accordance with applicable ethical standards and followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline.

Participants

Participants included undergraduate students enrolled in Taiwanese universities across all academic years and were sampled using a stratified multistage design as part of a nationwide surveillance survey. Sampling was conducted to proportionally represent the distribution of students by institution size, sex, and academic year within the national university student population. The analytic sample comprised 8,981 students from the 2023 academic year. Missing values were addressed before model estimation using the expectation–maximization (EM) algorithm, and structural models were estimated on the resulting complete dataset (see Statistical analysis). Demographic characteristics, including sex, academic year, body mass index (BMI), sports-related major status, sports club participation, sleep duration, and perceived health status, are summarized in Table 1 stratified by regular-physical-activity status.

Measures

Perceived physical literacy

Perceived physical literacy was assessed using a 9-item self-reported questionnaire rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The instrument is the standardized perceived physical literacy scale administered nationally by the Sports Administration, Ministry of Education, Taiwan, adapted from the internationally validated Perceived Physical Literacy Instrument [26] and fielded for six consecutive years; it is not an investigator-developed tool. As a self-report instrument, it captures the motivational, confidence, perceived-competence, and health-knowledge dimensions of physical literacy and does not measure objective physical competence, consistent with its purpose as a population surveillance measure where direct performance testing is not feasible. The instrument was designed to capture multidimensional aspects of physical literacy, consistent with Whitehead's conceptual framework of physical literacy across the life course.

The nine items load onto two empirically supported factors. The sports self-efficacy and resilience factor comprises six items: attaining an age-appropriate fitness level, self-management of fitness, self-evaluation of health, social skills, confidence in outdoor/wilderness situations, and coping with difficulties (standardized loadings 0.59–0.83). The sports attitudes and health cognition factor comprises three items: positive attitude and interest in sports, appreciation of one's own and others' participation, and recognition of the health benefits of exercise (standardized loadings 0.53–0.90). These two factors were modeled together as indicators of a single higher-order perceived-physical-literacy construct (factor loadings 0.88 and 0.84). The full item list and confirmatory factor loadings are provided in eTables 1 and 2. The two items that may appear only indirectly related to movement (social skills; confidence in outdoor situations) are retained because they form part of the validated PPLI self-efficacy/resilience dimension, which conceptualizes confidence and adaptive coping across varied movement and challenge contexts; both showed acceptable loadings (0.59).

Table 1 Demographic and Health-Related Characteristics by Regular Physical Activity Status ($n=8,981$)

Category	Total, <i>N</i> (%)	Regular PA: Yes, <i>N</i> (%)	Regular PA: No, <i>N</i> (%)	<i>P</i> value
Total	8,981 (100)	2,573 (28.6)	6,408 (71.4)	
Gender				<0.001
Male	4,423 (49.2)	1,642 (63.8)	2,781 (43.4)	
Female	4,558 (50.8)	931 (36.2)	3,627 (56.6)	
Year Level				0.132
Year 1 (Freshman)	3,548 (39.5)	1,062 (41.3)	2,486 (38.8)	
Year 2 (Sophomore)	2,408 (26.8)	676 (26.3)	1,732 (27.0)	
Year 3 (Junior)	1,508 (16.8)	427 (16.6)	1,081 (16.9)	
Year 4 (Senior)	1,517 (16.9)	408 (15.9)	1,109 (17.3)	
BMI Category				<0.001
Underweight	1,698 (18.9)	314 (12.2)	1,384 (21.6)	
Normal	5,127 (57.1)	1,537 (59.7)	3,590 (56.0)	
Overweight	1,159 (12.9)	424 (16.5)	735 (11.5)	
Obese	997 (11.1)	298 (11.6)	699 (10.9)	
Sports-related major				<0.001
Yes	978 (10.9)	451 (17.5)	527 (8.2)	
No	8,003 (89.1)	2,122 (82.5)	5,881 (91.8)	
Participation in sports club				<0.001
Yes	1,947 (21.7)	915 (35.6)	1,032 (16.1)	
No	7,034 (78.3)	1,658 (64.4)	5,376 (83.9)	
Sleep duration				<0.001
Less than 4 h	221 (2.5)	46 (1.8)	175 (2.7)	
4–5 h	1,135 (12.6)	283 (11.0)	852 (13.3)	
5–6 h	2,426 (27.0)	658 (25.6)	1,768 (27.6)	
6–7 h	3,167 (35.3)	971 (37.7)	2,196 (34.3)	
7–8 h	1,517 (16.9)	450 (17.5)	1,067 (16.7)	
8–9 h	336 (3.7)	107 (4.2)	229 (3.6)	
9 h or more	179 (2.0)	58 (2.3)	121 (1.9)	
Self-rated health				<0.001
Very unhealthy	202 (2.2)	40 (1.6)	162 (2.5)	
Unhealthy	1,184 (13.2)	235 (9.1)	949 (14.8)	
Average	4,347 (48.4)	1,101 (42.8)	3,246 (50.7)	
Healthy	2,409 (26.8)	835 (32.5)	1,574 (24.6)	
Very healthy	839 (9.3)	362 (14.1)	477 (7.4)	

Values are number (percentage); percentages are column percentages within each group. PA indicates physical activity; BMI, body mass index. *P* values are from χ^2 tests comparing students who met versus did not meet the criteria for regular physical activity. Detailed descriptive statistics for perceived physical literacy and its subdomains are provided in eTable 6

The original PPLI comprises nine items across three dimensions (sense of self and self-confidence; self-expression and communication with others; knowledge and understanding); in the present nationally administered adaptation, exploratory and confirmatory analyses supported a two-factor structure (sports self-efficacy and resilience; sports attitudes and health cognition) in this university population. Factor analyses supported this two-factor structure, which together explained 62.6% of the total variance. Internal consistency was acceptable (Cronbach's $\alpha=0.84$ and 0.78 for the two subscales; $\alpha=0.86$ for the total scale). Because the source instrument is a Chinese-language national scale, translation and adaptation from the source PPLI were undertaken during the original instrument development, and the scale has since been administered nationally for six consecutive years.

Sports team participation

Sports team participation was modeled as a latent construct indicated by two binary survey items—current participation in a university sports club and current membership of a varsity (representative) team (standardized loadings 0.90 and 0.94)—and was defined as participation in an organized, institution-affiliated team or club, excluding informal, unstructured exercise undertaken alone. It was conceptualized as an indicator of institutional and social participation rather than a direct measure of physical activity volume.

Regular physical activity

Regular physical activity was defined according to criteria used by the Sports Administration, Ministry of Education, Taiwan: engaging in physical activity at least three times per week, with each session lasting 30 min or longer and performed at an intensity sufficient to induce sweating and breathlessness. This frequency-duration-intensity criterion (at least three 30-minute sessions per week, i.e., approximately 90 min per week, at an intensity producing sweating and breathlessness) is the standard applied for this population; because the weekly volume is lower than, and does not necessarily satisfy, the WHO aggregate recommendation of ≥ 150 min/week of moderate-intensity activity, a more stringent WHO-aligned classification (≥ 150 min/week) was additionally examined in sensitivity analysis. This definition was operationalized as a binary outcome (regular physical activity vs. not).

Statistical analysis

Descriptive statistics were calculated for all study variables. Missing values were handled before model estimation using the expectation–maximization (EM) algorithm; the AMOS path model was then estimated on the resulting complete dataset. Listwise deletion and full information maximum likelihood were therefore not used as the primary missing-data approach. The binary indicators (regular physical activity; sports club and varsity-team membership) were entered into the AMOS path model as dummy-coded variables (1 = yes, 0 = no) with appropriate reference categories.

Internal consistency was evaluated using Cronbach's α . Factor structure was examined using exploratory and confirmatory factor analyses. Convergent validity was evaluated using standardized factor loadings, composite reliability (CR), and average variance extracted (AVE) [27, 28]. Discriminant validity was assessed using the Fornell–Larcker criterion [29] (the square root of each construct's AVE compared with its inter-construct correlations). To address the potential conceptual overlap between perceived physical literacy and physical activity, common-method bias was examined using Harman's single-factor test [30].

Structural equation modeling (SEM) was used to examine associations between perceived physical literacy and regular physical activity, as well as statistical indirect associations through sports team participation. Latent constructs were specified for perceived physical literacy (higher-order, two factors) and sports team participation (two binary indicators); regular physical activity was included as a single binary-indicator outcome. Explained variance (squared multiple correlation, R^2) was computed for each endogenous construct.

Because the data are cross-sectional and all constructs were measured simultaneously, temporal precedence cannot be established; the structural model tests only whether the data are consistent with the hypothesized associations, and the indirect term should not be interpreted as causal mediation. Reverse or reciprocal relationships—for example, that already-active students develop higher perceived physical literacy and are more likely to join teams—are equally plausible and cannot be ruled out.

The structural model was specified to test the theorized measurement-and-structural relationships among the three constructs. Demographic and health covariates (sex, BMI, academic year, sports-related major, sleep duration, and self-rated health) are presented stratified by regular-physical-activity status in Table 1; the structural model was not covariate-adjusted, and residual confounding is acknowledged as a limitation. Sampling weights were not applied because the undergraduate sample was drawn from day-division students with probability proportional to each institution's enrollment, yielding direct national representativeness without the need for post hoc weighting. Institution-level clustering was likewise not modeled: because the design was constructed to represent the national student population rather than individual institutions, school-level estimates would not be sufficiently representative, making institution-level clustering analysis inappropriate for this sampling frame.

Model fit was evaluated using the comparative fit index (CFI), Tucker–Lewis index (TLI), root mean square error of approximation (RMSEA), and standardized root mean square residual (SRMR), with CFI and TLI ≥ 0.90 and RMSEA and SRMR ≤ 0.08 considered acceptable. Indirect associations were evaluated using bias-corrected

bootstrapping with 2,000 resamples and 95% confidence intervals. All analyses were conducted using SPSS version 26.0 (IBM Corp) and AMOS version 22.0. Statistical significance was defined as a two-sided $P < 0.05$.

Sensitivity and subgroup analyses

To examine whether associations differed across social contexts, multi-group SEM analyses compared students surveyed during the COVID-19 pandemic period (2020) and the post-pandemic period (2023). Before comparing structural coefficients across periods, measurement invariance was tested stepwise (configural, metric, scalar), evaluating change in CFI against the threshold of Cheung and Rensvold [31] ($\Delta\text{CFI} \leq 0.01$); because the chi-square test is sensitive to large samples, ΔCFI was the primary criterion. A WHO-aligned sensitivity analysis re-estimated the full model with regular physical activity redefined as accumulating ≥ 150 min of activity per week (WHO recommendation for adults aged 18–64 years).

Results

Study sample

A total of 8,981 university students from the 2023 academic year were included. The sample included students from all academic years and a wide range of academic disciplines. Participant demographic and health-related characteristics, stratified by regular-physical-activity status, are summarized in Table 1.

Descriptive characteristics

Overall, 28.6% of participants met the criteria for regular physical activity. The mean (SD) overall perceived physical literacy score was 3.57 (0.63) on a 5-point scale. Students meeting the criteria for regular physical activity were more often male (63.8% vs. 43.4%), enrolled in a sports-related major (17.5% vs. 8.2%), and participating in a sports club (35.6% vs. 16.1%) than those who did not. Detailed descriptive statistics for perceived physical literacy and its subdomains are presented in eTable 6.

Measurement model

All standardized factor loadings were statistically significant and ranged from 0.53 to 0.94, exceeding the 0.50 threshold. Composite reliability ranged from 0.75 to 0.92, exceeding the 0.70 criterion, and average variance extracted ranged from 0.46 to 0.85, with most values exceeding 0.50 (the sports self-efficacy/resilience subscale showed $\text{AVE} = 0.46$ with acceptable $\text{CR} = 0.84$), supporting convergent validity (eTables 2 and 3). Discriminant validity was supported: the square root of each construct's AVE (0.86 for perceived physical literacy, 0.92 for sports team participation, 0.89 for regular physical activity) exceeded the inter-construct correlations (0.36–0.57; eTable 4). Harman's single-factor test indicated that the first unrotated factor accounted for 38.62% of the variance, below the 50% threshold, suggesting common-method bias was unlikely to account for the findings (eTable 5). The overall measurement model showed acceptable fit ($\text{CFI} = 0.94$; $\text{TLI} = 0.92$; $\text{RMSEA} = 0.046$; $\text{SRMR} = 0.041$).

Structural equation modeling

The structural equation model is shown in Fig. 1. Perceived physical literacy was positively associated with sports team participation (standardized $\beta = 0.48$; $P < 0.001$) and directly associated with regular physical activity (standardized $\beta = 0.11$; $P < 0.001$). Sports team participation was positively associated with regular physical

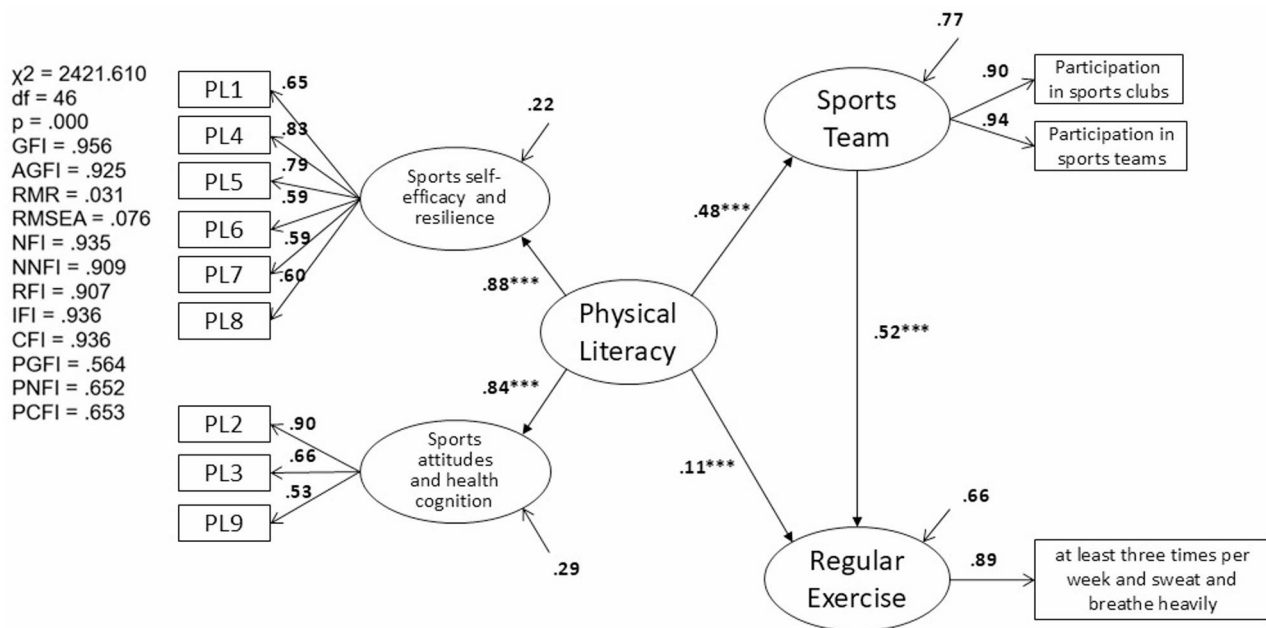


Fig. 1 Structural Equation Model of Associations Among Perceived Physical Literacy, Sports Team Participation, and Regular Physical Activity. Standardized path coefficients are shown. All displayed paths were statistically significant ($P < 0.001$). Circles represent latent constructs; rectangles represent observed indicators

Table 2 Direct and Indirect Effects in the Structural Equation Model

Pathway	Standardized β	95% CI	P Value
Perceived physical literacy $\rightarrow$ Sports team participation (direct)	0.48	0.44–0.53	<0.001
Sports team participation $\rightarrow$ Regular physical activity (direct)	0.52	0.46–0.59	<0.001
Perceived physical literacy $\rightarrow$ Regular physical activity (direct)	0.11	0.06–0.15	<0.001
Indirect via sports team participation	0.25	0.22–0.30	<0.001
Total effect of perceived physical literacy	0.36	0.34–0.38	<0.001

Standardized coefficients (β) from structural equation modeling; 95% bootstrap CIs (bias-corrected, 2,000 resamples). The standardized indirect $\beta = 0.25$ corresponds to an unstandardized $B = 0.10$ (95% CI, 0.09–0.12). Explained variance: $R^2 = 0.23$ (sports team participation) and 0.34 (regular physical activity). Measurement-validity, discriminant-validity, common-method, and invariance results are provided in eTables 3–5 and 7

activity (standardized $\beta = 0.52$; $P < 0.001$). The indirect association between perceived physical literacy and regular physical activity through sports team participation was statistically significant (standardized indirect $\beta = 0.25$; 95% CI, 0.22–0.30; unstandardized $B = 0.10$; 95% CI, 0.09–0.12), indicating that sports team participation statistically accounted for part of the association. Estimates of direct, indirect, and total effects are summarized in Table 2. The model explained 23% of the variance in sports team participation ($R^2 = 0.23$, a medium effect) and 34% of the variance in regular physical activity ($R^2 = 0.34$, a large effect) [32]. The overall structural model demonstrated acceptable fit ($CFI = 0.93$; $TLI = 0.91$; $RMSEA = 0.076$; $SRMR = 0.039$).

Pandemic and post-pandemic comparisons

Measurement invariance across the 2020 and 2023 samples was supported at all levels (eTable 7). Relative to the configural model ($CFI = 0.937$), metric invariance ($CFI = 0.936$; $\Delta CFI = -0.001$) and scalar invariance ($CFI = 0.935$; $\Delta CFI = -0.001$) each produced ΔCFI well below 0.01; although the chi-square differences were significant, this is expected with the large sample, and full invariance therefore justified comparison of structural coefficients across periods. Multi-group modeling indicated that the overall model structure held in both the

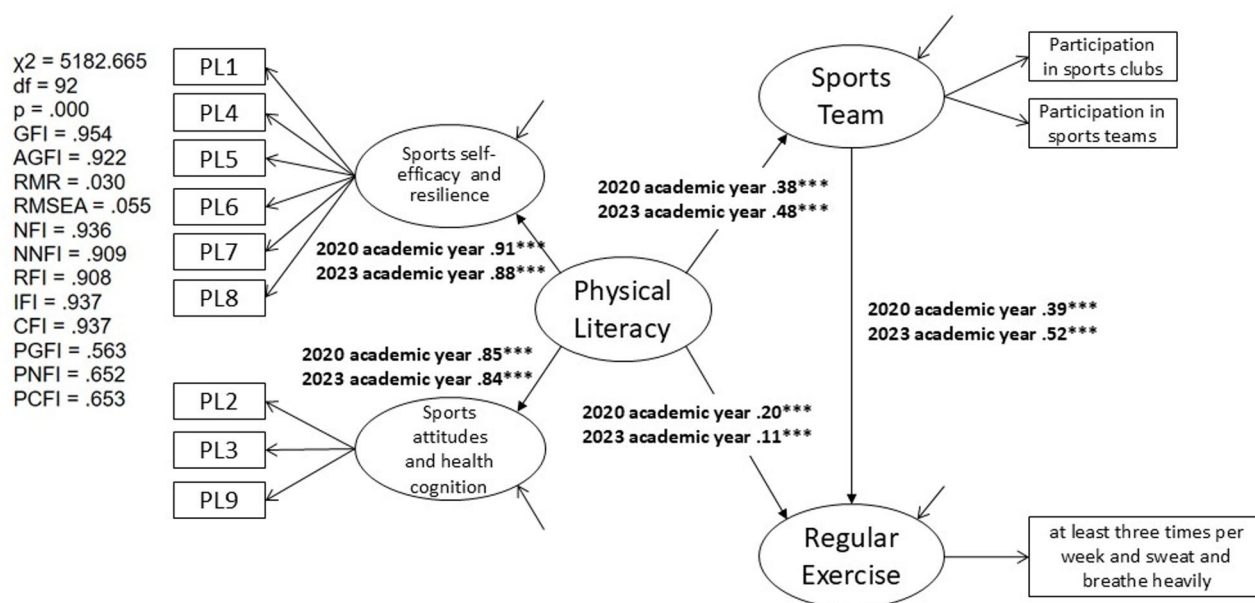


Fig. 2 Comparison of Structural Pathways During the COVID-19 Pandemic and Post-Pandemic Periods. Standardized path coefficients from multi-group structural equation modeling are shown for the pandemic (2020) and post-pandemic (2023) periods, following confirmation of full measurement invariance

pandemic (2020) and post-pandemic (2023) samples. The direction of associations was consistent across periods, but the strength of the association between sports team participation and regular physical activity was lower during the pandemic period (standardized $\beta = 0.39$ vs. 0.52).

During the pandemic period, the indirect association between perceived physical literacy and regular physical activity through sports team participation was weaker. Because no environmental or contextual variables were directly measured and the analysis compares repeated cross-sections rather than tracking individuals, these differences are described as descriptive variation co-occurring with periods of differing opportunity rather than as effects attributable to pandemic restrictions. The multi-group model and standardized path estimates are presented in Fig. 2 and eTable 8, with period-specific indirect effects in eTable 9.

Sensitivity analysis (WHO-aligned definition)

When regular physical activity was redefined using the WHO threshold of ≥ 150 min/week, the model retained acceptable fit ($\chi^2 = 2460.81$; df = 46; RMSEA = 0.076; CFI = 0.936; SRMR = 0.040) and the hypothesized associations remained statistically significant: perceived physical literacy $\rightarrow$ sports team participation ($\beta = 0.49$), sports team participation $\rightarrow$ regular physical activity ($\beta = 0.61$), perceived physical literacy $\rightarrow$ regular physical activity (direct $\beta = 0.06$), and the indirect association ($\beta = 0.29$). Compared with the primary model, the direct association was smaller and the sports team participation $\rightarrow$ activity association larger, indicating that under the more demanding WHO threshold the contribution of perceived physical literacy operated even more through structured team participation. The overall pattern of findings was therefore robust to the activity definition. Detailed estimates are provided in eTable 10, with the corresponding path diagram in eFigure 1.

Discussion

In this nationally representative study of university students in Taiwan, higher perceived physical literacy was associated with a greater likelihood of engaging in regular physical activity, and sports team participation statistically accounted for part of this association. These findings extend prior research by demonstrating that individual-level behavioral capacities and organized social participation contexts are jointly associated with regular physical activity during young adulthood [7–9, 16]. Because the data are cross-sectional, these associations should not be read as causal; it remains equally plausible that more active students develop higher perceived physical literacy and are more likely to join teams. University years may represent one of the final institutionalized opportunities associated with physical activity behaviors before entry into the workforce, a transition consistently associated with sharp declines in leisure-time physical activity [13].

Consistent with previous literature, our findings align with evidence documenting substantial declines in physical activity during the transition from adolescence to early adulthood [6, 10, 13]. Although many promotion efforts in higher-education settings have focused on increasing knowledge, motivation, or access to facilities, such approaches have shown limited effectiveness in sustaining participation at the population level [11, 12]. The present results suggest that perceived physical literacy—reflecting confidence, motivation, perceived competence, and health-related understanding—may represent an important behavioral capacity associated with the maintenance of regular physical activity [15, 16].

Organized social participation was also associated with regular physical activity, beyond individual capacity alone [16, 21]. Participation in sports teams and clubs was positively associated with regular physical activity and statistically accounted for part of the association between perceived physical literacy and physical activity. The strength of this measurement structure was supported by the high reliability of the sports team participation construct (composite reliability 0.92) and by full measurement invariance across periods. In exploratory sex-stratified analyses (eTables 11 and 12), the overall pattern of indirect association was observed in both male and female students. Sports teams may provide consistent schedules, peer support, and normative reinforcement that co-occur with sustained engagement among individuals with higher confidence and motivation [20, 21].

The differences between the pandemic and post-pandemic periods suggest that these associations vary by context. During periods marked by pandemic-related social and institutional constraints, opportunities for organized sports participation are likely to have been more constrained, and the indirect association through team participation was weaker [22, 23]. Because no contextual variables were directly measured and repeated cross-sections rather than individuals were compared, these patterns should not be attributed to the pandemic itself; they suggest that reductions in structured social opportunities may co-occur with weaker associations between individual behavioral capacities and regular physical activity [24, 25]. This interpretation is reinforced by the WHO-aligned sensitivity analysis, in which perceived physical literacy operated even more strongly through team participation, and is consistent with international evidence documenting declines in physical activity among university students during pandemic-related confinements [23].

These findings point to one practical implication for higher-education settings: strategies aimed solely at strengthening individual physical literacy may be insufficient if not accompanied by accessible, structured opportunities for social participation [16, 24]. In higher-education settings, investments in inclusive sports clubs, intramural teams, and other organized programs—together with club subsidies and protected timetabling—may help support regular physical activity at the population level [25]. By situating physical literacy within institutional contexts, universities may be useful settings for promoting regular physical activity in young adulthood, a period that shapes long-term cardiometabolic health [7, 8].

Limitations

This study has several limitations. First, the cross-sectional design precludes causal inference; temporal precedence cannot be established, and reverse or reciprocal relationships are equally plausible. Second, perceived

physical literacy, sports team participation, and physical activity were assessed using self-reported measures within the same survey, which may introduce reporting bias and common-method variance; although Harman's single-factor test (38.62% variance) and discriminant-validity indices suggested this was unlikely to drive the findings, some perceived-physical-literacy items reference activity-related content, and we interpret the associations with corresponding caution. Because the instrument captures perceived physical literacy, the objectively assessed physical-competence dimension is not directly represented, and findings pertain to self-perceived behavioral capacities rather than the full multidimensional construct.

Third, the structural model was not adjusted for covariates; although demographic and health characteristics are presented stratified by regular-physical-activity status in Table 1, residual confounding cannot be excluded. Fourth, although full measurement invariance supported the cross-period comparison, the comparison reflects repeated cross-sections rather than longitudinal tracking, and no contextual variables were measured to explain period differences.

Finally, although the survey was nationally representative of university students in Taiwan, the findings may not be generalizable to nonuniversity young adults or to higher-education systems in other countries. Future longitudinal studies and cross-national comparisons would help clarify temporal relationships and assess generalizability.

Conclusions

In this nationally representative study of university students, perceived physical literacy was associated with regular physical activity, with sports team participation statistically accounting for part of this association. The associations were robust to a WHO-aligned activity definition and were supported by full measurement invariance across the pandemic and post-pandemic periods. Together, the results indicate that regular physical activity in university students is associated with both perceived physical literacy and structured team participation. For public health policy, higher-education institutions could pair physical-literacy development with accessible, inclusive participation opportunities—intramural leagues, subsidized clubs, and protected timetabling—as one potential approach to supporting regular physical activity, while remaining mindful that the present associations are correlational.

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Authors' contributions Concept and design: Chuan-Chuan Huang, Yi-Jen Yang Acquisition, analysis, or interpretation of data: Chuan-Chuan Huang, Lien-Hsi Lin Drafting of the manuscript: Chuan-Chuan Huang, Hung-Yi Wang Critical revision of the manuscript for important intellectual content: Chuan-Chuan Huang, Hung-Yi Wang, Zi-yi Cheng Statistical analysis: Lien-Hsi Lin, Feng-I Chung, Chen-Te Hsu Obtained funding: Chuan-Chuan Huang, Hung-Yi Wang Administrative, technical, or material support: Yi-Jen Yang, Zi-yi Cheng Supervision: Chen-Te Hsu, Hung-Yi Wang.

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Data availability The data that support the findings of this study are available from the Survey Research Data Archive (SRDA), Academia Sinica, Taiwan, upon reasonable request and subject to approval by SRDA. Access to the data requires submission of a research proposal and relevant ethical approval documents, including Institutional Review Board (IRB) approval, in accordance with SRDA data governance regulations. Due to these regulations, the data are not publicly available.

Declarations

Ethics approval and consent to participate This study involved secondary analysis of fully deidentified data obtained from the Survey Research Data Archive (SRDA), Academia Sinica. The study protocol was reviewed and approved with exemption from full review by the Institutional Review Board of E-DA Hospital (IRB No. 2025013). In accordance with national regulations and institutional policies governing secondary analysis of anonymized data, the requirement for informed consent to participate was waived by the Institutional Review Board. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the principles of the Declaration of Helsinki.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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