

# Adaptive Gamified Wearables in University Physical Education: Effects on Physical Literacy, Motivation, and Well-Being in a Cluster Randomised Controlled Trial

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## Abstract

*The present study examined whether an adaptive gamified programme built around fitness trackers improves physical literacy and related psychological outcomes more than standard gamification or tracker-only monitoring at Chinese universities. A semester-long cluster randomised controlled trial was conducted with 248 undergraduate students in six groups allocated to three intervention types: adaptive gamification with personalised, recovery-sensitive goals and reflection, standard gamification with fixed goals, and a control intervention with trackers and reflection only. Physical literacy, motivation, well-being, and activity were assessed at baseline, post-intervention, and follow-up using questionnaires and the data from the used devices. Perceived physical literacy was pre-specified as the primary outcome. Because randomisation occurred at the student group level (six clusters), confirmatory inference relied on linear mixed-effects models with random intercepts for students' groups and individual students, and cluster-robust standard errors with the correction of degrees of freedom due to a small sample; repeated ANOVA and paired comparisons were reported as descriptive/supporting analyses. Correlation analyses and exploratory mediation models were used to probe potential behavioural pathways, and interviews/reflections were thematically coded. In the cluster-adjusted primary model, the adaptive group showed a larger post-intervention gain in perceived physical literacy than the*

control group ( $B = 0.49$ , robust  $SE = 0.09$ ,  $p = .003$ ), and this advantage remained evident at follow-up ( $B = 0.49$ , robust  $SE = 0.10$ ,  $p = .004$ ). The findings indicate that embedding trackers in a theoretically grounded, adaptive learning design can meaningfully strengthen students' capacity and willingness to lead active lives, and they offer scalable design principles for university-based health promotion.

**Keywords:** digital behaviour change; gamified physical education; self-determined motivation; university health promotion; wearable technology

## Introduction

Insufficient physical activity is one of the leading global health risks, with approximately a third of adults and four-fifths of adolescents not meeting recommended movement guidelines (World Health Organization, 2024). Recent pooled analyses of over 500 population-based surveys indicate that adults' insufficient activity reached 31.3 % in 2022 and continues to rise in more than half of the monitored countries, which indicates the limited impact of policy efforts so far (Strain et al., 2024). These trends co-occur with growing burdens of obesity, cardiometabolic disease, and mental health problems, which places pressure on education systems to foster durable, health-enhancing activity habits rather than short-term compliance with fitness tests.

Physical literacy has been advanced as an integrated construct that links motivation, confidence, competence, knowledge, and understanding required for lifelong engagement in physical activity (Fortnum et al., 2025). However, there is continuing debate over its operationalisation, and validation work demonstrates that perceived physical literacy instruments must be adapted carefully to specific languages and cultures, including emerging-adult populations (Gandrieau et al., 2023). In this study, physical literacy is operationalised as perceived physical literacy (PPLI), defined as students' perceived confidence, motivation, and knowledge/understanding of self-regulated movement. This operationalisation complements step-count and MVPA metrics because it targets the capacities that sustain activity across contexts; at the same time, it acknowledges a key challenge in the field: multidimensional constructs require culturally appropriate instruments and cannot be inferred from activity volume alone.

Self-tracking technologies and fitness wearables have become widespread, but their behavioural effects remain heterogeneous and are often difficult to sustain over time (Chen et al., 2025; Jin et al., 2022). Research on commercial smartwatch ecosystems further indicates that notification architecture and digital nudges can materially shape users' ongoing engagement with wearable feedback (Asimakopoulos et al., 2024). Adoption of wearable fitness devices is also influenced by perceived usefulness, ease of use, and device-specific attributes, which suggests that uptake depends on design quality as well as health intent (Hayat et al., 2023). Within physical education, gamified tracking systems appear most promising when behavioural data are embedded in pedagogically meaningful feedback rather than treated as stand-alone monitoring

tools (Vorlíček et al., 2024). A recent field experiment likewise found that gamified physical-activity conditions increased step counts, although improvements in intrinsic motivation and perceived usefulness were more limited, which underscored the importance of theoretically grounded design (Grech et al., 2024). At the same time, self-tracking based on wearable devices raises ethical concerns related to surveillance, datafication, and guilt when users struggle to meet targets, which makes supportive rather than controlling design especially important (Wieczorek et al., 2023). To explain why such a design should influence physical literacy rather than only activity volume, this study is framed by self-determination theory (SDT): interventions that support competence through attainable challenge and informational feedback, autonomy through self-referenced progress and meaningful choice, and relatedness through social support are more likely to strengthen autonomous motivation and durable self-regulation. Adaptive gamification is therefore conceptualised as a mechanism for maintaining optimally challenging and personally meaningful goals, while reflection tasks translate behavioural data into learning.

Existing research nevertheless leaves important conceptual and pedagogical issues unresolved. Physical literacy studies still often privilege discrete indicators of competence, while motivational, affective, and cognitive dimensions are less consistently integrated into intervention models, particularly in university settings where feasibility and instrument adaptation remain important constraints (Gandrieau et al., 2023; Peng & Zhang, 2025; Sanctuary et al., 2025; Welk et al., 2022). Relatedly, evidence from physical education shows that student engagement depends strongly on need-supportive climates shaped by autonomy, competence, and relatedness (Holt et al., 2019; Roure & Lentillon-Kaestner, 2022). Classroom-based research in physical education further indicates that teaching style and responses to disruption influence participation and sustained engagement in lesson activities (Hovdal et al., 2021). Curriculum analyses also suggest that formal physical education has often privileged organised sport cultures over learner agency and everyday movement practices, which reinforces the need for more student-centred designs (O'Connor & Penney, 2021). At the same time, digital tools in physical education are frequently used for surveillance, testing, or performance monitoring rather than for formative, literacy-oriented support, while wearable and gamified interventions have more often targeted activity volume than multidimensional learning outcomes (Lewis et al., 2020; Müller & Wagner, 2025; Mynbayeva et al., 2025; White et al., 2025).

These issues are especially salient in China, where university students face strong academic pressures alongside rapid digitalisation of everyday life. During the COVID-19 period, inadequate physical activity among Chinese college students was associated with higher symptoms of anxiety and depression, and more recent evidence continues to show insufficient activity and positive links between physical activity and health-related quality of life in Chinese university populations (Tao et al., 2025; Xiang et al., 2020). This context is particularly important because contemporary physical education increasingly treats mental health as a central pedagogical concern

rather than a peripheral issue separate from movement education (Smith, 2020; Solovyeva et al., 2023). Yet existing literature still tends to treat fitness trackers either as behaviour-change tools for increasing step counts or as consumer technologies studied outside formal curricula. What remains empirically under-specified is whether embedding wearables in recovery-sensitive adaptive goal design rather than fixed-goal gamification or monitoring alone can produce sustained gains in perceived physical literacy and related psychosocial outcomes within structured physical education at universities.

Accordingly, the present study addressed a specific gap in the literature: the lack of cluster-randomised evidence on whether adaptive gamified use of wearable trackers can strengthen perceived physical literacy within formal Chinese university physical education more effectively than standard gamification or tracker-only monitoring. Three aims were set in the study: first, to determine whether adaptive gamification yields larger and more sustained gains in perceived physical literacy; second, to examine whether it also improves autonomous motivation, basic psychological needs satisfaction, and well-being with regard to the comparable conditions; and third, to explore whether behavioural engagement and student experience help explain the differences in outcomes across the three types of intervention. Two hypotheses were formulated: H1 – adaptive gamification would produce larger and more sustained improvements in perceived physical literacy than standard gamification and tracker-only monitoring; and H2 – adaptive gamification would produce larger improvements in motivation, needs satisfaction, and well-being than standard gamification and tracker-only monitoring. Associations involving weekly goal attainment, device engagement, and student experience were treated as exploratory because the clustered design included only six courses.

## **Methodology**

### ***Methodological and theoretical foundations***

The study was designed as a cluster randomised controlled trial with a convergent mixed-methods approach. Cluster randomisation was used to minimise contamination of goal-setting and peer comparisons across conditions while preserving routine timetables and instruction. The convergent mixed-methods design was selected to integrate questionnaire outcomes and device logs with interviews/reflection data, which enabled mechanism-focused interpretation rather than just reporting outcomes. SDT guided the intervention logic: adaptive goal calibration and informational feedback were intended to support competence, self-referenced progress and choice to support autonomy, and structured group reflection to support relatedness.

### ***Instrument adaptation, scoring, and psychometric evaluation***

Because the study relied on locally adapted Chinese versions of the Perceived Physical Literacy Instrument (PPLI) and Behavioural Regulation in Exercise Questionnaire (BREQ-3), instrument preparation and psychometric evaluation

were documented explicitly. Where validated Chinese wording was available, it was retained; otherwise, items were translated and back-translated, then reviewed by bilingual researchers and physical-education specialists for semantic and contextual equivalence. Minor wording adjustments were made to improve clarity for Chinese university PE settings while preserving the meaning of constructs. WHO-5 was scored using the standard raw-sum multiplied by 4 transformation to a 0-100 scale.

### ***Study design and procedure***

The trial ran over one spring semester (March–July 2025). Week 0 covered briefing and consent, week 1 baseline tracking (steps, MVPA, sleep, and resting heart rate/HRV); week 2 entailed a technical run-in, Weeks 3-10 the eight 90-minute sessions (one per week) and weeks 11–16 follow-up monitoring. Six intact student classes from Jiangsu University and Hefei University of Technology were randomised (1:1:1) to adaptive gamification (Group A), standard gamification (Group B), or tracker-only control (Group C). Cluster allocation was generated in advance using a computer-based random sequence prepared by a researcher who was not involved in class teaching or outcome handling. To preserve site balance, randomisation was stratified by university, with one student class per intervention type allocated within each institution. Allocation was released only after class recruitment and baseline scheduling had been completed. Because the intervention involved visibly, different goal-setting rules, dashboards, and feedback procedures, blinding of students and instructors was not feasible. However, obtaining data from the devices followed a standardised workflow, the administration of the questionnaire used common scripts, and the clustered models were estimated on coded datasets.

In Group A, adaptive elements were updated weekly: step/MVPA targets were recalibrated using prior goal attainment and recovery-relevant indicators available in the tracker/app to preserve attainable challenge while maintaining progression. Feedback framing and some badge thresholds were also adjusted to emphasise self-referenced improvement rather than normative comparison. In Group B, gamified elements (goals/points/badges) followed a fixed schedule applied uniformly across students, without individualised recalibration. Fidelity was monitored using structured session checklists and periodic observations; inter-educator consistency was summarised as the proportion of planned components delivered per session and cross-site agreement on checklist ratings.

### ***Adaptive goal-setting logic***

In Group A, weekly targets were updated using the previous week's goal attainment and recovery-relevant indicators. In general, goals increased when the prior target had been achieved and recovery indicators remained acceptable. The goals were maintained when attainment was partial or recovery was borderline, or they were held or modestly reduced when poor sleep, suppressed HRV, or notable fatigue suggested inadequate recovery. The adaptive logic therefore aimed to preserve

attainable challenge while limiting repeated over-prescription. Badge framing and feedback messages were also adjusted toward self-referenced progress rather than normative comparison. By contrast, Group B received the same general gamified structure, but fixed goals and thresholds were applied uniformly across students.

Each session comprised a short micro-lesson on physical literacy, structured MVPA, and guided reflection. Figure 1 summarises the work flow at both the cluster (class) and individual (student) levels, whereas Figure 2 presents a schematic block diagram of the trial.

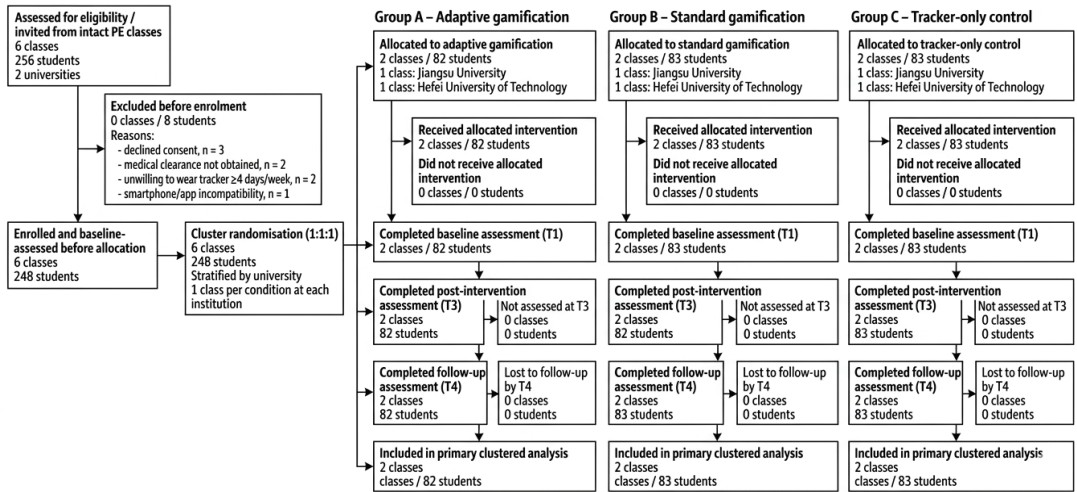


Figure 1. CONSORT flow diagram for the cluster-randomised trial, showing classes and students at each study stage  
Source: author's development

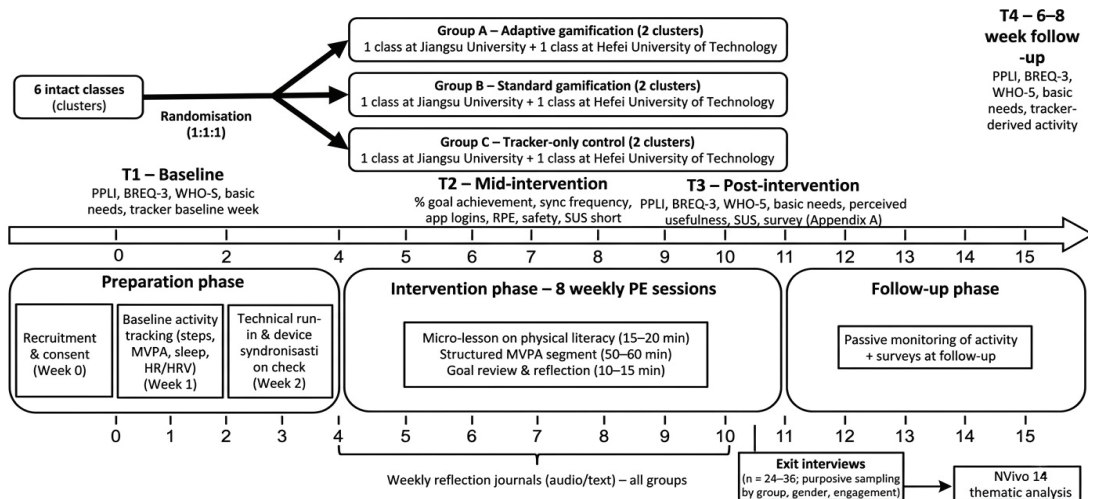


Figure 2. Cluster-randomised study design and measurement schedule  
Source: author's development

## **Analytical methods**

Primary endpoints (perceived physical literacy, motivation, well-being, basic needs) were collected at baseline, post-intervention, and follow-up; behavioural engagement metrics (steps, MVPA, goal attainment, app logins) were logged weekly; survey responses and qualitative data were obtained at post-intervention and follow-up.

## **Sample**

The study population comprised undergraduates enrolled in compulsory physical education or health-related courses. Within each institution, two parallel first- or second-year classes were selected in consultation with department heads, yielding six intact classes that were cluster-randomised to adaptive gamification, standard gamification, or tracker-only control, with one class per implementation model at each university. All students registered in these classes ( $\approx 40$ – $45$  per class;  $240$ – $270$  total) were invited. Eligibility required age  $\geq 18$  years, full enrolment for the semester, medical clearance for moderate-to-vigorous activity, ability to use a smartphone and wearable tracker, and consent to continuous monitoring and survey participation. Exclusion criteria included serious cardiovascular, neurological, or musculoskeletal conditions, severe mental illness, vestibular disorders, pregnancy, or unwillingness to wear the device  $\geq 4$  days per week. An a priori cluster power check used a design-effect adjustment (assumed ICC  $\approx 0.03$  and mean cluster size  $\approx 42$ ), indicating that six clusters provided adequate power to detect small-to-moderate group  $\times$  time effects in mixed-effects models (approximately  $f \approx 0.25$ ).

## **Wearable device, data extraction, and valid-wear rules**

Activity and recovery data were collected using Huawei Watch Fit 3 devices (firmware 4.0.0.168) linked to the Huawei Health application (version 14.1). Daily steps, MVPA, sleep duration, resting heart rate, and heart rate variability (HRV) were extracted from the device ecosystem as manufacturer-derived summary metrics. A valid wear day was defined as at least 10 hours of wear time, and weekly engagement metrics were computed when at least four valid days were available. Days below the wear threshold were treated as non-wear (missing) rather than as zero activity. Synchronisation status was checked weekly by research assistants, and implausible gaps were reviewed against device logs before aggregation. Tracker logs also yielded wear time, weekly goal-attainment status, synchronisation frequency, and app logins for the engagement analyses. MVPA was based on the manufacturer's activity-intensity classification, whereas sleep duration, resting heart rate, and heart rate variability were obtained from the device's automated physiological monitoring modules.

## **Expert assessors**

Each cluster was taught by a PE professor trained in the protocol and provided with standardised lesson scripts. Training comprised two structured workshops (delivery of the physical literacy micro-lessons, SDT-consistent feedback, and condition-

specific gamification workflows), followed by a brief practice run assessed with a readiness checklist. Two research assistants per site oversaw device distribution, synchronisation checks, survey administration, and fidelity monitoring via structured checklists. Checklist items captured delivery of core components (0 = not delivered, 1 = partially delivered, 2 = fully delivered), including adherence to the assigned gamification model and completion of the reflection segment. A subset of sessions was double-rated to estimate inter-rater agreement and support consistency across sites.

### ***Data analysis***

Data were processed in SPSS 27. Perceived physical literacy (PPLI) was pre-specified as the primary outcome, and the principal confirmatory comparison concerned differential change between the adaptive and control intervention model over time. Because randomisation occurred at the class level and only six clusters were available, confirmatory inference relied on linear mixed-effects models with random intercepts for student and class, fixed effects for group, time, group  $\times$  time, and cluster-robust standard errors at the class level. Small-sample degrees-of-freedom correction was used because conventional asymptotic cluster-robust inference may be unstable with few clusters. Repeated-measures ANOVA and paired t-tests were retained as descriptive/supporting analyses to facilitate comparison with prior findings in literature on educational interventions, but they were not treated as the primary basis for inference. Pearson correlations were computed to examine associations among changes and engagement metrics. Mediation analyses were treated as exploratory mechanism-probing models rather than confirmatory causal tests because the mediator was time-varying and the number of clusters was limited. Interviews were transcribed and thematically coded in NVivo 14.

### ***Engagement tracking and correlational analysis***

A valid wear day was defined as  $\geq 10$  hours of wear time; weekly engagement metrics (steps, MVPA, goal attainment) were computed when participants provided  $\geq 4$  valid wear days/week. Days not meeting the threshold were treated as non-wear (missing) rather than zero activity, and mixed-model analyses were used to reduce bias from intermittent gaps. Tracker logs yielded daily steps, MVPA minutes, wear time, weekly goal attainment status, synchronisation frequency, and app logins. These indicators were aggregated into engagement indices (e.g., proportion of weeks with goals achieved) and correlated with changes in physical literacy, motivation, and MVPA.

### ***Ethical considerations***

Ethical approval was obtained from both university ethics committees. Participation was voluntary; written informed consent was collected. Data were coded and stored on secure servers; only aggregated results are reported. Adverse events were defined as any incident plausibly related to participation (e.g., musculoskeletal pain/injury

requiring activity modification, dizziness, or abnormal fatigue) and were recorded via weekly brief check-ins plus instructor incident logs. Events triggered protocol-guided response (temporary activity modification, referral to campus health services if indicated), and were reviewed weekly by the study coordinator. Injury incidence per 1,000 PE lessons was calculated as the number of intervention-related injury events divided by the total attended PE lessons across participants during the intervention period, multiplied by 1,000.

## Results

At baseline, the three groups were comparable on the main demographic, behavioural, and psychosocial indicators (Table 1). Mean age, baseline steps/day, MVPA, PPLI, autonomous motivation, and WHO-5 scores showed no significant between-group differences. Because randomisation occurred at the students' class level and unconditional models indicated non-zero clustering for the primary outcome (baseline PPLI ICC = 0.04), confirmatory inference relied on linear mixed-effects models with cluster-robust standard errors; ANOVA summaries are reported only as descriptive complements.

Table 1  
Baseline characteristics of participants by group and omnibus tests

Variable	Group A (Adaptive) (n=82) M (SD)	Group B (Standard) (n=83) M (SD)	Group C (Control) (n=83) M (SD)	Omnibus test (ANOVA) F(2,245), p, $\eta^2$
Age (years)	19.5 (1.1)	19.4 (1.0)	19.7 (1.2)	1.04, p=.35, $\eta^2$ =.008
Steps/day (baseline week)	7,210 (2,140)	7,130 (2,060)	7,040 (2,120)	0.15, p=.86, $\eta^2$ =.001
MVPA min/day (baseline week)	32.4 (11.6)	31.9 (11.2)	32.1 (11.4)	0.04, p=.96, $\eta^2$ <.001
PPLI total score (1–5)	3.01 (0.46)	3.00 (0.45)	2.99 (0.47)	0.05, p=.95, $\eta^2$ <.001
Autonomous motivation (1–5)	3.24 (0.58)	3.23 (0.59)	3.21 (0.60)	0.06, p=.94, $\eta^2$ <.001
WHO-5 well- being (0–100)	58.7 (15.4)	58.1 (15.1)	58.3 (15.8)	0.02, p=.98, $\eta^2$ <.001

Source: author's development

Perceived physical literacy improved in all three groups, but gains were largest in the adaptive model and smallest in the control model (Table 2). In the primary cluster-adjusted model, post-intervention improvement was greater in the adaptive group than in the control group ( $B = 0.49$ , robust  $SE = 0.09$ ,  $p = .003$ ), and this advantage remained evident at follow-up ( $B = 0.49$ , robust  $SE = 0.10$ ,  $p = .004$ ). The standard gamification group also improved in comparison to the control group, although the contrast was smaller and weaker at follow-up (post:  $B = 0.25$ , robust  $SE = 0.09$ ,  $p = .039$ ; follow-up:  $B = 0.22$ , robust  $SE = 0.10$ ,  $p = .079$ ). These results indicate

that personalisation and recovery-sensitive adaptation add a layer of educational impact beyond generic gamification and simple tracking. Descriptive statistics on within-group changes and ANOVA summaries are reported in Table 2.

Table 2  
Perceived physical literacy (PPLI total score, 1–5): descriptive and inferential statistics

Group	T1 Baseline M (SD)	T3 Post M (SD)	T4 Follow-up M (SD)	$\Delta T1-T3$ M (SD)	$\Delta T1-T4$ M (SD)
A – Adaptive	3.01 (0.46)	3.64 (0.50)	3.59 (0.51)	+0.63 (0.42)	+0.58 (0.44)
B – Standard	3.00 (0.45)	3.39 (0.49)	3.31 (0.50)	+0.39 (0.40)	+0.31 (0.42)
C – Control	2.99 (0.47)	3.13 (0.48)	3.08 (0.49)	+0.14 (0.37)	+0.09 (0.38)
Within-group change (T1–T3)	t(df)	p	Cohen's d	95 % CI [x, y] for d	
A – Adaptive	t(81) = 12.17	<.001	1.34	[1.05, 1.63]	
B – Standard	t(82) = 9.09	<.001	0.99	[0.72, 1.26]	
C – Control	t(82) = 4.09	<.001	0.45	[0.22, 0.67]	
Mixed ANOVA (T1–T4)	F(df)	p	$\eta^2$	95 % CI [x, y] for mean difference (A–C, $\Delta T1-T3$ )	
Group $\times$ Time interaction (PPLI)	F(4, 488) = 11.27	<.001	0.085	0.36 to 0.70	

Source: author's development

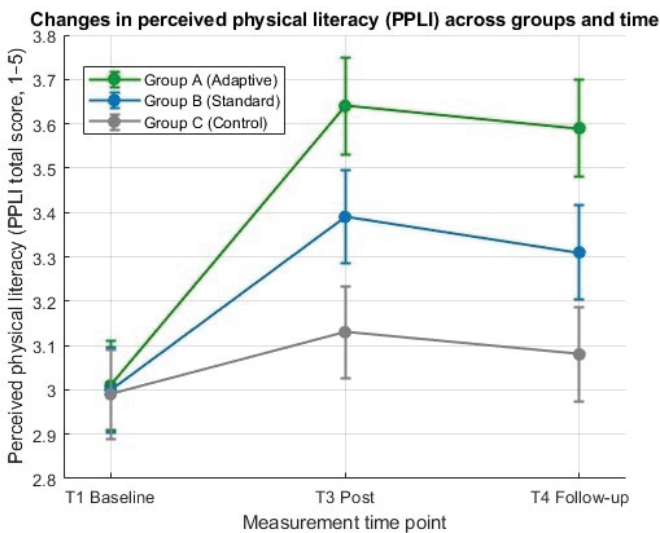


Figure 3. Changes in perceived physical literacy (PPLI total score) across groups and time  
Source: author's development

Note. Lines represent group means; error bars indicate 95 % confidence intervals.

Figure 3 shows the same pattern visually: all groups improved from baseline to post-intervention, but the adaptive group showed the largest gain and the smallest decline at follow-up. The change in the standard gamification group was intermediate, whereas the control group changed only modestly.

Secondary outcomes showed the same overall gradient across conditions (Table 3). In comparison to the control group, the adaptive model had larger post-intervention gains in autonomous motivation ( $B = 0.39$ , robust  $SE = 0.11$ ,  $p = .016$ ), WHO-5 well-being ( $B = 7.3$ , robust  $SE = 2.3$ ,  $p = .024$ ), and basic psychological needs satisfaction ( $B = 0.33$ , robust  $SE = 0.10$ ,  $p = .021$ ). Corresponding contrasts for the standard gamification group were smaller and not statistically robust in the clustered models. Descriptive within-group statistics and ANOVA summaries are presented in Table 3.

Table 3

Motivation, well-being, and basic needs: descriptive and inferential statistics (T1-T3)

Outcome / Group	T1 Baseline M (SD)	T3 Post M (SD)	$\Delta T1-T3$ M (SD)	
Autonomous motivation (1-5)				
A - Adaptive	3.24 (0.58)	3.82 (0.61)	+0.58 (0.47)	
B - Standard	3.23 (0.59)	3.56 (0.62)	+0.33 (0.44)	
C - Control	3.21 (0.60)	3.40 (0.61)	+0.19 (0.41)	
WHO-5 well-being (0-100)				
A - Adaptive	58.7 (15.4)	69.1 (15.0)	+10.4 (11.8)	
B - Standard	58.1 (15.1)	65.4 (15.2)	+7.3 (11.2)	
C - Control	58.3 (15.8)	61.4 (15.5)	+3.1 (10.9)	
Basic needs composite (1-5)				
A - Adaptive	3.11 (0.52)	3.57 (0.54)	+0.46 (0.43)	
B - Standard	3.10 (0.51)	3.39 (0.55)	+0.29 (0.41)	
C - Control	3.09 (0.53)	3.22 (0.54)	+0.13 (0.39)	
Within-group change (T1-T3)	t(df)	p	Cohen's d	95 % CI [x, y] for d
A - Auton. motivation	t(81)=10.09	<.001	1.11	[0.83, 1.39]
B - Auton. motivation	t(82)=7.21	<.001	0.79	[0.53, 1.05]
C - Auton. motivation	t(82)=3.79	<.001	0.42	[0.20, 0.64]
A - WHO-5	t(81)=7.43	<.001	0.82	[0.55, 1.09]
B - WHO-5	t(82)=5.63	<.001	0.62	[0.37, 0.87]
C - WHO-5	t(82)=2.45	0.016	0.27	[0.05, 0.49]
Mixed ANOVA (T1-T3)	F(df)	p	$\eta^2$	Example 95 % CI [x, y] for mean difference (A-C, $\Delta T1-T3$ )
Group $\times$ Time (Auton. motivation)	F(4, 488)=6.42	<.001	0.05	0.21 to 0.59
Group $\times$ Time (WHO-5)	F(4, 488)=4.87	0.001	0.038	4.0 to 10.4
Group $\times$ Time (Basic needs)	F(4, 488)=5.71	<.001	0.045	0.17 to 0.49

Source: author's development

Note. Descriptive ANOVA and paired t-test statistics are reported for comparability with prior literature.

Engagement indicators also differed across conditions (Table 4). The adaptive group showed higher valid wear days/week, weekly goal attainment, and app logins than the standard gamification and control group, whereas average rate of perceived exertion (RPE) and injury incidence were similar across groups. Between-group tests indicated the largest differences in weekly goal attainment, followed by app logins and valid wear days. Injury incidence is reported as events per 1,000 attended PE lessons.

Table 4  
Engagement indicators and between-group tests during the intervention (Weeks 3–10)

Indicator	Group A – Adaptive M (SD)	Group B – Standard M (SD)	Group C – Control M (SD)		
Valid wear days/week (≥10 h/day)	5.5 (1.0)	5.0 (1.1)	4.2 (1.3)		
Weekly goal attainment ( % of 8 weeks)	74.2 (18.6)	61.3 (20.4)	38.1 (22.7)		
App logins/ week	4.8 (2.1)	3.9 (2.0)	2.6 (1.8)		
Average RPE (0–10)	6.1 (1.1)	6.0 (1.2)	5.9 (1.1)		
Injury incidence (per 1,000 PE hours)	1.3 (—)	1.5 (—)	1.4 (—)		
Mixed ANOVA / ANOVA on engagement Group (goal attainment, average)	F(df)	p	$\eta^2$	Example pairwise d (A–C)	95 % CI [x, y] for d
Group (valid wear days/ week)	F(2, 245)=41.02	<.001	0.251	1.01	[0.72, 1.30]
Group (app logins/week)	F(2, 245)=15.87	<.001	0.115	0.77	[0.49, 1.05]
Group (logins/week)	F(2, 245)=19.43	<.001	0.137	0.83	[0.55, 1.11]

Source: author’s development  
Note. Injury incidence is reported as a rate; SD is not applicable.

Figure 4 shows that weekly goal attainment and valid wear days were highest in the adaptive group, intermediate in the standard gamification group, and lowest in the control group across the intervention period. Together, these panels indicate that adaptive gamification not only increases the frequency of achieving activity goals but also the reliability of using trackers, with no evidence of progressive disengagement over the intervention period. The standard gamification condition improves engagement when compared to the control model, but less strongly and less consistently than the adaptive model.

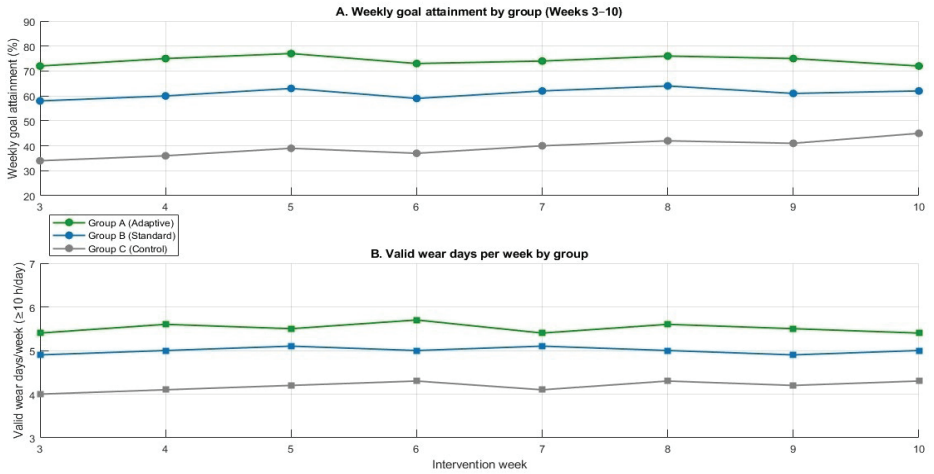


Figure 4. Weekly goal attainment rates and valid wear days per week by group during the intervention  
Source: author's development

Figure 5 shows positive correlations between engagement indices and change scores in physical literacy, motivation, well-being, and MVPA, with weekly goal attainment showing the strongest correlations.

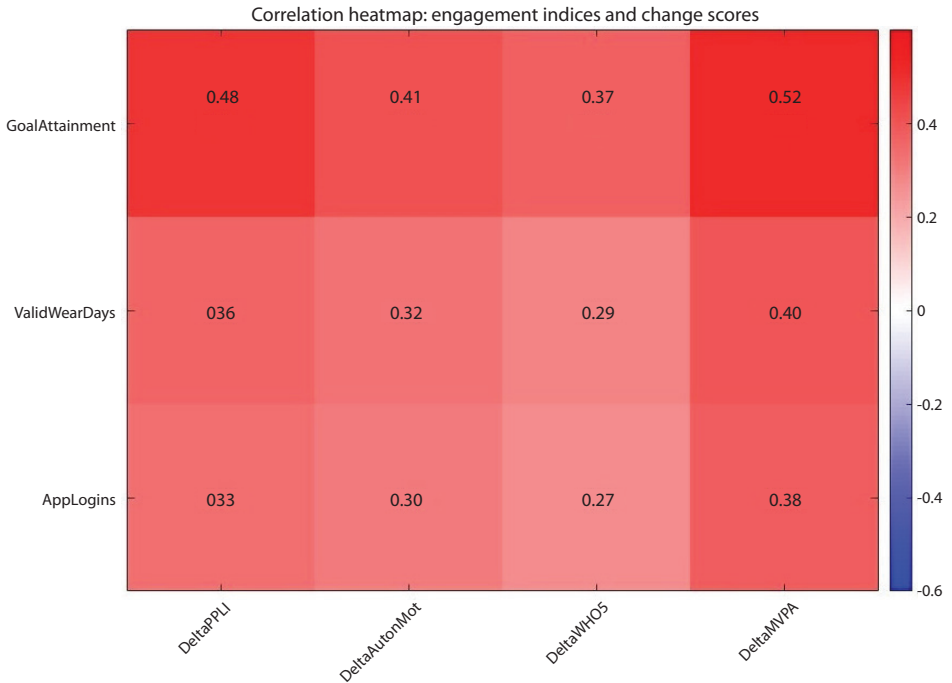


Figure 5. Correlation heatmap of engagement indices and change scores in physical literacy, motivation, well-being, and MVPA

Source: author's development  
Note. Cells represent Pearson's r coefficients.

## Discussion

The present findings demonstrate that adaptive gamified use of wearables can meaningfully enhance physical literacy, motivation, well-being and MVPA among university students, and that these gains are larger and more sustained than those produced by standard gamification or tracker-only monitoring. This pattern is broadly consistent with cluster-randomised work from the United States, where adding a wearable tracker to a credit-bearing activity course increased college students' weekly MVPA compared with usual instruction, although effects on psychological outcomes were not examined (Kim et al., 2018). The current study extends that evidence by embedding adaptive goal-setting, narrative framing and reflective journaling, and by targeting perceived physical literacy rather than only raw activity volume.

This interpretation is also consistent with trials showing that wearable-supported activity gains are often modest and prone to decline when interventions rely primarily on monitoring or short-term behaviour-change resources (Ridgers et al., 2021). In the present study, the more durable pattern observed in the adaptive instruction model suggests that recovery-sensitive goal calibration, self-referenced feedback, and structured reflection may help sustain engagement more effectively than fixed-goal gamification or tracker use alone. At the same time, the small improvements observed in the tracker-only instructional model are compatible with prior reviews indicating that wearables can produce incremental behavioural benefits even in less elaborated intervention formats (Casado-Robles et al., 2022; Golikova et al., 2025).

More broadly, the findings align with emerging evidence that technology-enhanced physical education is most effective when digital tools are embedded in theoretically grounded pedagogical designs rather than used only for monitoring or competition (Fernández-Vázquez et al., 2024; Wang et al., 2025). Qualitative research on smartwatch use also indicates that self-tracking is shaped by local body norms and informal coaching cultures, suggesting that wearable-based pedagogy should be interpreted within broader social meanings of health and self-management rather than as a purely technical intervention (Antwi & Finn, 2025). They also fit recent Chinese evidence linking digital health capacities, physical activity, and physical literacy in university populations (Jiang et al., 2024). Taken together, the study found cluster-randomised evidence proving that self-determination-informed adaptive gamification can extend wearable-based physical education beyond step-count outcomes towards physical literacy and related psychosocial outcomes in a real-world university context.

### ***Limitations and practical implications***

The study has several limitations. Cluster randomisation with only six student classes limited power to detect between-cluster variability and increased sensitivity to contextual differences across classes. Self-report measures remained vulnerable to the bias of giving socially desirable answers, and not wearing devices or synchronisation failures may have introduced some gaps and errors in measurement. The inclusion of only two

universities in the study and its duration of one semester also limit generalisability to other institutional and regional contexts. These limitations were partly mitigated by scripted delivery, fidelity observations, robust mixed-effects models, repeated incomplete measures, and triangulation of self-reports, device logs, and interviews. Practically, the findings indicate that universities should move beyond passive tracker distribution towards curriculum-integrated programmes in which adaptive goals, dashboards, and structured reflection support students' physical literacy and self-management of activity. Future research should test the model over longer time periods, across more diverse institutions, and with closer attention to cost, implementation barriers, and subgroup-specific design needs.

## **Conclusions**

This study demonstrates that embedding wearable trackers within an adaptive, gamified university physical education programme can produce stronger and more sustained benefits than standard gamification or tracker-only monitoring. Within the cluster-randomised design, students in the adaptive instruction model showed the most favourable pattern of change in perceived physical literacy, alongside parallel improvements in autonomous motivation, psychological need satisfaction, well-being, and behavioural engagement. These findings suggest that the educational value of wearables in university PE depends less on device use alone than on how behavioural data are translated into adaptive goals, meaningful feedback, and structured reflection within the curriculum. In this respect, the study extends wearable-based physical activity research by indicating that tracker-supported interventions can influence not only activity-related behaviour but also literacy-oriented outcomes linked to long-term self-regulation and active living. From a practical perspective, the results support a shift away from passive distribution of commercial trackers towards pedagogically integrated models in which instructors use adaptive target-setting, progress feedback, and reflective tasks to scaffold students' engagement with movement. Such an approach appears especially relevant in university contexts where sustainable, self-managed activity habits are a central educational objective. At the same time, the findings of the study should be interpreted in light of its limitations, which include the small number of classes, short duration and only two participating universities. Future research should examine the durability, scalability, and cost-effectiveness of this model across longer intervention periods, more diverse institutional contexts, and different student subgroups.

## **Acknowledgment**

Coded data on the participants, the data dictionary, and analysis syntax for the clustered models are available from the corresponding author on reasonable request, subject to institutional ethics approval and data-protection constraints.

This study was funded by Jiangxi Provincial Sports Bureau (Grant Number: 2025025) and by Jiangxi Provincial Department of Education (Grant Number: BKJG-2026-5-49).

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# Prilagodljivi igrificirani uređaji za nošenje u sveučilišnom kolegiju Tjelesne i zdravstvene kulture: učinci na tjelesnu pismenost, motivaciju i dobrobit u randomiziranome kontroliranom istraživanju

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## Sažetak

Ova studija provedena je na kineskim sveučilištima, a ispitala je poboljšava li prilagodljivi igrificirani program temeljen na uređajima za praćenje aktivnosti tjelesnu pismenost i povezane psihološke ishode u većoj mjeri nego standardna igrifikacija ili praćenja isključivo putem pametnih satova. Randomizirano kontrolirano istraživanje trajalo je jedan semestar i provedeno je s 248 dodiplomskih studenata u šest skupina prema tri modela: prilagodljiva igrifikacija s personaliziranim ciljevima usmjerenima na oporavak i refleksiju, standardna igrifikacija s fiksnim ciljevima i kontrolni model provedbe koji je uključivao samo naprave za praćenje i refleksiju. Fizička pismenost, motivacija, dobrobit i aktivnost procjenjivani su na početku, nakon intervencije i pri praćenju pomoću upitnika i podataka s korištenih uređaja. Percepcija tjelesne pismenosti unaprijed je definirana kao primarni ishod. Budući da je randomizacija provedena na razini šest studentskih skupina, potvrdni je zaključak temeljen na linearnim mješovitim modelima s nasumičnim presjekom za skupinu studenata i pojedinoga studenta te klaster-robustnim standardnim pogreškama s korekcijom stupnjeva slobode zbog maloga uzorka, ANOVA i usporedbe parova ponovljeni su kao deskriptivne/pomoćne analize. Analize korelacije i istraživački modeli posredovanja korišteni su za ispitivanje potencijalnih ponašanja, a intervjui, tj. refleksije, tematski su kodirani. U primarnome modelu prilagođenom skupinama, adaptivna skupina pokazala je veći postintervencijski dobitak u percipiranoj tjelesnoj pismenosti od kontrolne skupine ( $B = 0,49$ , robusni  $SE = 0,09$ ,  $p = 0,003$ ), a ta je prednost ostala vidljiva i pri praćenju ( $B = 0,49$ , robusni  $SE = 0,10$ ,  $p = 0,004$ ). Rezultati pokazuju

da ugradnja uređaja za praćenje u teorijski utemeljen dizajn prilagodljivoga učenja može značajno ojačati sposobnost i spremnost studenata da vode aktivan život te nudi mjerljive principe dizajna za promicanje zdravlja na sveučilištu.

**Ključne riječi:** igrificirano tjelesno obrazovanje; motivacija samoodređenja; nosiva tehnologija; promicanje zdravlja na sveučilištu; promjena digitalnoga ponašanja

## Uvod

Nedovoljna tjelesna aktivnost jedan je od vodećih globalnih zdravstvenih rizika, pri čemu otprilike trećina odraslih i četiri petine adolescenata ne ispunjavaju preporučene smjernice za kretanje (Svjetska zdravstvena organizacija, 2024.). Nedavne objedinjene analize više od 500 istraživanja u populaciji pokazuju da je nedovoljna aktivnost odraslih dosegla 31,3 % u 2022. godini i nastavlja rasti u više od polovice praćenih zemalja, što ukazuje na ograničen utjecaj dosadašnjih nastojanja tvorca politika (Strain i sur., 2024). Ti se trendovi pojavljuju istovremeno s rastućim problemima pretilosti, kardiometaboličkih bolesti i narušenoga mentalnog zdravlja, što obrazovne sustave potiče na razvijanje trajnih navika tjelesne aktivnosti koje poboljšavaju zdravlje, a ne samo kratkoročno pridržavanje testova tjelesne spremne.

Fizička pismenost promiče se kao integrirani konstrukt koji povezuje motivaciju, samopouzdanje, kompetenciju, znanje i razumijevanje potrebne za cjeloživotno sudjelovanje u tjelesnim aktivnostima (Fortnum i sur., 2025). Međutim, i dalje se vodi rasprava o njezinoj operacionalizaciji, a nastojanja validacije pokazuju da se instrumenti za percipiranu fizičku pismenost moraju pažljivo prilagoditi specifičnim jezicima i kulturama, uključujući populaciju mladih odraslih osoba (Gandrieau i sur., 2023). U ovoj studiji tjelesna pismenost operacionalizirana je kao percipirana tjelesna pismenost (PTP) definirana kao percipirano samopouzdanje studenata te motivacija i poznavanje/razumijevanje samoreguliranoga kretanja. Ova operacionalizacija nadopunjuje mjere broja koraka i tjelesne aktivnosti umjerenoga do jakoga intenziteta (MVPA) jer se usmjerava na sposobnosti koje održavaju aktivnost u različitim kontekstima istodobno prepoznajući ključni izazov u ovome području: višedimenzionalni konstrukt zahtijeva instrumente primjerene kulturnome kontekstu te se ne može pouzdano izvesti isključivo iz volumena aktivnosti.

Tehnologije samopraćenja i fitness uređaji za nošenje sve su prisutniji, ali njihov utjecaj na ponašanje ostaje raznolik i često ga je teško održati tijekom vremena (Chen i dr., 2025; Jin i dr., 2022). Istraživanja komercijalnih ekosustava pametnih satova dodatno ukazuju na činjenicu da struktura obavijesti i digitalni poticaji mogu značajno oblikovati stalno uključivanje korisnika u povratne informacije s nosivih uređaja (Asimakopoulos i dr., 2024). Usvajanje nosivih fitness uređaja također ovisi o percipiranoj korisnosti, jednostavnosti upotrebe i značajkama specifičnima za uređaj, što sugerira da ono ovisi o kvaliteti dizajna, kao i o namjeri za očuvanje zdravlja (Hayat i dr., 2023.). U okviru tjelesne i zdravstvene kulture, igrificirani sustavi za praćenje čine se najperspektivnijima kada su podatci o ponašanju ugrađeni u pedagoški smisleni

povratnu informaciju, a ne kada se tretiraju kao samostalni alati za praćenje (Vorlíček i dr., 2024). Novije terensko istraživanje također je pokazalo da su uvjeti igrificirane tjelesne aktivnosti povećali broj koraka, iako su poboljšanja intrinzične motivacije i percipirane korisnosti bili ograničeni, što naglašava važnost teorijski utemeljenoga dizajna (Grech i dr., 2024). U isto vrijeme, samopraćenje pomoću nosivih uređaja izaziva zabrinutost zbog etičkih pitanja nadzora, podatkovifikacije i osjećaja krivnje korisnika u slučaju otežanoga postizanja ciljeva, zbog čega su suportivni, a ne kontrolirajući dizajni osobito važni (Wieczorek i dr., 2023). Kako bi se objasnilo zašto bi takav dizajn trebao utjecati na tjelesnu pismenost, a ne samo na količinu aktivnosti, ova je studija utemeljena na teoriji samoodređenja (SDT): intervencije koje podržavaju kompetenciju u ostvarivim izazovima i informativnom povratnom informacijom, autonomiju putem samoreferenciranoga napretka i smislenoga izbora te povezanost putem socijalne podrške vjerojatnije će ojačati samosvojnu motivaciju i trajnu samoregulaciju. Stoga se adaptivna igrifikacija konceptualizira kao mehanizam za održavanje optimalno izazovnih i osobno značajnih ciljeva, dok zadatci refleksije pretvaraju podatke o ponašanju u učenje.

Ipak, postojeća istraživanja još uvijek nisu riješila važna konceptualna i pedagoška pitanja. Istraživanja tjelesne pismenosti i dalje često daju prednost pojedinačnim pokazateljima kompetencija, dok su motivacijske, afektivne i kognitivne dimenzije manje dosljedno integrirane u modele intervencija, osobito u sveučilišnim okružjima, gdje izvedivost i prilagodba instrumenata ostaju važna ograničenja (Gandrieau i dr., 2023; Peng i Zhang, 2025; Sanctuary i dr., 2025; Welk i dr., 2022). U vezi s tim, dokazi iz područja tjelesnoga i zdravstvenoga obrazovanja pokazuju da angažman učenika uvelike ovisi o klimi koja podržava njihove potrebe, a koju oblikuju autonomija, kompetencija i povezanost (Holt i dr., 2019.; Roure i Lentillon-Kaestner, 2022.). Istraživanja nastave tjelesne i zdravstvene kulture dodatno ukazuju na to da stil poučavanja i reakcije na ometanja utječu na sudjelovanje i održivi angažman u aktivnostima na nastavi (Hovdal i dr., 2021). Analize kurikula također pokazuju da je formalni tjelesni odgoj često davao prednost organiziranim sportskim kulturama nad autonomijom učenika i svakodnevnim praksama kretanja, čime se potvrđuje potreba za pristupima usmjerenima na učenika (O'Connor i Penney, 2021). Istovremeno se digitalni alati u tjelesnoj i zdravstvenoj kulturi često koriste za nadzor, testiranje ili praćenje izvedbe, a ne za formativnu podršku usmjerenu na pismenost, dok su nosive i igrificirane intervencije češće usmjerene na opseg aktivnosti nego na višedimenzionalne ishode učenja (Lewis i dr., 2020; Müller i Wagner, 2025; Mynbayeva i sur., 2025; White i dr., 2025).

Ovi su problemi osobito izraženi u Kini, gdje se studenti suočavaju sa snažnim akademskim pritiscima uz brzu digitalizaciju svakodnevnoga života. Tijekom razdoblja bolesti COVID-19, nedostatna tjelesna aktivnost među kineskim studentima bila je povezana s jačim simptomima anksioznosti i depresije, a noviji dokazi i dalje pokazuju nedostatnu aktivnost i pozitivne veze između tjelesne aktivnosti i

kvalitete života te zdravlja u populaciji kineskih studenata (Tao i dr., 2025; Xiang i dr., 2020). Ovaj je kontekst posebno važan jer suvremena znanstvena istraživanja u području tjelesne i zdravstvene kulture sve više mentalno zdravlje tretiraju kao središnje pedagoško pitanje, a ne kao periferni konstrukt odvojen od obrazovanja o kretanju (Smith, 2020; Solovyeva i sur., 2023). Ipak, u postojećoj literaturi uređaji za praćenje kondicije i dalje su predstavljeni kao alati za promjenu ponašanja usmjerenu na povećanja broja koraka ili kao potrošačka tehnologija koja se proučava izvan formalnih kurikula. Pitanje koje ostaje empirijski nedovoljno razjašnjeno jest može li se unutar strukturirane sveučilišne nastave tjelesne i zdravstvene kulture uključivanjem nosivih uređaja u adaptivno postavljanje ciljeva osjetljivih na oporavak, umjesto igrifikacije ili samoga praćenja s fiksnim ciljevima, postići održivi napredak u percipiranoj tjelesnoj pismenosti i povezanim psihosocijalnim ishodima.

U skladu s tim, ovom se studijom nastojalo prevladati specifična manjkavost u literaturi: nedostatak dokaza iz klaster-randomiziranih kontroliranih ispitivanja koji bi potvrdili može li prilagodljiva igrificirana upotreba nosivih uređaja za praćenje na kineskim sveučilištima učinkovitije unaprijediti percipiranu tjelesnu pismenost u formalnoj nastavi tjelesne i zdravstvene kulture nego standardna igrifikacija ili praćenje samo pomoću uređaja. U studiji su postavljena tri cilja: prvo, utvrditi dovodi li adaptivna igrifikacija do većih i održivijih dobitaka u percipiranoj tjelesnoj pismenosti; drugo, ispitati poboljšava li također autonomnu motivaciju, zadovoljavanje osnovnih psiholoških potreba i dobrobit s obzirom na usporedive uvjete i treće, istražiti pomažu li angažman i iskustvo studenata u objašnjavanju razlika u ishodima između različitih modela provede. Formulirane su dvije hipoteze: H1 – prilagodljiva igrifikacija proizvest će veća i dugotrajnija poboljšanja u percipiranoj tjelesnoj pismenosti od standardne igrifikacije i praćenja samo pomoću uređaja i H2 – prilagodljiva igrifikacija proizvest će veća poboljšanja u motivaciji, zadovoljavanju temeljnih psiholoških potreba i dobrobiti od standardne ili praćenja isključivo putem uređaja. Veze koje uključuju postizanje tjednih ciljeva, korištenje uređaja i iskustvo studenata tretirane su kao istraživačke jer je grupni dizajn uključivao samo šest skupina studenata.

## **Metodologija**

### ***Metodološke i teorijske osnove***

Ovo istraživanje osmišljeno je kao kontrolirano ispitivanje nasumično raspoređenih skupina, a korišten je konvergentni pristup miješanih metoda. Nasumično raspoređivanje, tj. randomizacija skupina korištena je kako bi se minimalizirala kontaminacija postavljanja ciljeva i usporedbe među vršnjacima u svim modelima provedbe, uz očuvanje rutinskoga rasporeda i nastave. Odabran je konvergentni dizajn mješovitih metoda kako bi se integrirali rezultati upitnika i zapisi uređaja s podacima iz intervjua/refleksije, što omogućuje interpretaciju usmjerenu na mehanizme, a ne samo izvještavanje o ishodima. Sama intervencija vođena je

teorijom samoodređenja: prilagodljivo kalibriranje ciljeva i informativna povratna sprega imali su za cilj podržati kompetenciju, napredak usmjeren na vlastito iskustvo i slobodu izbora radi poticanja autonomije te strukturiranu grupnu refleksiju radi poticanja povezanosti.

### ***Prilagodba instrumenta, bodovanje i psihometrijska evaluacija***

Budući da se studija oslanjala na kinesku verziju Instrumenta za procjenu percipirane tjelesne pismenosti (IPTP) i anketu o upravljanju vježbanjem (BREQ-3) prilagođenu lokalnim uvjetima, priprema instrumenata i psihometrijska evaluacija bili su izričito dokumentirani. Zadržane su valjane kineske formulacije, a ostale su stavke prevedene i povratno prevedene, a zatim su ih pregledali dvojezični istraživači i stručnjaci za tjelesnu i zdravstvenu kulturu radi semantičke i kontekstualne ekvivalentnosti. Napravljene su manje prilagodbe formulacija radi poboljšanja jasnoće u kontekstu tjelesno-sportskih okružja na kineskim sveučilištima, uz očuvanje značenja konstrukta. Indeks dobrobiti Svjetske zdravstvene organizacije (WHO-5) izračunat je prema standardnoj transformaciji sirovoga zbroja, koji se množi s 4 čime se dobiva skala od 0 do 100.

### ***Dizajn istraživanja i postupak***

Ispitivanje je trajalo jedan proljetni semestar (od ožujka do srpnja 2025). Nulti tjedan uključivao je informiranje i pristanak, prvi tjedan osnovno praćenje (koraci, MVPA, spavanje, otkucaji srca u mirovanju), drugi tjedan tehničku uhodanost, tjedni 3. – 10. osam sesija od 90 minuta (jednu tjedno), a tjedni 11. – 16. naknadno praćenje. Šest studentskih skupina s Jingsau sveučilišta i Tehnološkoga sveučilišta u Hefeiju nasumično su raspoređene (1:1:1) u okružja prilagodljive igrifikacije (skupina A), standardne igrifikacije (skupina B) ili u okružje kontrole samo putem uređaja za praćenje (skupina C). Skupne su unaprijed raspodijeljene pomoću računalno generiranoga nasumičnog slijeda koji je pripremio istraživač koji nije bio uključen u nastavu ili obradu ishoda. Kako bi se očuvala ravnoteža između lokacija, randomizacija je bila stratificirana po sveučilištima, pri čemu je unutar svake institucije dodijeljena po jedna skupina studenata za svaku skupinu uvjeta. Raspodjela je objavljena nakon dovršetka upisa u studentske grupe i uspostavljanja osnovnoga rasporeda. Budući da je intervencija uključivala vidljivo različita pravila postavljanja ciljeva, nadzorne ploče i postupke povratnih informacija, zasljepljivanje studenata i instruktora nije bilo izvedivo. Međutim, ekstrakcija podataka s uređaja provodila se prema standardiziranom tijeku rada, administracija upitnika koristila je zajedničke skripte, a grupirani modeli procjenjivani su na anonimnim skupovima podataka.

U skupini A adaptivni su elementi ažurirani tjedno: ciljevi koraka/MVPA ponovno su kalibrirani na temelju dosadašnjega postizanja ciljeva i pokazatelja relevantnih za oporavak dostupnih u uređaju/aplikaciji kako bi se sačuvao ostvariv izazov uz

održavanje napretka. Okvir povratnih informacija i neki pragovi za dodjelu značke također su prilagođeni kako bi se naglasio isključivo individualno izvještavanje napredak umjesto normativnoga uspoređivanja. U skupini B igrificirani elementi (ciljevi/bodovi/značke) slijedili su fiksni raspored primijenjen jednako na sve studente, bez individualizirane ponovne kalibracije. Pouzdanost je praćena pomoću strukturiranih kontrolnih popisa za sesije i periodičnih opažanja, a dosljednost među edukatorima sažeta je kao omjer ostvarenih planiranih komponenti po sesiji i suglasnosti među lokacijama s obzirom na ocjene s kontrolnih popisa.

### ***Logika adaptivnoga postavljanja ciljeva***

U skupini A tjedni su ciljevi ažurirani na temelju postignuća ciljeva iz prethodnoga tjedna i pokazatelja relevantnih za oporavak. Općenito, ciljevi su povećavani kada je prethodni cilj ostvaren, a pokazatelji oporavka ostali prihvatljivi. Ostajali su isti kada je postignuće bilo djelomično ili je oporavak bio na granici, a zadržani ili blago smanjeni kada su loš san, smanjena varijabilnost srčanoga ritma (HRV) ili značajan umor ukazivali na neadekvatan oporavak. Stoga je prilagodljiva logika nastojala očuvati ostvarive izazove, ograničavajući pritom ponovno prekomjerno propisivanje. Značke i povratne informacije nisu bili u funkciji normativnoga uspoređivanja, već su prilagođeni tako da naglašavaju napredak u odnosu na vlastiti učinak. Nasuprot tome, skupina B funkcionirala je u istoj, općoj igrificiranoj strukturi, ali s fiksnim ciljevima i pragovima koji su se jednako primjenjivali na sve studente.

Svaka je sesija obuhvaćala kratku lekciju o tjelesnoj pismenosti, strukturiranu MVPA i vođenu refleksiju. Slika 1 prikazuje tijek sudjelovanja na razini skupina i pojedinca (studenata), dok Slika 2 prikazuje shematski blok-dijagram ispitivanja.

Slika 1

Slika 2

### ***Analitičke metode***

Primarni ishodi (percipirana fizička pismenost, motivacija, dobrobit, osnovne potrebe) ustanovljeni su na početku, prilikom naknadne intervencije i praćenja; mjere aktivnosti, tj. angažmana (koraci, MVPA, postizanje ciljeva, prijave u aplikaciju) bilježeni su tjedno; odgovori na pitanja intervjua i kvalitativni podatci prikupljeni su u fazama naknadne intervencije i praćenja.

### ***Uzorak***

Uzorak istraživanja uključivao je studente preddiplomskih studija upisane na obvezni kolegij Tjelesne i zdravstvene kulture. Unutar svake ustanove odabrane su dvije paralelne grupe studenata prve ili druge godine u konzultaciji s voditeljima odsjeka, čime je dobiveno šest cjelovitih studentskih skupina koje su nasumično raspoređene u modele provedbe s adaptivnom igrifikacijom, standardnom igrifikacijom ili model kontrole samo putem uređaja za praćenje, pri čemu je na svakom

sveučilištu bila po jedna studentska skupina u svakoj od tri navedene intervencije. Svi studenti upisani u te studijske grupe ( $\approx 40 - 45$  po grupi; ukupno  $240 - 270$ ) bili su pozvani na sudjelovanje. Uvjeti za sudjelovanje bili su dob  $\geq 18$  godina, redovni upis na semestar, liječnička potvrda za umjerenu do snažnu aktivnost, sposobnost korištenja pametnoga telefona i nosivoga uređaja te pristanak na kontinuirano praćenje i sudjelovanje u anketama. Isključeni su sudionici s ozbiljnim kardiovaskularnim, neurološkim ili mišićno-koštanim stanjima, teškim mentalnim bolestima, vestibularnim poremećajima, trudnoćom ili nevoljkošću nošenja uređaja najmanje 4 dana tjedno. A priori provjera snage klastera koristila je prilagodbu za učinak dizajna (pretpostavljeni ICC  $\approx 0,03$  i prosječna veličina klastera  $\approx 42$ ), što je ukazivalo da je šest klastera osiguralo adekvatnu snagu za otkrivanje malih do umjerenih učinaka skupina  $\times$  vrijeme u modelima miješanih učinaka (približno  $f \approx 0,25$ ).

### ***Nosivi uređaji, ekstrakcija podataka i pravila ispravnoga nošenja***

Podatci o aktivnosti i oporavku prikupljeni su pomoću uređaja Huawei Watch Fit 3 (ugrađeni program 4.0.0.168) povezanih s aplikacijom Huawei Health (verzija 14.1). Broj dnevnih koraka, MVPA, trajanje sna, broj otkucaja srca u mirovanju i varijabilnost srčanoga ritma (HRV) izdvojeni su iz ekosustava uređaja kao sažeti metrički pokazatelji proizvođača. Valjani dan nošenja definiran je kao dan s najmanje 10 sati nošenja, a tjedni metrički pokazatelji sudjelovanja izračunati su kada je bilo dostupno najmanje 4 valjana dana nošenja. Dani ispod praga nošenja tretirani su kao dani bez nošenja (izostavljeni) umjesto kao dani s nultom aktivnošću. Status sinkronizacije istraživački su asistenti provjeravali na tjednoj razini, a pauze uspoređivane su sa zapisnicima uređaja prije sažimanja podataka. Zapisi praćenja također su uključivali vrijeme nošenja, status tjednoga postizanja cilja, učestalost sinkronizacije i prijave u aplikaciju za analize aktivnosti. MVPA je temeljena na klasifikaciji intenziteta aktivnosti proizvođača, dok su trajanje sna, broj otkucaja srca u mirovanju i HRV dobiveni iz automatiziranih modula za fiziološki nadzor uređaja.

### ***Stručni ocjenjivači***

Svaku skupinu studenata poučavao je profesor Tjelesne i zdravstvene kulture obučan za protokol i opremljen standardiziranim scenarijima lekcija. Poučavanje je obuhvatilo dvije strukturirane radionice (izvođenje kratkih lekcija o tjelesnoj pismenosti, povratne informacije usklađene s teorijom samoodređenja te tijekom rada igrifikacije specifičan za dodijeljeni model provedbe), nakon čega je uslijedila kratka proba ocijenjena kontrolnim popisom spremnosti. Dva istraživačka asistenta po lokaciji nadzirala su raspodjelu uređaja, provjeru sinkronizacije, provođenje anketa i praćenje vjernosti putem strukturiranih kontrolnih popisa. Pojedine stavke kontrolnoga popisa odnosile su se na ostvarivanje ključnih komponenti (0 = nije ostvareno, 1 = djelomično ostvareno, 2 = u potpunosti ostvareno), uključujući

podržavanje dodijeljenih uvjeta igrifikacije i dovršetak segmenta refleksije. Podskupina sesija ocijenjena je dvaput kako bi se procijenilo međusobno slaganje ocjenjivača i podržala dosljednost među lokacijama.

### ***Analiza podataka***

Podatci su obrađeni u programu SPSS 27. Percepcija tjelesne pismenosti (PTP) unaprijed je definirana kao primarni ishod, a glavna potvrдна usporedba odnosila se na diferencijalnu promjenu između adaptivnih i kontrolnih uvjeta tijekom vremena. Budući da je randomizacija provedena na razini studijskih godina, tj. skupina kojih je bilo samo šest, postupak izvođenja afirmativnih zaključaka temeljio se na linearnim modelima mješovitih učinaka s nasumičnim prekidima za pojedinca i grupu studenata, fiksnim učincima za grupu, vrijeme i interakciju skupina  $\times$  vrijeme te klaster-robustnim standardnim pogreškama na razini grupe. Primijenjena je korekcija stupnjeva slobode za male uzorke jer konvencionalni asimptotski klaster-robustni postupak donošenja zaključaka može biti nestabilan pri malom broju skupina. Ponovljene mjere ANOVA-e i uparenih t-testova zadržane su kao deskriptivne/pomoćne analize radi lakše usporedbe s rezultatima iz prethodnih istraživanja navedenima u literaturi o obrazovnim intervencijama, ali se ne smatraju primarnom osnovom za izvođenje zaključaka. Pearsonovi koeficijenti korelacije izračunati su kako bi se ispitali odnosi između promjena i pokazatelja angažiranosti. Analize posredovanja tretirane su kao istraživački modeli za ispitivanje mehanizama, ne kao potvrđni testovi uzročnosti jer je posrednik bio vremenski varijabilan, a broj skupina ograničen. Intervjui su transkribirani i tematski kodirani u programu NVivo 14.

### ***Praćenje angažmana i korelacijska analiza***

Valjani dan nošenja uređaja za praćenje definiran je kao najmanje 10 sati nošenja; tjedni pokazatelji sudjelovanja (koraci, MVPA, ostvarenje ciljeva) izračunati su kada su sudionici imali najmanje 4 valjana dana nošenja tjedno. Dani koji nisu zadovoljili prag tretirani su kao nenošenje (izostavljeni) umjesto kao nulta aktivnost, a za smanjenje pristranosti uzrokovane povremenim izostancima korištene su analize mješovitih modela. Zapisi s uređaja za praćenje sadržavali su broj koraka dnevno, minute MVPA, vrijeme nošenja, tjedni status ostvarenja ciljeva, učestalost sinkronizacije i prijave u aplikaciju. Ti su pokazatelji objedinjeni u indekse angažiranosti (npr. udio tjedana s ostvarenim ciljevima) i korelirani s promjenama u tjelesnoj pismenosti, motivaciji i MVPA-u.

### ***Etički obziri***

Etičko odobrenje dobiveno je od etičkih povjerenstava obaju sveučilišta, a sudjelovanje u istraživanju bilo je dobrovoljno, na osnovu pisane informirane suglasnosti. Podatci su šifrirani i pohranjeni na sigurnim poslužiteljima; izvješteni su samo grupni rezultati. Neželjeni događaji definirani su kao svaki incident povezan

sa sudjelovanjem (npr. mišićno-koštana bol/ozljeda koja zahtijeva prilagodbu aktivnosti, vrtoglavica ili neuobičajeni umor) i bilježeni su putem tjednih kratkih provjera te dnevnika edukatora. Takvi događaji pokrenuli bi protokolarnu reakciju, tj. odgovor (privremena prilagodba aktivnosti, upućivanje na zdravstvene usluge na kampusu ako je bilo potrebno) te su ih koordinatori studije pregledavali na tjednoj razini. Incidencija ozljeda na 1000 sati tjelesne i zdravstvene kulture izračunata je kao omjer broja ozljeda koje su zahtijevale intervenciju i ukupnog broja sati tjelesne i zdravstvene kulture na kojima su sudionici nazočili tijekom razdoblja intervencije, pomnožen s 1000.

## Rezultati

Na početnoj razini tri su skupine bile usporedive po glavnim demografskim, ponašajnim i psihosocijalnim pokazateljima (Tablica 1). Skupine se nisu značajno razlikovale prema prosječnoj dobi, broju dnevno učinjenih koraka na početnoj razini, MVPA-u, PFP, samosvojnoj motivaciji i WHO-5. Budući da je randomizacija provedena na razini skupina studenata, a bezuvjetni modeli su ukazali na grupiranje podataka koji nisu nula za primarni ishod (PFP ICC na početku = 0,04), potvrdni zaključak temeljio se na linearnim modelima miješanih učinaka s robusnim standardnim pogreškama grupiranim po skupinama studenata; sažetci ANOVA-e navedeni su samo kao deskriptivni dodatci.

### Tablica 1

Percipirana tjelesna pismenost poboljšala se u sve tri skupine, ali su dobitci bili najveći u adaptivnoj, a najmanji u kontrolnoj skupini (Tablica 2). U primarnom modelu prilagođenom skupinama poboljšanje nakon intervencije bilo je veće u adaptivnoj skupini nego u kontrolnoj skupini ( $B = 0,49$ , robusni SE = 0,09,  $p = 0,003$ ), a ta je prednost ostala vidljiva pri praćenju ( $B = 0,49$ , robusni SE = 0,10,  $p = 0,004$ ). Standardna skupina s igrifikacijom također se poboljšala u odnosu na kontrolnu skupinu, iako je kontrast bio manji i slabiji pri praćenju (nakon intervencije:  $B = 0,25$ , robusni SE = 0,09,  $p = 0,039$ ; pri praćenju:  $B = 0,22$ , robusni SE = 0,10,  $p = 0,079$ ). Ovi rezultati ukazuju na to da personalizacija i prilagodba osjetljiva na oporavak dodaju sloj obrazovnoga utjecaja izvan opće igrifikacije i jednostavnoga praćenja. Podatci deskriptivne statistike o promjenama unutar grupe i sažetci ANOVA-e navedeni su u Tablici 2.

### Tablica 2

Slika 3 prikazuje isti obrazac: sve su se skupine poboljšale od početne do postintervencijske faze, ali je adaptivna skupina pokazala najveći dobitak i najmanji pad pri praćenju. Standardna igrifikacijska skupina bila je na sredini, dok se kontrolna skupina promijenila samo umjereno.

### Slika 3.

Sekundarni ishodi pokazali su isti ukupni gradijent među uvjetima (Tablica 3). U usporedbi s kontrolnom skupinom, adaptivna skupina imala je veće postintervencijske dobitke u samosvojnoj motivaciji ( $B = 0,39$ , robusni  $SE = 0,11$ ,  $p = 0,016$ ), dobiti prema WHO-5 ( $B = 7,3$ , robusni  $SE = 2,3$ ,  $p = .024$ ). Odgovarajući kontrasti za standardnu grupu igrifikacije bili su manji i nisu bili statistički značajni u grupiranim modelima. Podatci deskriptivne statistike unutar skupina i sažetci ANOVA-e prikazani su u Tablici 3.

#### Tablica 3

Pokazatelji angažmana također su se razlikovali među modelima provedbe (Tablica 4). Adaptivna skupina pokazala je više valjanih dana nošenja tjedno, postotka ostvarenja tjednih ciljeva i prijava u aplikaciju nego standardna igrifikacijska i kontrolna skupina, dok su prosječna stopa percipiranoga napora (RPE) i incidencija ozljeda bili slični među skupinama. Testovi među skupinama pokazali su najveću razliku u postotku ostvarenja tjednih ciljeva, zatim u broju prijava u aplikaciju i broju valjanih dana nošenja. Incidencija ozljeda navedena je kao broj događaja na 1000 sati nastave tjelesne i zdravstvene kulture.

#### Tablica 4

Slika 4 pokazuje da su tjedno postizanje ciljeva i broj valjanih dana nošenja bili najveći u adaptivnoj skupini, srednji u skupini sa standardnom igrifikacijom i najniži u kontrolnoj skupini tijekom razdoblja intervencije. Ovi podatci pokazuju da adaptivna igrifikacija ne samo da povećava učestalost postizanja ciljeva aktivnosti studenata, već i pouzdanost korištenja uređaja za praćenje, bez dokaza o progresivnom odvajanju tijekom razdoblja intervencije. Standardna igrifikacija poboljšava angažman u usporedbi s kontrolnom skupinom, ali manje značajno i manje dosljedno nego intervencija u uvjetima prilagodljive igrifikacije.

#### Slika 4.

Slika 5 prikazuje pozitivne korelacije između indeksa angažmana i rezultata promjena u tjelesnoj pismenosti, motivaciji, dobiti i MVPA-u, pri čemu postizanje tjednih ciljeva pokazuje najjače povezanosti.

#### Slika 5.

## Diskusija

Rezultati ovoga istraživanja pokazuju da prilagodljiva igrificirana upotreba nosivih uređaja može značajno poboljšati tjelesnu pismenost, motivaciju, dobiti i MVPA sveučilišnih studenata te da su ta poboljšanja veća i dugotrajnija od onih postignutih standardnom igrifikacijom ili praćenjem samo pomoću uređaja. Dobiveni rezultati u skladu su s rezultatima studije provedene metodom randomizacije klastera u Sjedinjenim Američkim Državama, pri čemu je dodavanje nosivoga uređaja

za praćenje u bodovani kolegij povećalo tjednu MVPA studenata u usporedbi s uobičajenom nastavom, iako učinci na psihološke ishode nisu bili ispitani (Kim i dr., 2018). Ova studija proširuje te dokaze uključivanjem prilagodljivoga postavljanja ciljeva, narativnoga okvira i refleksivnoga vođenja dnevnika te usmjeravanjem na percipiranu tjelesnu pismenost umjesto samo na sirovi volumen aktivnosti.

Ovo tumačenje također je u skladu s ispitivanjima koja pokazuju da su koristi aktivnosti potpomognute nosivim uređajima često skromne i podložne opadanju kada se intervencije oslanjaju prvenstveno na praćenje ili resurse za promjenu ponašanja kratkoga roka (Ridgers i dr., 2021). U ovoj studiji postojaniji obrazac opažen u prilagodljivim uvjetima pokazuje da konfiguriranje ciljeva osjetljivih na oporavak, povratne informacije temeljene na vlastitim opažanjima i strukturirana refleksija mogu održati angažman učinkovitije od igrifikacije s fiksnim ciljevima ili same upotrebe uređaja za praćenje. Istovremeno, mala poboljšanja uočena u uvjetima korištenja samo uređaja za praćenje u skladu su s prethodnim istraživanjima koja pokazuju da uređaji za nošenje na tijelu mogu donijeti postupne koristi čak i u manje razrađenim oblicima intervencija (Casado-Robles i dr., 2022; Golikova i dr., 2025).

Šire gledano, rezultati su u skladu s novijim dokazima koji govore da je tjelesna i zdravstveno obrazovanje potpomognuto tehnologijom najučinkovitija kada su digitalni alati ugrađeni u pedagoške koncepte utemeljene na teoriji, a ne kada se koriste samo za praćenje ili natjecanje (Fernández-Vázquez i dr., 2024; Wang i dr., 2025). Kvantitativna istraživanja o korištenju pametnih satova također pokazuju da je samopraćenje oblikovano lokalno prihvaćenim normama tjelesnoga izgleda i neformalnim kulturama treniranja, što upućuje na to da pedagogiju temeljenu na nosivim uređajima treba tumačiti u širim društvenim kontekstima zdravlja i upravljanja vlastitim zdravljem, a ne kao isključivo tehničku intervenciju (Antwi i Finn, 2025). Dobiveni rezultati također su u skladu s recentnim istraživanjima u Kini koja povezuju kapacitete digitalnoga zdravlja, tjelesnu aktivnost i tjelesnu pismenost među studentskom populacijom (Jiang i sur., 2024). Sve u svemu, rezultati ove studije navode na zaključak da adaptivna igrifikacija utemeljena na samoodređenju može unaprijediti tjelesni odgoj temeljen na nosivim uređajima kako bi osim ishoda brojanja koraka uključio i tjelesnu pismenost i srodne psihosocijalne ishode u stvarnome sveučilišnom kontekstu.

### ***Ograničenja i praktične implikacije***

Ovo istraživanje ima nekoliko ograničenja. Nasumično raspoređivanje samo šest skupina studenata ograničilo je moć otkrivanja varijabilnosti između skupina i povećalo osjetljivost na kontekstualne razlike među njima. Metoda samoizvještavanja potencijalno je osjetljiva na pristranost uzrokovanu društveno poželjnim ponašanjem, a nenošenje uređaja ili kvarovi sinkronizacije mogli su dovesti do nekih praznina i pogreške u mjerenju. Dizajn koji je obuhvatio dva sveučilišta i jedan semestar također ograničava mogućnost uopćavanja rezultata na druge institucionalne i regionalne kontekste. Ova su ograničenja djelomično ublažena standardiziranom provedbom, kontrolom

pridržavanja protokola, mješovitim modelima učinaka i ponavljanjem nepotpunih mjera te triangulacijom samoizvijestjenih podataka, zapisa s uređaja i intervjua. S obzirom na implikacije u praksi, rezultati ukazuju na to da bi sveučilišta trebala zamijeniti pasivnu distribuciju uređaja za praćenje nastavnim planovima i programima u kojima prilagodljivi ciljevi, nadzorne ploče i strukturirano promišljanje podržavaju tjelesnu pismenost studenata i njihovo samoupravljanje aktivnošću. Buduća istraživanja trebala bi testirati model tijekom dužih razdoblja i na specifičnim podskupinama, u raznolikijim institucijama i s većim obzirom za troškove i prepreke u provedbi.

## **Zaključak**

Ovom studijom pokazuje se da ugradnja nosivih uređaja za praćenje u adaptivni, igrificirani sveučilišni program tjelesne i zdravstvene kulture može donijeti snažnije i dugotrajnije koristi od standardne igrifikacije ili praćenja samo pomoću uređaja. U okviru randomiziranoga kontroliranog istraživanja, studenti u adaptivnoj skupini pokazali su najpovoljniji obrazac promjene u percipiranoj tjelesnoj pismenosti, uz paralelna poboljšanja u autonomnoj motivaciji, zadovoljavanju psiholoških potreba, dobrobiti i angažmanu u ponašanju. Ovi rezultati upućuju na to da obrazovna vrijednost nosivih uređaja u sveučilišnoj tjelesnoj i zdravstvenoj kulturi manje ovisi o samoj upotrebi uređaja, a više o tome kako se podtaci o ponašanju prevode u prilagodljive ciljeve, smislenu povratnu informaciju i strukturiranu refleksiju unutar nastavnoga programa. U tome pogledu, studija proširuje istraživanja tjelesne aktivnosti temeljena na nosivim uređajima ukazujući na to da intervencije potpomognute uređajima za praćenje mogu utjecati ne samo na ponašanje povezano s aktivnošću, već i na ishode usmjerene na tjelesnu pismenost, dugoročnu samoregulaciju i aktivan način života. S praktičnoga stajališta rezultati podupiru pomak od pasivne raspodjele komercijalnih uređaja za praćenje prema pedagoški integriranim modelima u kojima edukatori koriste adaptivno postavljanje ciljeva, povratne informacije o napretku i refleksivne zadatke kako bi potaknuli angažman studenata u kretanju. Takav pristup čini se osobito relevantnim u sveučilišnim kontekstima, pri čemu su održive navike aktivnosti samoregulacije i određenja središnji obrazovni cilj. Istovremeno, rezultate treba tumačiti u svjetlu ograničenja dizajna studije, uključujući ograničen broj predavanja i trajanje od jednoga semestra na dva sveučilišta. Buduća istraživanja trebala bi ispitati trajnost, skalabilnost i isplativost ovoga modela tijekom duljih razdoblja intervencije, u raznolikijim institucionalnim kontekstima i različitim podskupinama studenata.

## **Napomena**

Anonimni podatci o sudionicima, rječnik podataka i sintaksa analize za grupirane modele dostupni su na upit autoru, uz uvjet odobrenja institucionalnoga etičkog povjerenstva i ograničenja zaštite podataka.

Ovu studiju financirali su Sportski ured pokrajine Jiangxi (broj potpore: 2025025) i Odjel za obrazovanje pokrajine Jiangxi (broj potpore: BKJG-2026-5-49).