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Active Commuting and its Association With Mental Health and Lifestyle Among Spanish University Students

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Abstract

Active commuting contributes to physical activity among young people, which is associated with numerous health benefits. The objective of this study was to analyze how students at a Spanish university commute to their place of study, examining the relationship between various sociodemographic variables, lifestyle habits, and mental health indicators. A cross-sectional study was conducted on a sample of 1,142 students (23.655 ± 7.84) from a university in northern Spain. The study assessed active commuting to the university, emotional and behavioral problems, emotional intelligence, self-esteem, life satisfaction, perceived stress, suicidal behavior, adherence to the Mediterranean diet, physical activity and sedentary behaviors, alcohol consumption, and compulsive internet use. 52.7% of the students were active commuters (on foot or by bicycle). This commuting mode was significantly associated with higher weekly physical activity ($p = .023$), lower perceived stress ($p = .006$) and higher life satisfaction ($p = .031$). Logistic regression analysis showed that younger age ($OR = 0.98$; $p = .030$), not being in paid employment ($OR = 0.64$; $p = .004$), lower levels of stress ($OR = 0.98$; $p = .048$) and higher life satisfaction ($OR = 1.04$; $p = .020$) were significantly associated with active commuting. The positive impact of active commuting on physical and psychosocial wellbeing suggests that governments should promote strategies to improve public health. These strategies should focus on groups where active commuting is less common, such as older students or those with higher incomes.

Keywords: college, healthy habits, physical activity, transportation, wellbeing

Introduction

Physical inactivity is recognized as one of the primary risk factors for non-communicable diseases, chronic conditions, and mental health problems (Katzmarzyk et al., 2022; Teno et al., 2024). Additionally, higher levels of total physical activity and reduced sedentary time are associated with a substantial reduction in the risk of premature mortality in adults (Ekelund et al., 2019). Moreover, globally, it has been estimated that physically inactive lifestyles generate high economic costs due to the direct medical expenses associated with diseases and problems related to physical inactivity (Santos et al., 2023).

Literature has confirmed that regular physical activity (PA) has beneficial effects on both present and future health, positioning it as one of the most influential modifiable factors in the well-being of the population (Warburton et al., 2006). However, a recent study conducted in 28 EU member countries revealed that 36.2% of adults aged 18 to 64 are physically inactive, with the highest rates observed in Southern European countries (Nikitara et al., 2021). Similarly, Guthold et al. (2018) found that globally, 27.5% of the adult population does not meet the recommended levels of PA, with these rates being significantly higher in high-income countries compared to low-income countries (36.8% vs. 16.2%).

Given this situation, a recommended strategy to increase PA levels is active commuting, which is defined as traveling by means that involve metabolic expenditure, such as walking, cycling, or skating (Nieuwenhuijsen et al., 2020). However, the percentage of university students who choose active commuting varies by context. Previous studies conducted in Spanish universities before the COVID-19 pandemic reported passive commuting rates ranging from 65% to 87.76% among students, with the car being the preferred means of transportation to university (Martín-López et al., 2024; Molina-García et al., 2014; Palma-Leal et al., 2022a).

On the other hand, active commuting not only contributes to increasing daily PA levels and meeting established recommendations (Fishman et al., 2015) but is also associated with an active lifestyle that benefits various dimensions of health and the environment (Henriques-Neto et al., 2020; Tainio et al., 2021). Additionally, PA has proven to be a potentially beneficial tool for influencing other health-related behaviors, such as preventing and reducing alcohol and drug use (Thompson et al., 2020).

In terms of its relationship with mental health, although various studies have linked subjective well-being and mental health with different characteristics of active commuting, the literature does not show consistency in these findings (Liu et al., 2022). Conversely, experimental studies have demonstrated promising improvements in the mental health of individuals who use active commuting modes compared to those who use motorized vehicles (Scrivano et al., 2023). Additionally, active commuting to work or educational centers, when perceived as positive experiences, has been directly associated with greater life satisfaction (Fordham et al., 2018) and a reduced risk of mental disorders (Marques et al., 2020). In the case of schoolchildren, there is a noted relationship between active commuting and better academic performance, mediated by self-esteem and emotional and behavioral difficulties (Walker & Gamble, 2023). In this sense, the frequency of active commuting during university years is crucial for its maintenance into adulthood, underscoring the importance of this educational stage for the present and future health of students (Bopp et al., 2019).

However, the choice of transportation mode by university students depends on a range of psychosocial, personal, and environmental factors, such as perceived safety, personal motivation, physical effort required, distance to the educational center, weather conditions, and time investment, among others (Castillo-Paredes et al., 2021; Palma-Leal, 2023). Moreover, these commuting choices are also influenced by various sociodemographic factors, such as socioeconomic status, gender, type of university, age, and place of residence, which directly affect the likelihood of engaging in active commuting to the university (Palma-Leal, 2021).

This study was conducted at the University of La Rioja (UR), a public on-site institution in Logroño (La Rioja, Spain). The university promotes healthy lifestyles through various institutional initiatives, such as sports programs, health and well-being awareness activities, and the provision of sports facilities accessible to the entire university community. Likewise, the UR has a specific program called "Sustainable Mobility," which aims to promote active and sustainable transport among students, teaching staff, and administrative and service personnel. Developed by the Sustainability Office, this initiative provides information on various active transport options, including maps and recommendations based on the chosen mode of transport. It can be accessed on the official website of the University of La Rioja. The main campus is in an urban area with good pedestrian access; however, the surrounding cycling network remains limited. In addition, the geographical distribution of the student body and the distance between students' hometowns and the campus make active commuting less viable daily.

Determining the factors associated with active commuting is essential for establishing intervention strategies that promote an active lifestyle within educational contexts, through measures and initiatives implemented by universities and public management bodies. Therefore, the main objective of this study was to analyze the association between commuting mode among Spanish university students and various sociodemographic, lifestyle, and mental health variables. Specifically, the study aimed to identify which factors are significantly associated with active commuting (walking or cycling) compared to passive commuting (motorized transport). It was hypothesized that students who engage in active commuting would show healthier lifestyle habits, including higher physical activity levels and better adherence to the Mediterranean diet, as well as better psychological well-being, reflected in lower stress and higher life satisfaction, compared to those who commute passively.

Material and Methods

Participants

This study was conducted at the University of La Rioja (Spain), a public higher education institution located in northern Spain. During the 2020–2021 academic year, the university had a total of 4,408 enrolled students, distributed across five faculties and two higher education schools. Prior to sampling, students enrolled in distance education programs and those who did not understand Spanish (e.g., international exchange students) were excluded, resulting in a target population of 4,259 students.

A cross-sectional study was designed using a convenience sampling method. Participants were recruited from different faculties and academic years to ensure heterogeneity in the sample. Initially, 2,200 students voluntarily agreed to participate, representing approximately 52% of the eligible population. After excluding incomplete questionnaires and those with random, pseudo-random, or inconsistent responses, as well as students studying exclusively online, the final sample consisted of 1,142 students (742 women and 400 men), aged between 17 and 80 (M = 23.0, SD = 7.84). The wide age range observed in the sample reflects the diversity of the university population, which includes both recently enrolled young students and older individuals pursuing second degrees or lifelong learning opportunities. This heterogeneity is characteristic of Spanish public universities and allows for a more comprehensive understanding of health and lifestyle profiles across different stages of adulthood.

Although a convenience sampling approach was used, which may introduce selection bias due to the voluntary nature of participation, several measures were taken to mitigate this limitation. Students from all faculties and academic years were invited to participate to ensure heterogeneity, and the final sample size (N = 1,142) represents a substantial proportion of the university population. These factors contribute to improving the generalizability of the findings, although the results should still be interpreted with caution regarding their external validity.

Ethical Considerations

Throughout the research process, the ethical principles of the Declaration of Helsinki were followed, and prior approval for the study was obtained from the Ethics Committee of the University of La Rioja. Verification URL: https://sede.unirioja.es/csv/code/rVGMmMvkfVdA05wUtVEifww6IDkItSiy.

Procedure

Participants were invited to participate in the survey via email, where they were provided with information about the study's purpose and asked to provide informed consent online before accessing the questionnaire. Participation in the research was voluntary and anonymous. The questionnaire was sent to all students via the university's institutional email, presenting the study and providing access to the survey through a SurveyMonkey link. Responses were collected between November 2020 and March 2021.

Instruments

In this study, a single instrument was developed, incorporating a total of eleven validated tests and questionnaires along with a series of sociodemographic questions (age, gender, nationality, education level, residence, employment status, income, and income satisfaction). The various questionnaires that comprise the instrument are described below.

The assessment of active commuting behavior to the university was conducted through the question, “How do you usually travel from your home to the university?”, using the ESVIAUN questionnaire (Bennasar, 2012). The response options were six: “I don’t commute to university (distance learning)”; “In a private vehicle shared with other students”; “In a private vehicle”; “By public transport”; “By bicycle”; and “Walking”. Subsequently, students who were studying online were excluded from the analysis, and two groups were created based on the commuting mode: the first comprised students who engaged in active commuting (by bicycle or walking), and the second comprised those who engaged in passive commuting (by public transport or motorized vehicle).

Physical activity and sedentary habits were assessed using the short Spanish version of the International Physical Activity Questionnaire (IPAQ-SF) (Craig et al., 2003). This questionnaire analyzes, over the seven days prior to administration, the intensity and type of PA performed, distinguishing between vigorous, moderate, and walking activities, as well as sitting time. For each type of activity, frequency and duration are recorded. Total scores are calculated by combining the duration (in minutes) and frequency (days) of walking, moderate, and vigorous PA, resulting in metabolic equivalent task (MET) minutes per week. The questionnaire also evaluates sitting time on weekdays and weekends. Additionally, sedentary behavior was measured through a single item assessing daily sitting time.

Adherence to the Mediterranean diet was measured using the KIDMED questionnaire (Serra-Majem et al., 2004). It consists of 16 dichotomous items (yes or no) that evaluate dietary patterns consistent with the Mediterranean diet. The final score ranges from −4 to 12, with higher values indicating greater adherence to the Mediterranean diet. The reliability of this instrument was stablished in a validation study with Spanish children and young people up to 24 years of age (Serra-Majem, 2001).

To identify harmful alcohol consumption patterns among students, the AUDIT scale was used, validated in its Spanish version for university students (García-Carretero et al., 2016). Developed by the World Health Organization (WHO), it consists of 10 questions about the quantity, frequency, and consequences of alcohol consumption, with scores ranging from 0 to 4 for each item. The total score is obtained by summing the individual item scores, with possible results ranging from 0 to 40. Higher scores indicate greater alcohol consumption.

Problematic internet use was assessed using the Spanish version of the Compulsive Internet Use Scale (CIUS) (Ortuño-Sierra et al., 2022). This scale consists of 14 Likert-type items with five response options (never, rarely, sometimes, often, very often), distributed across five dimensions: loss of control (items 1, 2, 5, and 9), preoccupation (items 4, 6, and 7), withdrawal symptoms (item 14), coping/mood alteration (items 12 and 13), and interpersonal and intrapersonal conflict (items 3, 8, 10, and 11). The total score is obtained by adding the individual item scores, with higher scores indicating more compulsive internet use.

Emotional and behavioral variables were measured using the Strengths and Difficulties Questionnaire (SDQ), validated in young Spanish populations by Ortuño-Sierra et al. (2016). This questionnaire evaluates emotional and behavioral difficulties through 25 items grouped into five subscales: emotional problems, conduct problems, peer problems, hyperactivity, and prosocial behavior. Each subscale consists of five items with responses on a three-point Likert scale (“0 = not true”, “1 = somewhat true”, “2 = certainly true”), resulting in subscale scores ranging from 0 to 10. The total difficulties score is calculated by summing the individual scores of all subscales except the prosocial subscale, which assesses social strengths and is analyzed independently. Total difficulty scores range from 0 to 40.

Emotional intelligence was assessed using the short Spanish version of the Trait Meta-Mood Scale (TMMs) by Fernández-Berrocal et al. (2004). It measures three cognitive components of emotional intelligence: attention to feelings, emotional clarity, and emotional repair. The original scale contains 48 items, but this study used the 24-item version. Responses are collected on a five-point Likert scale (from “strongly disagree” to “strongly agree”). Scores are calculated for each of the three emotional intelligence components individually, ranging from 8 to 40, as each component comprises eight items. Higher scores indicate greater emotional intelligence in each dimension.

Self-esteem was evaluated using the Rosenberg Self-Esteem Scale, validated in Spanish university students (Martín-Albo et al., 2007). This scale measures respondents’ general perceptions of their self-esteem and self-worth. It is unidimensional and consists of 10 Likert-type items with four response options, ranging from 1 (strongly disagree) to 4 (strongly agree). Final scores range from 10 to 40, with higher scores indicating higher self-esteem.

Overall life satisfaction was measured using the Satisfaction with Life Scale (SWLS) in its validated Spanish version by Atienza et al. (2000). This instrument assesses global cognitive judgments of one's life satisfaction through 5 items, with responses on a five-point Likert scale ranging from "strongly disagree (1)" to "strongly agree (5)". Final scores range from 5 to 35, with higher scores indicating greater life satisfaction.

Perceived stress was measured using the Spanish version of the Perceived Stress Scale (PSS) (Remor, 2006), originally developed by Cohen et al. (1983). This instrument assesses feelings and thoughts experienced during the month prior to the scale administration. It consists of 14 items with five response options ranging from 0 (never) to 4 (very often), based on the frequency of these feelings. The total score is obtained by summing the individual item scores, with final scores ranging from 0 to 56. Higher scores indicate higher levels of perceived stress.

Suicidal behavior was evaluated using the SENTIA-Brief Scale (Díez-Gómez et al., 2021), consisting of five statements related to individuals' thoughts and feelings during the six months prior to administration. Response options are dichotomous (yes or no), with a value of 0 assigned to affirmative responses and 1 to negative responses. Thus, total scores range from 0 to 5, with higher scores indicating greater severity or risk of suicide.

Finally, six pairs of questions from the Oviedo Infrequency Scale (INF-OV) were randomly interspersed among all questionnaire items. Fonseca-Pedrero et al. (2009) designed this scale to detect respondents who provide random, pseudo-random, or dishonest responses. It consists of 12 questions designed to have an obviously correct answer (yes or no), such as: "Have you ever seen a movie on TV?" and "Do you know people who wear glasses?". Students who provided two or more logically inconsistent answers on this scale were excluded from the subsequent analysis. Based on this, a total of 14 participants were excluded.

Statistical Analysis

Quantitative variables are represented according to their means and standard deviations, and qualitative variables according to their frequencies. The normality and homoscedasticity of the data for all variables were evaluated using the Kolmogorov-Smirnov test with Lilliefors correction and Levene's test.

Table 1
Synthesis of variables and the instruments used

DIMENSIONS	VARIABLES	INSTRUMENTS
Physical activity	Physical activity and sedentary behavior	International Physical Activity Questionnaire – Short Form (IPAQ-SF)
Lifestyle	Commuting mode	ESVIAUN questionnaire
	Adherence to the Mediterranean diet	KIDMED questionnaire
	Alcohol consumption	AUDIT Scale – Alcohol Use Disorders Identification Test
	Compulsive Internet use	Compulsive Internet Use Scale (CIUS)
Quality of life and mental health	Emotional intelligence	Trait Meta-Mood Scale – Short Version (TMMS-24)
	Emotional and behavioral difficulties	Strengths and Difficulties Questionnaire (SDQ) (Ortuño-Sierra et al., 2016)
	Self-esteem	Rosenberg Self-Esteem Scale
	Life satisfaction	Satisfaction With Life Scale (SWLS)
	Perceived stress	Perceived Stress Scale (PSS-14)
	Suicidal behavior	SENTIA-Brief Scale
Sociodemographic data	Age, gender, nationality, residence, employment status, income, income satisfaction	Ad hoc questionnaire
Control questions	Random or inconsistent responses	Oviedo Infrequency Scale (INF-OV)

Mean comparisons were performed using Student's *t* test for normally distributed variables and the Mann-Whitney *U* test for non-normally distributed variables. The association between qualitative variables was analyzed using the Pearson chi-square test.

To identify variables associated with active commuting, binary logistic regression analysis (backward elimination method) was conducted. The variables included were age, place of birth, gender, employment status, perceived stress, suicidal behavior, self-esteem, life satisfaction, emotional and behavioral difficulties, PA (MET), weekly sedentary time, adherence to the Mediterranean diet, alcohol consumption, and compulsive internet use. Statistical analysis was performed using IBM-SPSS® (version 29) for Windows, with statistical significance set at $p < .05$.

Results

The most frequent nonactive commuting modes were private vehicles (25.2%) and public transport (20%). In contrast, the percentage of students who commuted actively was 48.4% on foot and 4.3% by bicycle. Table 2 shows the frequencies of active and nonactive commuting based on different sociodemographic factors. The frequency of use of both types of transport differed significantly based on type of residence, employment status, income level, and income satisfaction.

Table 2
Frequency of commuting mode based on various sociodemographic factors

			Nonactive commuting (*n* = 540)	Active commuting (*n* = 602)	*p* value
		N	%	%	
Age			23.18 ± 7.28	21.94 ± 5.83	.002
Nationality	Native-born	1002	47.7	52.3	.448
	Migrant	140	44.3	55.7	
Gender	Male	400	46.8	53.3	.790
	Female	742	47.6	52.4	
Education level	Bachelor's	980	46.3	53.7	.241
	Master's	103	51.5	48.5	
	Doctorate	59	55.9	44.1	
Residence	Alone or with partner	136	58.1	41.9	< .001
	With friends	279	10.4	89.6	
	With family	658	65.2	34.8	
	University residence	69	4.3	95.7	
Employment status	Yes	242	58.3	41.7	< .001
	No	900	44.3	55.7	
Income	0-499	726	45.7	54.3	< .001
	500-999	183	37.7	62.3	
	1,000-1,499	112	54.5	45.5	
	1,500 or more	121	64.5	35.5	
Income satisfaction	Totally insufficient	82	64.6	35.4	< .001
	Sufficient	739	48.2	51.8	
	Totally sufficient	321	40.8	59.2	

Additionally, the mean age of students using active commuting was significantly lower than that of those reporting other commuting alternatives (21.94 ± 5.83 vs. 23.18 ± 7.28; $p = .002$).

On the other hand, Table 3 shows the differences in lifestyle factors related to PA, sedentary behavior, and dietary habits among the participants based on their mode of commuting to the university. As can be seen, no associations were found between the variables, except for PA levels. Students who commuted by walking or cycling demonstrated significantly higher weekly PA levels compared to their peers who commuted passively.

Similarly, Table 4 presents the differences in well-being, mental health, and emotional variables according to commuting mode. In this case, significant differences were observed in perceived stress and life satisfaction. Active commuting was associated with lower perceived stress levels and greater life satisfaction compared to nonactive commuting.

Table 3
Differences in lifestyles according to commuting modes

	Nonactive commuting (*n* = 540)		Active commuting (*n* = 602)		*p* value
	M	*SD*	*M*	*SD*	
Physical activity (METS)	2554.76	2385.08	2792.61	2377.59	.023
Weekly sedentary time	384.69	222.64	379.85	210.46	.603
Mediterranean diet (KIDMED)	5.91	2.53	5.97	2.45	.932
Alcohol consumption (AUDIT)	3.36	3.37	3.90	3.96	.051
Compulsive internet use (CIUS)	16.97	11.14	17.10	10.33	.596

Table 4
Mental and emotional well-being values according to commuting modes

	Nonactive commuting (*n* = 540)		Active commuting (*n* = 602)		*p* value
	M	*SD*	*M*	*SD*	
Perceived stress (PSS)	27.98	8.74	26.63	8.55	.006
Suicidal behavior (SENTIA)	0.46	1.06	0.51	1.11	.307
Self-esteem (Rosenberg)	31.40	6.11	30.95	6.04	.157
Life satisfaction (SWLS)	16.81	4.22	17.48	3.82	.031
Emotional and Behavioral difficulties (SDQ)	12.49	5.66	12.40	5.16	.932
Emotional problems	3.96	2.89	3.94	2.74	.925
Conduct problems	2.07	1.33	2.12	1.39	.572
Hyperactivity	3.95	2.16	3.88	2.14	.678
Peer problems	2.50	1.64	2.45	1.60	.588
Prosocial behavior	8.44	1.50	8.46	1.70	.216
Emotional intelligence (attention) (TMMS)	25.96	6.66	25.63	7.18	.317
Emotional intelligence (clarity) (TMMS)	24.71	6.60	24.15	6.88	.166
Emotional intelligence (repair) (TMMS)	25.39	6.55	24.76	6.37	.086

Table 5
Factors associated with active commuting to university

	B	Standard error	Wald	*p* value	OR	95% CI	R^2 Nagelkerke
Age	-0.022	0.010	4.691	.030	0.978	0.959- 0.998	.030
Employment (YES)	-0.453	0.159	8.129	.004	0.636	0.466- 0.868	
Perceived stress	-0.016	0.008	3.905	.048	0.984	0.969-1.000	
Life satisfaction	0.041	0.018	5.440	.020	1.042	1.007-1.079	

Finally, Table 5 displays only the results that reached statistical significance in the binary logistic regression analysis of acting commuting. Younger age, employment status, lower stress levels, and higher life satisfaction were associated with active commuting to the university. However, these factors together explained only about 5% of the variance.

Discussion

This study analyzed active commuting patterns among university students, as well as their relationship with various lifestyle habits and indicators of mental and emotional health. Overall, 52.7% of students reported actively commuting (n = 602), while 47.3% used nonactive commuting modes (n = 540). The most frequent passive commuting modes were private vehicles (25.2%) and public transport (20%), while walking was the predominant form of active commuting (48.4%). These results indicate a relatively balanced distribution between active and nonactive commuting, with a slightly higher prevalence of the former among students. Similar trends have been observed in previous studies, where the choice of commuting mode varies depending on factors such as distance, weather conditions, and sociodemographic characteristics (Palma-Leal et al., 2023). By way of comparison, a recent study conducted in neighboring Portugal reported that walking accounted for 28% of commutes, public transport for another 28% and car use for 42% (Ribeiro & Fonseca, 2022).

The moderate levels of active commuting can be explained, to a large extent, by the structural nature of the campus and the urban setting of the city of Logroño. Although the University of La Rioja promotes awareness initiatives such as Sustainable Mobility Week, the existing cycling infrastructure does not guarantee continuous and fully integrated access from all student neighborhoods. The campus layout includes some sections of cycle lanes and indoor and outdoor bicycle parking facilities, although they do not yet form a comprehensive network that provides widespread active mobility. Simultaneously, Logroño City Council is driving forward municipal projects to improve cycling connections between the university and the city center, yet these initiatives are still in the development phase and may not yet have had a significant impact on students' commuting habits. The university also has various sports facilities (sports complex, courts, fitness studios, etc.), reflecting an institutional commitment to physical activity. However, the lack of changing rooms and showers specifically for cyclists or walkers, as well as the limited infrastructure to support active daily commuting, could restrict the choice of these modes of travel. Collectively, these structural and environmental factors, combined with the residential dispersion of the student body, provide a coherent explanatory framework for interpreting the observed balance between active and passive commuting in the sample analyzed (University of La Rioja, 2025).

Regarding sociodemographic variables, several factors have demonstrated a significant influence on active commuting. First, the type of residence stands out. Students living alone, with a partner, or with family members showed active commuting rates ranging from 34% to 42%, whereas those living with friends or in university residences had rates exceeding 89%. This disparity may be associated with proximity to the university, as student apartments and university residences are often located close to campus to facilitate daily activities. Conversely, students living with family or in other arrangements may have less proximity due to the location of the family home or other considerations, thus hindering accessibility.

A study by Teuber and Sudeck (2021) involving nearly a thousand university students in southwest Germany found that proximity to the university was a major factor influencing active commuting, with 78% of students living nearby commuting actively compared to only 22% of those living farther away. Similarly, studies such as Ross et al. (2020) have shown that distance to the educational institution is a significant barrier to active commuting among pre-university students, with fewer students opting for active modes as distance increases. However, in university populations, other factors appear to exert as much or even greater influence than distance. For instance, Rybarczyk (2018), in a study of university students in Michigan, found that distance is not a universal barrier to active commuting, highlighting the importance of personal, household, population density, and urban design factors. Along similar lines, Zannat et al. (2020) reported that, among French university students, urban design, intersection density, and the presence of safety measures and infrastructure supporting active commuting play critical roles in students' decisions to walk or bike.

Another crucial factor influencing students' mode of transportation is the compatibility of their studies with paid employment. Students who juggle both activities tend to engage less in active commuting. Research conducted in Toronto found that students working 20 hours or more per week were less likely to commute actively to campus (Allen & Farber, 2018), potentially due to limited leisure time. Similarly, a study by Castillo-Paredes et al. (2021) among Chilean university students found that time constraints were a significant barrier to active commuting for both genders.

Additionally, having paid employment is directly linked to socioeconomic status, another determinant examined in this study. Higher income levels and greater satisfaction with income were associated with lower rates of active commuting. Specifically, students earning less than one thousand euros had active commuting rates ranging from 45% to 62%, whereas those earning more had rates reduced to 35% to 45%. This inverse relationship between socioeconomic status and active commuting has been reported in various studies, including among children and adolescents (Rodríguez-Rodríguez et al., 2022), as well as among university students in Brazil (Henning et al., 2020) and Chile (Palma-Leal et al., 2021). Similarly, research conducted among more than 500 university students in Valencia, Spain, found that students with lower socioeconomic status expended significantly more energy on active commuting (Molina-García et al., 2014). These authors attribute this relationship to the greater likelihood of vehicle ownership among higher income groups. This rationale may also explain why students who commute by vehicle tend to be significantly older than those who commute actively, as financial autonomy typically increases with age.

Regarding the relationship between lifestyle habits and modes of transportation, no associations were found between active commuting and internet use, alcohol consumption, sedentary time, or adherence to the Mediterranean diet. However, students who engaged in active commuting reported statistically higher levels of PA compared to their peers who commuted passively. Numerous previous studies have explored this relationship, and recent reviews have summarized key findings in this area. Bailey et al. (2023) highlighted that well-designed interventions promoting active commuting significantly increase PA levels among European children and adolescents. Similarly, a meta-analysis examining various systematic reviews concluded that active commuting to school or work contributes to increases in daily PA levels of 5 to 45 minutes among children, youth, and adults (Prince et al., 2021). In the case of university students, prior research has yielded similar results (Bopp et al., 2022; Palma-Leal et al., 2022b).

This finding is crucial, as engaging in active commuting not only helps individuals achieve recommended activity levels but also offers physical health benefits. For example, a systematic review by Dinu et al. (2018) found that individuals who engage in active commuting have a lower risk of all-cause mortality, as well as reduced incidence of cardiovascular disease and diabetes. Among university populations, Bopp et al. (2015) similarly found that students who actively commute to campus demonstrate better cardiovascular fitness, greater flexibility, and lower systolic blood pressure compared to motor vehicle commuters.

However, while the relationship between commuting modes and physical health has been extensively studied, there is less evidence regarding their psychosocial health effects. This study found that active commuting was significantly associated with lower perceived stress and higher life satisfaction, which were identified as factors significantly associated in the logistic regression model. Consistent with these findings, a seven-year longitudinal study in the United Kingdom involving more than 100,000 participants reported improved physical and mental health among individuals switching from passive to active commuting, with greater benefits observed among females (Jacob et al., 2020). Similarly, a Canadian study found that individuals who commuted actively were 35% less likely to be dissatisfied with their work-life balance, with female commuters also reporting lower levels of life stress (Herman & Larouche, 2021). Singleton (2019) also demonstrated positive implications of active commuting for mental well-being, confidence, and enjoyment among adult populations in the United States.

According to these authors, the beneficial impact of active commuting on mental well-being may result from physiological effects such as increased adrenaline levels or endorphin release, as well as from the psychological enjoyment associated with walking or cycling compared to driving. Additionally, being aware of engaging in a healthy behavior can be reassuring. Finally, sociodemographic factors may also play a role, as there may be a discrepancy between preferences and actual options; individuals who opt for passive commuting may do so due to lack of alternatives, which could increase levels of dissatisfaction. While there is less evidence confirming these effects on mental health among university students specifically, it is reasonable to extrapolate from general population data, given higher rates of stress, anxiety and depression among university students compared to the general population (Ibrahim et al., 2013; Rotenstein et al., 2016), as well as the significant impact of PA on their mental health (Chen, 2023).

This study examines sociodemographic factors influencing active commuting and its impact on lifestyle and mental well-being in a large sample of university students. These findings provide valuable scientific evidence supporting strategies that promote active commuting as a key element for physical and psychosocial health. However, several limitations should be acknowledged. First, its cross-sectional design prevents the establishment of causal relationships among the variables studied, suggesting that future research should employ longitudinal approaches to clarify the directionality of these associations. In addition, the use of a convenience sample limits the generalizability of the results, and although participants were recruited from different faculties and academic years, data were obtained from a single public university. Therefore, caution is advised when extrapolating these findings to other academic or regional contexts. Second, all variables were assessed through self-report questionnaires, which are inherently subjective and may be affected by recall or social desirability bias. This limitation is particularly relevant for behavioral variables such as physical activity and commuting habits. Moreover, the study did not include objective measures of physical activity (e.g., accelerometry), which could have provided more accurate and complementary information. Nevertheless, all instruments employed were validated and previously used in similar populations, and data quality was ensured through procedures designed to detect and exclude random or inconsistent responses. Finally, while this research focused on students from a single public university, the inclusion of participants from diverse disciplines increases its representativeness. Future studies should extend the sample to private universities and different regions to determine the generalizability of the observed trends.

Conclusion

The results of the present study demonstrate that engaging in active commuting among university students is associated with higher overall levels of weekly PA practice, as well as lower perceived stress and greater life satisfaction. Additionally, the findings highlight that commuting modes are influenced by several sociodemographic factors, such as age, the compatibility of studies with paid employment, income level, and income satisfaction. Given the positive associations that active commuting appears to have on both physical and psychosocial well-being, the evidence derived from this research should be taken into consideration by relevant authorities to promote strategies that contribute to better public health outcomes. Furthermore, these strategies should focus on demographic groups in which active commuting is less common, such as older students, those living farther from the university, those with higher incomes, and ultimately, those who are more likely to have access to alternative modes of transportation. Future interventions should focus on students with a higher socioeconomic status, those who combine their studies with part-time jobs, and those who live in suburban or rural areas far from campus. These groups tend to be more dependent on private or motorized transport and have lower levels of daily physical activity, making them priority targets for the design of both behavioral and structural interventions aimed at promoting active travel. Gender-sensitive approaches should also be incorporated so that both men and women perceive the university environment as a safe, accessible and inclusive space for walking or cycling. Furthermore, the number of secure bicycle parking facilities could be increased, and their use encouraged through recognition or reward programs, such as earning points on the university health card for active travel. At the institutional and governmental levels, these efforts could be complemented by the creation of an integrated network of bike lanes and safe pedestrian pathways connecting the university with different city neighborhoods, thereby promoting a more sustainable and health-conscious urban environment.

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PHYSICAL EDUCATION

Impact of Explicit Teaching Promoting Self-Regulation of Muscle Strengthening: An Interrupted Time-Series Study

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Abstract

The low frequency of muscle-strengthening physical activity (MSPA) in adolescents contrasts with the strength of its health benefits. This study analyzed the impact of a school-based intervention that combined explicit teaching and self-regulated learning (SRL) to improve MSPA practice and self-regulatory processes in physical education (PE) students. A total of 61 adolescents participated (*M* = 15.75 years, *SD* ± 0.54; 45.9% girls, 54.1% boys), grouped according to their initial level of MSPA: no practice, low practice and practice according to World Health Organization (WHO) recommendations. A mixed-methods (qualitative-quantitative) quasi-experimental interrupted time-series design (A1–B1–A2–A3–B2–A4) was applied, with pretest-posttest, validated questionnaires and SRL microanalysis interviews. The intervention, implemented in 10 PE sessions, integrated direct instruction with a sequential model of self-regulatory development. The quantitative results showed significant improvements in MSPA frequency, especially in the subgroups with low initial levels: the no-practice group increased from 0 to 1.8 days/week, and the low-practice group from 1.57 to 2.61. Improvements were also observed in self-regulated learning, especially in these subgroups. Qualitatively, only the group with higher initial MSPA showed changes in the reflection phase, shifting its self-evaluations from internal factors to external factors. No relevant differences were found in the other self-regulatory subprocesses. Overall, explicit teaching of muscle-strengthening knowledge and strategies through a sequential SRL approach in PE improves MSPA and strengthens self-regulated learning, especially in students with lower initial performance.

Keywords: active teaching, health promotion, metacognition, muscle resistance training, secondary education, self-regulation

Introduction

Knowledge related to movement and health, which is essential for promoting active lifestyles from physical education (PE), is part of the construct of physical literacy, which also includes motivation, confidence and physical competence, considered essential for sustaining continued physical activity (PA) throughout life (Cale & Harris, 2018). In this regard, to promote healthy PA habits from PE, a comprehensive educational approach is required that provides students with practical and contextualized tools on what to do, how to do it and when to act appropriately (Ennis, 2015).

Among the most efficient methodological approaches for promoting this learning, explicit teaching (ET) should be highlighted, presented in the literature under different names, such as direct instruction, explicit instruction or guided instruction (Gori et al., 2022). All of them share a common basis characterized by direct and systematic instruction, with clear objectives, guided practice and formative feedback. This approach facilitates access to knowledge and content progression, especially among students with less experience or lower performance. In particular, the "I do, we do, you do" model (Wheldall et al., 2014) represents a consolidated formulation of ET, structured into three phases (modeling, guided practice and autonomous performance) and based on scaffolding, understood as teacher support that is progressively withdrawn as students gain autonomy.

Cope and Cushion (2020) highlight direct instruction as a fundamental teaching strategy for the development of complex motor skills, which do not emerge spontaneously. This approach, centered on task sequencing and constant feedback, is reflected both in active teaching in PE proposed by Siedentop (1998) and in the Direct Instruction model of Metzler and Colquitt (2021). The latter structure learning into six key phases: review of prior knowledge, presentation of content, guided practice, feedback, independent practice and periodic reviews (Rosenshine, 1983, cited in Metzler & Colquitt, 2021).

Direct instruction, teacher scaffolding and a favorable educational climate are essential components in effective self-regulated learning (SRL) interventions, especially when they are integrated into the teaching of curricular content (Greene, 2018). In relation to this, SRL is conceived as a cyclical process of thoughts, emotions and actions aimed at achieving personal goals, composed of three cyclical phases that feed back into one another: forethought, performance and self-reflection (Zimmerman & Moylan, 2009). The model explains how students regulate their learning through the interaction between self-regulatory subprocesses (such as goal setting and metacognitive monitoring), motivational beliefs (such as self-efficacy) and self-reflection processes (such as causal attributions, self-evaluations and adaptive inferences). To facilitate the progressive acquisition of SRL, Zimmerman and Kitsantas (2005) proposed a model of four sequential levels: observation, emulation, self-control and self-regulation. The interactions between self-regulatory subprocesses are articulated at the different levels of the sequential model of self-regulation development, which guides their progressive development (Schunk et al., 2018). Its adaptation to PE has shown positive effects on motor performance and on the adoption of effective learning strategies (Kolovelonis & Goudas, 2013).

This line of research has shown that, in PE, expert learners use self-regulatory strategies more frequently, set better goals and attribute their performance more effectively (Cleary & Zimmerman, 2001; Kitsantas & Zimmerman, 2002). In particular, Cleary et al. (2006) showed that PE interventions that incorporated a greater number of phases of the self-regulatory cycle (forethought, performance and reflection) generated more significant improvements in performance, as well as in students' metacognitive and motivational processes.

In the specific area of muscle strengthening, guided and structured strength exercise practice contributes to the development of physical literacy (Zwolski et al., 2017). However, adolescent participation in these activities is low (Bennie et al., 2022), despite their physical, mental and cognitive benefits (Robinson et al., 2023). This situation could be due to insufficient motor competence, a key factor for adherence to physical practice (Barnett et al., 2023).

In view of this challenge, the development of strength skills literacy within the subject of PE has been considered of vital importance (Faigenbaum & McFarland, 2023). Along these lines, Kitsantas et al. (2018) proposed integrating self-regulation into health and PE teaching through lesson plans focused on goals, self-monitoring and self-evaluation. Through strategies such as goal setting, reflection and continuous feedback, they demonstrated that it is possible to teach students to self-regulate their learning and transfer these skills to other contexts. From this perspective, integrating ET with the development of self-regulation could be especially relevant for fostering sustainable habits of muscle-strengthening physical activity (MSPA). Pilot school interventions have begun to explore this path, articulating programs centered on SRL of muscular endurance exercises, with preliminary positive results in MSPA practice among adolescents (Bujosa-Quetglas et al., 2025).

Despite these advances, a gap persists in the literature regarding interventions in the real-world PE context that integrate ET and a sequential SRL model in a structured way to address the deficit in MSPA among adolescents, using mixed methods to evaluate both changes in PA habits and self-regulation processes.

To address this gap, the aim of the present study was to evaluate the impact of an intervention that combined explicit teaching and a progressive model of self-regulation on the frequency of MSPA and self-regulated learning processes in adolescent PE students.

An interrupted time-series design with multiple phases (A1–B1–A2–A3–B2–A4) was applied, corresponding to two complete SRL cycles (forethought, performance and evaluation) and to specific evaluation or intervention periods: A1 represented the SRL forethought phase (planning and goal setting) and the baseline before the intervention; B1 corresponded to the performance phase (performing exercises and metacognitive monitoring) and the first block of program implementation; A2 covered the SRL evaluation phase (self-evaluation, causal attributions and adaptive inferences) and the first intermediate evaluation; subsequently, this SRL cycle was repeated in A3 (forethought phase and second intermediate evaluation), B2 (performance phase and second intervention block) and A4 (evaluation phase and final follow-up evaluation).

It was proposed that the implementation of the program would progressively increase self-regulation and the perceived MSPA, with significant improvements between baseline (A1) and subsequent evaluations (A2, A3 and A4), except between A2 and A3 due to their temporal proximity, especially in adolescents with low or no initial practice. Likewise, an increase was hypothesized in the frequency of self-regulatory subprocesses (such as goal setting, strategic planning, metacognitive monitoring, causal attributions, evaluation and adaptive inferences) between the first (A1, B1, A2) and second cycle (A3, B2, A4) of self-regulation developed during the intervention.

Method

Research Design

A mixed design (qualitative-quantitative) was used, integrating three case studies with a pretest-posttest methodology (Cleary et al., 2008) and a quasi-experimental interrupted time-series design (A1–B1–A2–A3–B2–A4) (Losada & Marmo, 2022) in a single group. In this design, the A phases corresponded to baseline or evaluation periods without intervention, while the B phases included the implementation of the educational intervention, based on the self-regulatory development model of Zimmerman and Kitsantas (2005). This approach made it possible to evaluate the effectiveness of the intervention by analyzing whether changes in the dependent variables (MSPA frequency and self-regulation) coincided with the introduction of the treatment phases (B1 and B2), thereby strengthening causal inference without requiring a control group. The absence of a control group was justified by the impossibility of applying differentiated conditions without generating inequalities in access to the intervention, because the principal investigator was the only teacher involved in the research and there were time and curricular restrictions in the educational program. Students were grouped into three categories according to their initial level of MSPA: no MSPA, low MSPA (1–2 days per week) and MSPA according to the World Health Organization (WHO) recommendations (≥ 3 days per week) (Bull et al., 2020). Quantitative and qualitative data were combined to evaluate the effects of the intervention on self-regulatory processes and MSPA practice.

Participants

The intervention was implemented in 2 class groups of 4th year of Compulsory Secondary Education and 2 groups of 1st year of Baccalaureate at a public school located in Mallorca (Balearic Islands). A total of 61 participants were included (M = 15.75 years, SD ± 0.54; 45.9% girls, 54.1% boys) who met the criteria of attendance (> 80%), informed consent and medical fitness.

Instruments

The perceived MSPA was evaluated using an item from the Physical Activity Questionnaire of the European Health Interview Survey (EHIS-PAQ) (Finger et al., 2015), translated into Spanish through double translation and with adequate test-retest reliability (ICC = .55). Specifically, the question asked was: "How many days in the last week have you done exercises to strengthen or tone your muscles?" (0-7 days). According to their responses, the 61 participants were classified into three subgroups: no MSPA (n = 10), low MSPA (n = 28) and MSPA according to the WHO recommendations (n = 23).

The Self-Regulated Learning Questionnaire for Muscular Endurance Exercises in Physical Education (CAAERMEF in Spanish) was used, which evaluates motivational (effort, self-efficacy) and metacognitive (planning, self-monitoring, evaluation, reflection) processes in muscular endurance exercises (Bujosa-Quetglas et al., 2024), with high reliability (self-efficacy α = .926, planning α = .852, effort α = .880, self-monitoring α = .879, evaluation α = .847, reflection α = .758). The total score (global level of self-regulation) was calculated by adding the scores of the six questionnaire subprocesses.

Table 1
SRL microanalysis interviews applied in each phase of the study

Study phase	SRL phase	Self-regulatory subprocesses and questions from the semi-structured SRL microanalysis interviews
A1, A3	Forethought phase	• Goal setting: "When you do muscle-strengthening exercises, do you set yourself any specific goals? If so, could you describe that goal in detail and how you plan to achieve it?" • Planning: "What specific strategies or steps do you follow to ensure that muscle-strengthening exercises are performed correctly? How do you prepare to avoid possible difficulties?"
B1, B2	Performance phase	• Self-observation or metacognitive monitoring: "While performing muscular endurance exercises, what specific aspects do you focus on to ensure that you are performing them correctly?"
A2, A4	Reflection phase	• Self-evaluation: "How do you evaluate your performance after practicing muscular endurance exercises? What indicators or signs help you know whether you have achieved significant improvement?" • Causal attributions: "What factors do you attribute your performance in the exercises to? Do you think it is due to your effort, to the strategies you used or to some other aspect?" • Adaptive inferences: "Based on your current experience, what do you think you should change or improve to increase your performance in muscle-strengthening exercises in future sessions?"

Note. SRL = Self-regulated learning.

Qualitative information on students' use of strategies and cognitive processes was collected through contextualized SRL microanalysis interviews, using specific task-related questions asked while students participated in specific learning activities (Cleary & Russo, 2024). Based on the SRL model of Zimmerman and Moylan (2009), the SRL microanalytic questions were applied in the forethought, performance and reflection phases (Table 1). These procedures have been used to differentiate high- and low-performing students (Cleary et al., 2006; Kitsantas & Zimmerman, 2002) and have proven useful for obtaining qualitative information on students' cognitive processes. In this study, the authors collected information on the self-regulatory subprocesses of goal setting and planning in the forethought phase; self-observation or metacognitive monitoring in the performance phase; and self-evaluation, causal attributions and adaptive inferences in the reflection phase. The principal investigator defined the categories for each self-regulatory subprocess evaluated, based on previous research (Bujosa-Quetglas et al., 2025; Cleary & Russo, 2024). The reliability of the qualitative analysis was verified through double coding. A second researcher independently reviewed the category system and a sample of its application, obtaining initial agreement above 90%. The few discrepancies were resolved through discussion and consensus. The questions implemented in each phase of the study are detailed in Table 1.

Procedure

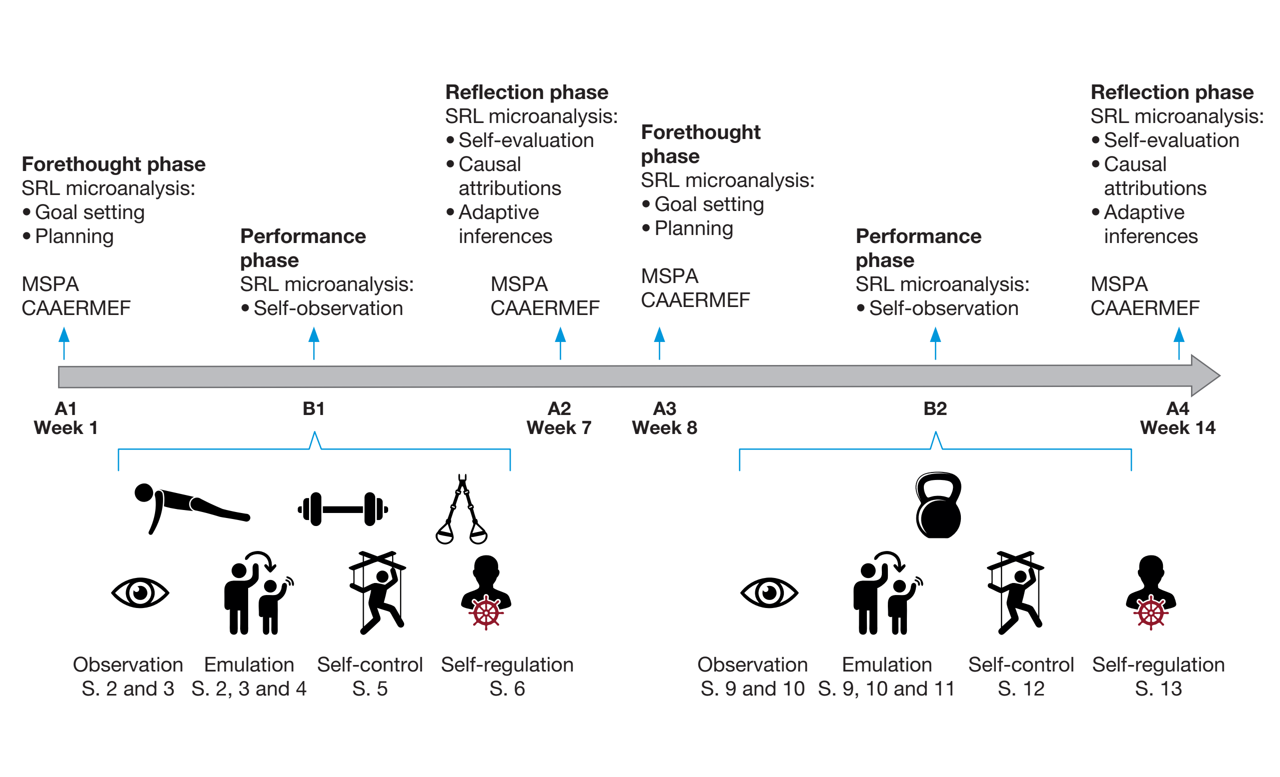
The research was approved by the Research Ethics Committee of the University of the Balearic Islands (ref. 384CER23) and had the informed consent of the school management team, the participating students and their legal representatives. The intervention was implemented by the principal investigator, a PE teacher with 22 years of experience at the school.

Data Collection

The data collection process was carried out at different moments of the intervention. In the A phases (A1, A2, A3 and A4), data were collected only by applying the CAAERMEF (Bujosa-Quetglas et al., 2024) and the question on MSPA practice from the European Health Interview Survey (EHIS-PAQ) (Finger et al., 2015). In turn, in A1 and A3, SRL microanalysis interviews focused on the forethought phase were conducted, while in A2 and A4 they focused on the reflection phase.

During the B phases (B1 and B2), the intervention program was implemented and SRL microanalysis interviews were applied, focused on the performance phase. Figure 1 details the duration of each phase of the study, the quantitative and qualitative instruments used in each one, and the levels of self-regulation development (Zimmerman & Kitsantas, 2005) implemented in each intervention session.

Figure 1
Phases of the study, instruments used and levels of self-regulation development implemented in each session



Note. MSPA = Muscle-strengthening physical activity; S = Session; SRL = Self-regulated learning; CAAERMEF = Self-Regulated Learning Questionnaire for Muscular Endurance Exercises in Physical Education.

Intervention Program

The "Self-Regulate Your Muscle Strengthening" intervention (phases B1 and B2 of the study; Table 2) was developed over 10 weeks, throughout 10 PE sessions (2 hours each), organized into two cycles of five sessions. The proposal combined explicit instruction (review of prior knowledge, presentation of content, initial practice, feedback, independent practice and periodic reviews (Rosenshine, 1983, cited in Metzler & Colquitt, 2021) with an approach aimed at developing self-regulation (Zimmerman & Kitsantas, 2005) in muscular endurance exercises (Kitsantas et al., 2018).

The sessions included four key components: (1) dynamic warm-up with cooperative games; (2) didactic progression adapted to SRL, from teacher-directed to more autonomous approaches, with modeling, guided practice, independent practice and autonomous routine design; (3) circuits, games and challenges for the development of muscular strength-endurance, using body weight, resistance bands, dumbbells and TRX in the first cycle, and *kettlebells* in the second cycle; and (4) relaxation with static stretching. Resources such as music, information cards and reciprocal teaching, self-evaluation and routine planning worksheets were used.

Data Analysis

To verify initial equivalence between the subgroups, pretest scores (A1) were compared using a one-way ANOVA, considering the three levels of MSPA (no practice, little practice and practice according to the WHO recommendations).

Quantitative data were obtained through the application of two mixed repeated-measures ANOVAs, where the MSPA subgroup acted as the between-participants factor and the evaluation time point (A1, A2, A3, A4) as the within-subject factor. The first model analyzed the evolution of the perceived MSPA, and the second analyzed the evolution of the total self-regulation score. Before interpreting the main models, the relevant statistical assumptions were checked, including normality and homogeneity of variances. The analyses were performed using jamovi software (version 2.6.26), and the results were presented as mean (M) and standard deviation (SD).

Qualitative data were collected through semi-structured interviews in the forethought (A1 and A3), performance (B1 and B2) and reflection (A2 and A4) phases, following Cleary and Russo's (2024) SRL microanalysis approach. The responses were transcribed, coded dichotomously (1 = present, 0 = absent) and analyzed with NVivo 14 to examine the frequency and evolution of the self-regulatory subprocesses.

Table 2
Description of the intervention

Level of SRL development	Purposes. Teaching style	Phase B1		Phase B2	
		Sessions	Material. Activities	Sessions	Material. Activities
Observation	Moderate intensity and emphasis on technique development Command style Oral instructions Demonstrations Modeling	1	Worksheets with key performance points 4 core ex. (with their 8 variants in total). 2 leg ex. (with their 6 variants in total)	6	Worksheets with key performance points: Deadlift (3 variants), Hip Thrust (3 variants), Superman Hold Over (3 variants)
		2	Worksheets with key performance points 5 arm ex. (with their 8 variants in total) 3 arm ex. (with their 7 variants in total)	7	Worksheets with key performance points: Bent Over Row (3 variants), Push Press (3 variants), Russian Twist (3 variants)
Emulation	Guided practice Acquiring the key points of each exercise Feedback from the teacher (task assignment; circuits sessions 1, 2, 6 and 7) Feedback from peers (reciprocal teaching; sessions 3 and 8)	1	8-station circuit: 4 core ex. (8 variants) 6-station circuit: 2 leg ex. (6 variants)	6	9-station circuit: Deadlift (3 variants), Hip Thrust (3 variants), Superman Hold Over (3 variants)
		2	8-station circuit: 5 arm ex. (8 variants) 7-station circuit: 3 arm ex. (7 variants)	7	9-station circuit: Bent Over Row (3 variants), Push Press (3 variants), Russian Twist (3 variants)
		3	Reciprocal teaching worksheets: 4 core ex (8 variants), 2 leg ex. (6 variants), 8 arm ex. (15 variants)	8	Reciprocal teaching worksheets: Deadlift (3 variants), Hip Thrust (3 variants), Superman Hold Over (3 variants), Bent Over Row (3 variants), Push Press (3 variants), Russian Twist (3 variants)
Self-control	Independent practice guided by goal setting (selection of exercise, sets, repetitions, etc.) Inclusion Self-evaluation	4	Self-evaluation worksheets. In pairs, choose and perform one variant of each exercise: 4 *core*, 2 leg and 8 arm exercises. Perform two sets: in the first, exceed your partner's repetitions (other-referenced goal). In the second, exceed your own previous repetitions (self-referenced goal)	9	Self-evaluation worksheets. In pairs, choose and perform one variant of each exercise with *kettlebells* (6). Perform two sets: in the first, exceed your partner's repetitions (other-referenced goal). In the second, exceed your own previous repetitions (self-referenced goal)
Self-regulation	Individual autonomous practice applying exercises learned to form one's personal strength-training routine Performance goals (variant, number of repetitions and sets) and monitoring Divergent discovery	5	Individually, using the exercise selection sheet, design and perform a personal exercise routine with body weight, dumbbells and TRX. The criterion for mastery is to complete 8 correct repetitions per exercise and follow the routine without distractions in a 14-station circuit (4 core, 2 leg, 8 arm). Choose the sequence, variant, sets and repetitions. Use the self-check worksheet to set goals and record your performance, focusing on the key points of each exercise (process goals)	10	Individually, using the exercise selection sheet, design and perform a personal exercise routine with kettlebells. The criterion for mastery is to complete 8 correct repetitions per exercise and follow the routine without distractions in a 6-station circuit. Choose the sequence, variant, sets and repetitions. Use the self-check worksheet to set goals and record your performance, focusing on the key points of each exercise (process goals)

Note. SRL = Self-regulated learning; ex. = exercises.

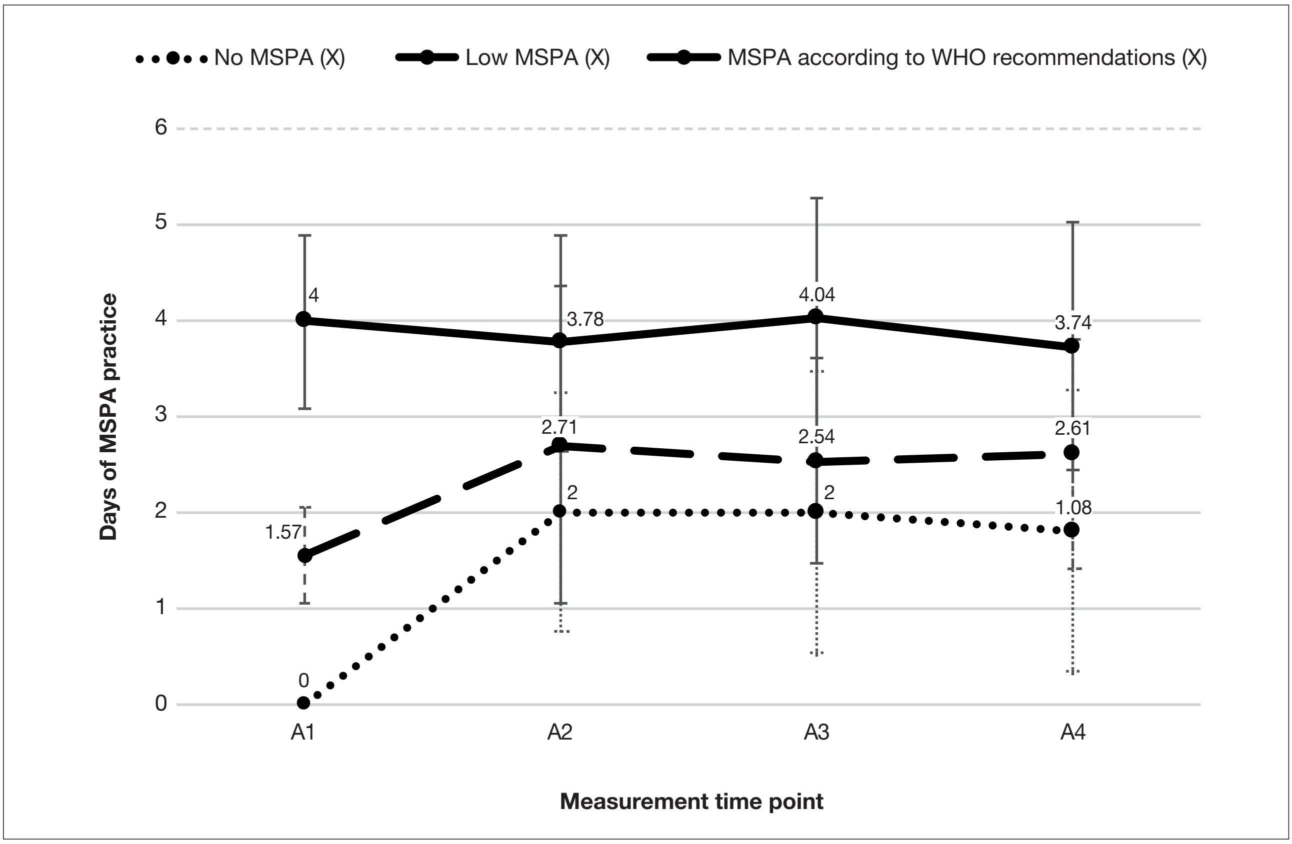
Chi-square tests were applied independently to identify significant differences in frequencies between the first cycle of the intervention (A1, B1 and A2) and the second (A3, B2 and A4), for the total sample (n = 61) and each of the three initial MSPA performance subgroups (no MSPA, n = 10; low MSPA, n = 28; and MSPA according to the WHO recommendations, n = 23). Previously, to meet statistical assumptions, the responses were regrouped into broad categories while respecting the self-regulatory subprocesses of the phases of Zimmerman and Moylan's (2009) SRL model. In the forethought phase, the categories of the goal-setting subprocess were grouped into process, outcome or other goals; in strategic planning, they were grouped into technical planning and general planning. In the performance phase, the self-observation subprocess was coded into self-observation of external references or guidelines; self-observation of pace, load and physical sensations; self-observation of performance; and self-observation of technique. In the reflection phase, causal attributions were regrouped into causal attribution of effort and concentration, of planning and class context, technical causal attribution, and causal attribution to external factors; the categories of the self-regulatory subprocess of self-evaluation were regrouped into self-evaluation of internal or external factors; finally, the categories of the self-regulatory subprocess of adaptive inferences were regrouped into behavioral adaptive inferences in practice, adaptive inferences of personal factors or absence of inferences.

Results

The one-way ANOVA applied to the pretest scores (n = 61) revealed no significant differences between the three subgroups according to their initial level of MSPA ($p > .05$), indicating a homogeneous baseline.

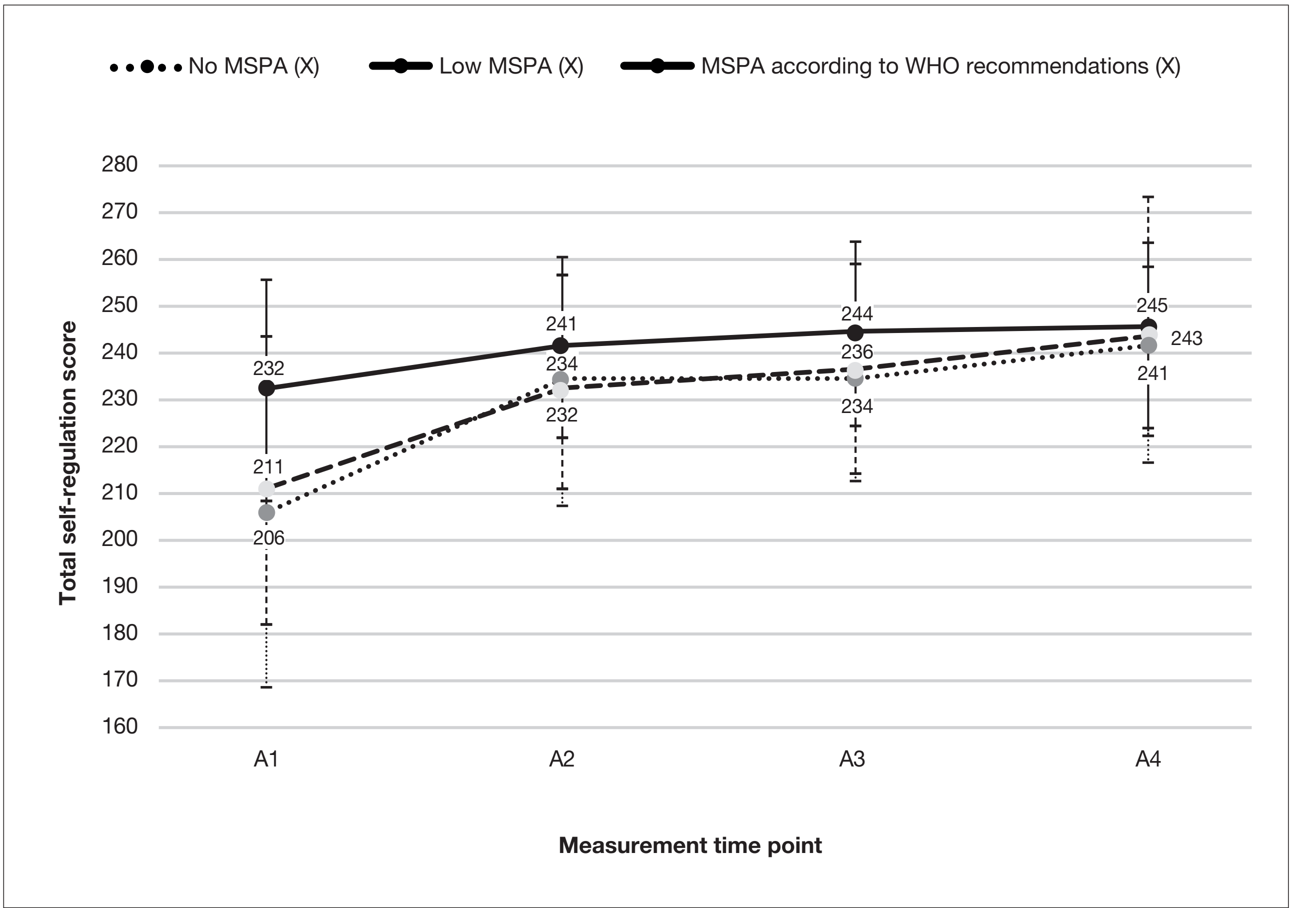
The repeated-measures ANOVA with perceived MSPA as the dependent variable (Figure 2) showed significant differences between time points and groups (F = 6.19; $p < .001$). The no MSPA group increased from 0 in A1 to 2 (± 1.25) in A2, 2 (± 1.49) in A3 and 1.80 (± 1.48) in A4. The low MSPA group increased from 1.57 (± 0.50) in A1 to 2.71 (± 1.65) in A2, 2.54 (± 1.07) in A3 and 2.61 (± 1.20) in A4. The group with MSPA according to WHO recommendations went from 4 (± 0.90) in A1 to 3.78 (± 1.13) in A2, 4.04 (± 1.26) in A3 and 3.74 (± 1.29) in A4.

Figure 2
Evolution of the perceived days of muscle-strengthening physical activity (MSPA) practice by group (no MSPA, low MSPA and MSPA according to WHO recommendations) and measurement time point



Note. A1 = pretest; A2 = posttest; A3 = follow-up 1; A4 = follow-up 2. Scores show the mean (0–7 scale) with error bars (± *SD*). Statistically significant differences were observed according to measurement time point and MSPA group ($p < .001$).

Figure 3
Evolution of perceived total self-regulation by group (no MSPA, low MSPA and MSPA according to WHO recommendations) and measurement time point



Note. A1 = pretest; A2 = posttest; A3 = follow-up 1; A4 = follow-up 2. Scores correspond to means from the repeated-measures ANOVA. Error bars represent the standard deviation. Significant differences were identified according to measurement time point and MSPA group ($p < .005$).

The repeated-measures ANOVA with the total self-regulation score as the dependent variable (Figure 3) reflected significant differences ($F = 3.87$; $p = .005$): the no MSPA group increased from 206 (± 37.3) in A1, to 234 (± 23.1) in A2, and from 234 (± 14.4) in A3, reaching 241 (± 17.2) in A4; the low MSPA group increased from 211 (± 28.9) in A1, to 232 (± 24.6) in A2, and from 236 (± 23.2) in A3, to 245 (± 28.3) in A4; finally, the high MSPA group evolved from 232 (± 23.7) in A1, to 241 (± 19.4) in A2, and from 244 (± 19.8) in A3 to 243 (± 20.6) in A4.

Table 3 shows the frequency of the self-regulatory subprocesses of the forethought phase (goal setting and planning) obtained at two time points of the intervention (phases A1 and A3), according to the subgroups of initial MSPA performance.

No significant differences were observed in goal setting between phases A1 and A3 for the whole sample ($\chi^2(2) = 1.45$, $p = .484$, $n = 82$), nor in the subgroups: no MSPA: $\chi^2 = 1.23$, $p = .542$; low MSPA: $\chi^2 = 0.66$, $p = .719$; and MSPA according to WHO recommendations: $\chi^2 = 0.62$, $p = .732$. No differences were found in strategic planning between phases A1 and A3 either, for the whole sample ($\chi^2(1) = 0.089$, $p = .765$), nor by subgroups: no MSPA: $\chi^2 = 2.49$, $p = .114$; low MSPA: $\chi^2 = 0.354$, $p = .552$; and MSPA according to WHO recommendations: $\chi^2 = 0.431$, $p = .212$.

Table 4 shows the frequency of the self-regulatory subprocesses of the performance phase (self-observation or metacognitive monitoring) obtained at two time points of the intervention (phases B1 and B2), according to the subgroups of initial MSPA performance.

Table 3
Frequencies of goal-setting and strategic planning attributions in the forethought phases of the intervention (A1 and A3), according to initial MSPA performance subgroup

Categories of self-regulatory subprocesses in the forethought phase		No MSPA		Low MSPA		MSPA according to WHO	
Grouped	Initial	A1	A3	A1	A3	A1	A3
Process goals	Specific process goal	2	0	3	1	5	0
	General process goal	5	6	4	5	2	5
Outcome goals	Specific outcome goal	2	4	0	1	3	3
	General outcome goal	6	2	4	5	2	3
Other goals	Goal of seeking external assistance and feedback	0	1	0	0	2	1
	Goal of using external visual references	0	0	0	2	0	0
	Goal of visualization or mental imagery	0	0	1	0	0	0
	No goal	0	0	0	0	0	0
	Goals of aesthetic improvement and long-term health	0	0	0	0	0	1
	Other goals	0	0	0	0	0	0
	Goals related to physical sensation and subsequent effects	0	0	0	0	0	1
General planning	No planning	1	0	1	0	2	1
	Other types of planning	1	0	0	0	0	0
	Planning to request help	1	1	0	1	1	2
	Visualization planning	2	3	4	3	1	0
Technical planning	Planning of performance pace	2	1	0	1	0	0
	Planning of specific techniques	0	3	1	2	2	3
	Planning of general techniques	6	7	5	5	7	9

Note. MSPA = Muscle-strengthening physical activity; WHO = World Health Organization.

Table 4
Frequencies of self-observation attributions in the performance phases of the intervention (B1 and B2), according to initial MSPA performance subgroup

Categories of self-regulatory subprocesses in the performance phase		No MSPA		Low MSPA		MSPA according to WHO	
Grouped	Initial	B1	B2	B1	B2	B1	B2
Self-observation of external references or guidelines	Self-observation of external references or guidelines	5	7	1	3	0	2
Self-observation of pace, load and physical sensations	Self-observation of pace, speed and load	0	1	0	1	0	1
	Muscular or sensory self-observation	4	1	3	2	4	4
Self-observation of performance	Self-observation of specific performance	0	0	1	1	1	1
	Self-observation of general performance	1	0	2	2	0	0
Self-observation of technique	Self-observation of specific technique	3	1	3	3	4	4
	Self-observation of general technique	4	2	5	2	2	3

Note. MSPA = Muscle-strengthening physical activity; WHO = World Health Organization.

Table 5
Frequencies of causal attributions, self-evaluation and adaptive inferences in the reflection phases of the intervention (A2 and A4), according to initial MSPA performance subgroup

Categories of self-regulatory subprocesses in the reflection phase		No MSPA		Low MSPA		MSPA according to WHO	
Grouped	Initial	A2	A4	A2	A4	A2	A4
Causal attribution of effort and concentration	Causal attribution of concentration	0	0	0	1	0	0
	Causal attribution of effort	1	3	2	2	0	0
Causal attribution of planning and class context	Causal attribution of planning or routine adequacy	3	1	1	0	0	0
	Causal attribution of class practice	0	1	3	1	4	3
Causal attribution of technique	Causal attribution of technique	3	4	2	3	2	2
Self-evaluation of external factors	Self-evaluation of other factors	6	5	2	2	0	5
	Self-evaluation of others' performance	1	0	0	0	0	0
Self-evaluation of internal factors	Self-evaluation of personal improvement during practice	0	0	1	1	0	0
	Self-evaluation of one's own performance in repetitions and sets	0	2	2	1	5	0
	Self-evaluation of physical sensations and fatigue	0	1	1	2	1	1
	Self-evaluation of personal use of appropriate strategies	0	0	1	0	0	0
Adaptive inferences of personal factors	Adaptive inferences of concentration	0	0	0	0	1	0
	Adaptive inferences of effort	2	1	0	0	0	0
Behavioral adaptive inferences in practice	Adaptive inferences of routine adjustment	4	6	4	4	4	1
	Adaptive inferences of class practice	0	0	0	0	0	0
	Adaptive inferences of technique	1	0	3	2	0	1
No adaptive inferences	No adaptive inferences	1	1	0	1	1	4

Note. MSPA = Muscle-strengthening physical activity; WHO = World Health Organization.

No significant differences were found in the observation categories for the whole sample (χ^2 total = 3.11, p = .375), nor by subgroups (no MSPA: χ^2 = 2.82, p = .420; low MSPA: χ^2 = 1.66, p = .646; MSPA according to WHO recommendations: χ^2 = 1.61, p = .657).

Table 5 shows the frequency of the self-regulatory subprocesses of the reflection phase (causal attributions, self-evaluation and adaptive inferences) obtained at two time points of the intervention (phases A2 and A4), according to the subgroups of initial MSPA performance.

Causal attributions showed no significant differences in the total sample ($\chi^2(2)$ = 2.72, p = .257), nor in the no MSPA ($\chi^2(2)$ = 1.11, p = .574) and low MSPA ($\chi^2(2)$ = 2.14, p = .343) subgroups. In the subgroup with MSPA according to WHO recommendations, the analysis could not be performed due to the presence of empty cells.

No significant differences were found in self-evaluation in the total sample ($\chi^2(1)$ = 0.90, p = .342), nor in the no MSPA ($\chi^2(1)$ = 3.28, p = .070) and low MSPA ($\chi^2(1)$ = 0.03, p = .853) subgroups. By contrast, the subgroup meeting WHO recommendations for MSPA showed a significant change ($\chi^2(1)$ = 8.57, p = .003), shifting from self-evaluations focused on internal factors in A2 to evaluations based on external factors in A4.

Regarding adaptive inferences, no significant differences were observed either overall ($\chi^2(2)$ = 3.13, p = .209) or in the no MSPA ($\chi^2(2)$ = 0.42, p = .809) and MSPA according to WHO recommendations ($\chi^2(2)$ = 3.47, p = .177) subgroups. In the low MSPA subgroup, it was not possible to perform the analysis due to the absence of cases in some categories.

Discussion

This study implemented and evaluated the impact of a pedagogical intervention based on the integration of explicit teaching and a sequential model of self-regulation, aimed at adolescents in PE. The main findings showed a significant improvement in the frequency of MSPA and in overall self-regulation, particularly in students with lower initial levels of MSPA. Qualitatively, only the group that met the WHO recommendations for MSPA showed changes in the reflection phase, changing its self-evaluations from internal factors to external factors.

These results derive from an intervention that combined a direct and systematic instructional sequence (Rosenshine, 1983, cited in Metzler & Colquitt, 2021) with the progressive development of self-regulation through Zimmerman and Kitsantas's (2005) four-level model, applied to strength-endurance tasks (Kitsantas et al., 2018). This methodological integration facilitated the learning of key strength-endurance skills (such as technique, effort control and progression) through modeling, guided practice and autonomous performance (Wheldall et al., 2014), while promoting student autonomy through the metacognitive and motivational development inherent to the self-regulatory cycle (Zimmerman & Moylan, 2009).

The research design used (mixed-methods) made it possible to address in a complementary way both the quantitative effects of the intervention on self-regulation and MSPA practice, and the qualitative processes involved in how students experienced and made sense of their SRL in a real educational environment. In this regard, Kermarrec et al. (2022) state that mixed approaches to SRL in PE offer greater interpretive richness by integrating observable performance with the way students understand and value their learning.

These findings support the efficacy of the sequential model of self-regulation development (observation, emulation, self-control and self-regulation) proposed by Zimmerman and Kitsantas (2005) as an effective pedagogical approach to fostering the gradual development of SRL and its transfer to MSPA practice outside the school setting. In particular, the improvement observed in students with less initial MSPA experience supports the usefulness of scaffolding and direct instruction as key strategies for facilitating access to essential knowledge in PE, necessary for engaging in physically active lifestyles. As Cale and Harris (2018) note, without adequate knowledge and understanding, people are unlikely to be able to make informed decisions about PA or participate in it in a meaningful and sustainable way.

This evidence partially coincides with previous studies reporting benefits of the developmental model of SRL in the context of a PE class group, in which multiple skills and games are developed. In particular, the study by Susaki (2021) analyzed the effects of an intervention based on the sequential model of SRL on motor skills, learning strategies and self-efficacy, applied in PE classes focused on soccer-specific motor skills. It reported significant improvements in dribbling skills ($p = .01$, $\eta^2 = .16$) and evaluation strategies ($p = .01$) in university students with low initial performance. Likewise, the study by Sproule et al. (2017) evaluated the effect of an intervention, based on Zimmerman and Kitsantas's (2005) 4-level model of self-regulation, in PE students in Taiwan, measuring changes in motivation, learning strategies and self-regulation. The intervention improved goal setting, and the application and monitoring of self-regulatory strategies, with variable effects according to prior experience, confirming the value of progressive and adapted interventions for strengthening self-regulation in PE.

Along similar lines, in the area of promoting PA habits, Calkins (2015) noted that the development of SRL significantly increased students' use of self-regulatory strategies and improved their muscular endurance, underscoring the pedagogical value of integrating these strategies into the secondary PE curriculum. Along the same lines, the recent study by Li et al. (2023) showed that a PE course based on SRL produced significant improvements in all dimensions of physical literacy (cognition, skill, experience and behavior), reinforcing the value of this approach for promoting sustainable and autonomous PA habits in university students.

The study suggests that integrating two complete cycles of the self-regulatory process (forethought, performance and reflection phases) enhances the effect of the intervention on self-regulation and MSPA practice. These results coincide with Cleary et al. (2006), who showed a progressive improvement in motor performance when multiple phases were addressed, underscoring the greater effectiveness of programs that integrate them comprehensively.

Although no significant changes were observed in the overall frequency of the self-regulatory subprocesses between the two intervention cycles (A1, B1, A2 vs. A3, B2, A4), the subgroup that met the WHO recommendations for MSPA showed significant development in its self-evaluation ($\chi^2 = 8.57$, $p = .003$), shifting from internal to comparative judgments. This pattern differs from that observed by Cleary et al. (2006), who found an increase in process-oriented self-evaluations in controlled settings. The differences could be attributed to contextual and methodological factors. Whereas the study by Cleary et al. (2006) focused on simple tasks such as free throws in basketball, this research was conducted in group PE classes with more complex activities such as the design of muscular endurance routines, which could explain a more contextualized, though less introspective, form of self-regulation.

This work is in line with the body of studies that implement instruction in PE grounded in the social-cognitive perspective of SRL, which emphasizes the dynamic interaction between cognitive, motivational and contextual processes that influence learning and PA practice (Hendrayana, 2010; Calkins, 2017; Kolovelonis & Goudas, 2014). This approach recognizes that the development of SRL in PE involves not only the acquisition of motor skills, but also the strengthening of metacognition, self-efficacy and students' ability to plan, monitor and adjust their own learning in real and socially contextualized environments.

The study supports the efficacy of explicit teaching oriented toward the development of self-regulation for increasing MSPA practice in adolescents. It also expands the evidence on the effectiveness of the model proposed by Zimmerman and Kitsantas (2005), whose sequential progression in phases (observation, emulation, self-control and self-regulation) guided the intervention and favored improvements both in MSPA performance and in students' active involvement in their learning process.

Regarding the limitations of the study, the absence of a control group should be highlighted, which suggests caution when generalizing the results. Future research should consider experimental designs with parallel groups, extend the follow-up period and further explore the contextual factors that influence the effectiveness of self-regulatory strategies, including the motivational climate in the classroom, the level of autonomy promoted by the teacher, or students' socioeconomic characteristics. It would be relevant to compare this intervention with other active methodologies, such as cooperative learning, sport education or challenge-based learning, to assess their impact on self-regulation and muscle-strengthening habits. Furthermore, it is recommended to explore the potential of formative feedback and educational technologies (such as mobile applications or tutorial videos) as support for fostering self-regulation in the practice of strength-endurance exercises, both in school and out-of-school settings.

On the other hand, measurement of MSPA was based on weekly self-reports, which may be subject to biases such as social desirability or inaccurate recall. Although this limitation is relevant, there are currently no validated instruments that more precisely measure the frequency, intensity, duration or type of MSPA in adolescents (Bennie et al., 2022).

Conclusion

The pedagogical intervention, based on a structured combination of explicit instruction and a progressive model of self-regulation, proved effective in increasing muscle-strengthening habits and self-regulation capacity in adolescents within the PE context. This approach was particularly beneficial for students with lower initial MSPA practice, underscoring its potential to promote equity and adherence to PA through PE. Consequently, the integration of this hybrid approach (explicit instruction and progressive development of self-regulation) into PE programs is proposed as a viable strategy to foster student autonomy and sustainable strength-endurance habits beyond the school context.

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PHYSICAL EDUCATION

Enhancing Critical Thinking and Resilience in a Teacher Education Master's Program

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Artistic swimmers performing a synchronized figure with technical precision and postural control.
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Abstract

This study analyzes the effects of a gamification project inspired by the television series *Black Mirror* to evaluate critical thinking, resilience, and social and emotional skills in students enrolled in a Master's in Education program (concentration in physical education). The idea arose from the need to address emotional and educational challenges during the college years, particularly in the training of future teachers, who must acquire solid social and emotional skills to manage complex educational situations. The intervention included a sample of 26 students, a quasi-experimental design, and pre- and post-intervention measurements. The project also featured an ad hoc mobile application designed to provoke the same feelings and emotions as those portrayed in the "Nosedive" episode of *Black Mirror*, a fundamental aspect in any gamification project. The results showed statistically meaningful improvements in all the dimensions of critical thinking, with especially strong effects in recognition of assumptions and in the overall score. Some 96% of the students also increased their initial resilience score. Regarding emotional intelligence, more than half of the students shifted from having low or excessive attention to feelings to more adequate levels, although no meaningful changes were detected in the "clarity" or "emotional regulation" variables. These findings support the value of meaningful narratives, technological resources, and student-centered strategies in fostering the development of teaching skills that can be applied to their future teaching careers.

Keywords: critical thinking, emotional intelligence, gamification, higher education, resilience

Introduction

Education systems have recently undergone various structural and pedagogical transformations that often do not prioritize the emotional needs of students (Peña-Casares & Aguaded-Ramírez, 2019). In this sense, it is essential to restore the importance of emotional intelligence, as it is one of the main predictors of both academic and professional success (Menéndez, 2018). The college years are a crucial period for developing these social and emotional skills, as this environment involves academic and social adaptation challenges that require effective strategies and openness to creative solutions (Raj et al., 2022). In fact, college students were one of the most vulnerable groups to the consequences of the pandemic (Browning et al., 2022), which had a negative impact on their mental health, as evidenced in higher levels of anxiety, stress, and mood disorders (Charles et al., 2021).

With this in mind, it is essential to provide students with tools that foster the development of cross-cutting skills and competencies related to problem-solving and adaptation to change, as these are highly transferable to their personal and professional lives (Bezanilla et al., 2021). This need is even more pronounced in the training of future teachers, since developing emotional intelligence-related strategies not only impacts their well-being but also strengthens their motivation and professional commitment (Paraguay-Delgado & Teves-Quispe, 2024; Rabal-Alonso & González-Romero, 2023). Within the development of emotional intelligence as a whole, we focus on three social and emotional skills or competencies: attention to feelings, clarity, and emotional regulation. Attention to feelings refers to the ability to identify and recognize emotions or feelings; clarity refers to the ability to understand and describe one's own emotions; and emotional regulation refers to the ability to control emotions, both positive and negative, which may be experienced with varying degrees of intensity (American Psychological Association, 2018). Emotional regulation is also associated with the ability to flexibly and consciously modulate emotional responses, which entails dynamic adaptation (Gross, 2015). This involves evaluating one's experiences and developing the ability to respond to them, preparing individuals to act in diverse situations (Cole et al., 2004). Research such as that by Fernández-Martínez et al. (2017) or You (2016) have explored the connection between emotional regulation, resilience, and students' commitment to learning, concluding that students with greater resilience are more committed, and consequently perform better academically. Resilience, which is conditioned by psychological, physiological, and sociological factors, is an essential resource for adaptively coping with adverse situations (Chen & Bonnano, 2020; Valverde-Janer et al., 2023).

Together with social and emotional skills, critical thinking is another fundamental ability during this stage and is understood as the ability to examine, draw logical conclusions, question, and organize information effectively (Eales-Reynolds et al., 2013). This skill is key to problem-solving in different contexts and is essential for analyzing the veracity of information and making important decisions (Karakuş, 2024). Not only cognitive abilities are important, but also the willingness to think critically; that is, the internal motivation to use reasoning, question assumptions, and evaluate objectivity (Yilmaz & Salman, 2022).

To meet these educational demands, we must foster students' autonomy, self-awareness, decision-making, and emotion management (Muntaner-Guasp et al., 2020), while promoting methodological approaches in which teachers facilitate learning and students remain the true protagonists (Hailikari et al., 2022). In this vein, scientific research shows that when gamification incorporates the diverse pillars and triggers required for its implementation (Pérez-López & Navarro-Mateos, 2023), it has strong potential to foster both resilience and emotional intelligence in higher education settings (Navarro-Mateos et al., 2024; Pérez-López et al., 2025).

Thus, with the aim of fostering the development of skills that are fundamental in the early stages of future teacher training, such as critical thinking, resilience, and attention to feelings, we conducted a gamification project with a group of Master's in Education students.

Implementation of the Experience

The gamification project was based on the television series *Black Mirror*. This choice was made, on the one hand, because of the educational value of the series, which consistently questions the ethical implications of the use of technology, and, on the other hand, because of its relevance to the students, as previously identified through a survey of their interests.

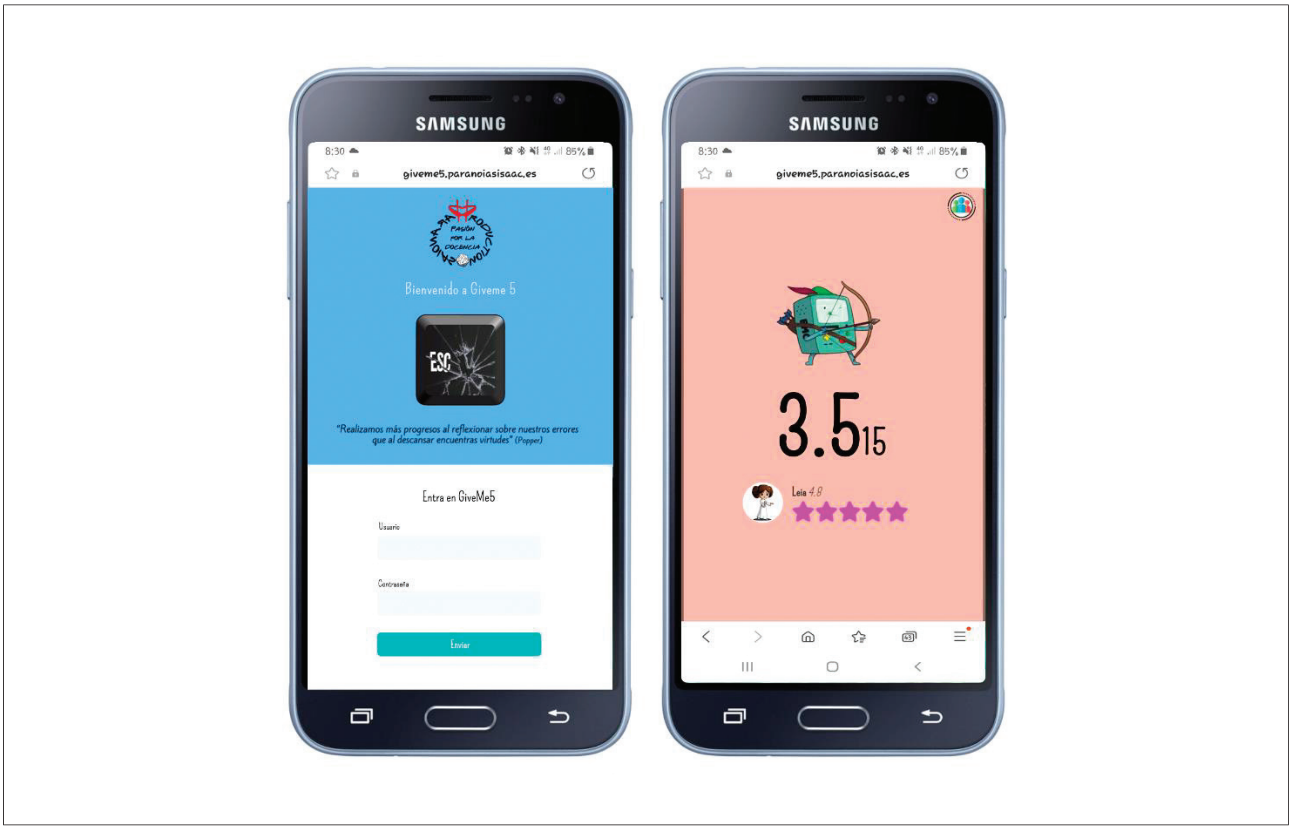
The course content and skills were connected to various episodes of *Black Mirror*, with each class starting with a clip from an episode to encourage reflection and a subsequent debate among the students. The theme of the project was inspired by the first episode of season three, titled "Nosedive". This episode presents a world in which social ratings recorded in a mobile application determine status and access to opportunities. In this world, people are continuously rated via their smartphones, with every social interaction rated from one to five stars. To recreate the emotions and feelings experienced in the episode, which is one of the fundamental pillars of gamification according to Model 10-40 (Pérez-López & Navarro-Mateos, 2023), an ad hoc application similar to the one used in the episode was designed for the project (Figure 1). Using their smartphones, students rated their classmates based on the quality of their contributions in class, the presentation of the training challenges they completed, and their interactions with one another (inside and outside the classroom). The ratings were anonymous, meaning that only the recipient could view them. The ratings also impacted the course, as they determined the students' options for choosing their partner, date, and topic for the practical session they had to prepare; they also provided advantages when completing the educational challenges available to them. As a result, this created a tense, high-pressure atmosphere that tested the group's emotional skills, promoting emotional regulation and, in many cases, resilience. At the same time, it helped the students become fully immersed in the narrative by faithfully recreating what the protagonists in the episode experienced. Using fiction as a basis for reality, we created a real-life setting in which to develop critical thinking for future transfer to teaching roles. The wide range of situations that arose from the ratings given and received by the participants (and the reasons behind them) led students to question their appropriateness, as well as the reactions they elicited in their classmates, not only from a theoretical perspective but also through their own personal experience.

Method

Study Design and Sample

This study was framed within the positivist paradigm of research and used a quantitative approach, as it focused on the objective evaluation of an innovative educational intervention targeting critical thinking, resilience, and social and emotional skills (attention to feelings, clarity, and emotional regulation). The study employed a one-group quasi-experimental design with pre- and post-measurements and evaluated the impact of a gamification activity based on the television series *Black Mirror*, comparing the students' results before and after the intervention. Quasi-experimental designs are common in action research studies, in real-life classroom settings with a natural, non-randomized group.

Figure 1
Application created for the project



The sample included 26 students from the Master's in Education program (group 3), consisting of 12 women and 14 men. All students were enrolled in the course "Learning and Teaching Physical Education" which is part of the Master's in Secondary Education, Teaching Training, and Language Teaching (Physical Education concentration) at the University of Granada. The study's ethical standards were ensured through an approved informed consent process that guaranteed participant confidentiality and anonymity (University of Granada Human Research Ethics Review Committee, approval code 5268/CEIH/2025).

The main objectives of the course included developing the fundamental skills of a physical education teacher; learning and analyzing the curricular elements of physical education; planning and evaluating from a critical perspective; and demonstrating the acquisition of essential practices for developing effective teaching strategies.

Study Variables

Critical thinking

We used the validated Critical Thinking Questionnaire (Zaldívar, 2010), which has demonstrated adequate reliability and internal consistency in the Spanish population (Cronbach's α = .81). The questionnaire consists of 20 items rated on a Likert scale ranging from 1 ("Never") to 6 ("Always"). Three well-defined dimensions of critical thinking were derived from the 20 items: recognition of assumptions (taking information as true in view of a future action, as a product of reflection on the environment), evaluation of arguments (distinguishing between the ability to narrate, express, and argue with consistent ideas versus weak arguments, without deviating from the topic when responding), and interpretation (understanding reality based on conclusions drawn beyond reasonable doubt and identifying solutions to problems). The total score was calculated by summing the items within each dimension.

Resilience

The Spanish version of the 10-item Connor-Davidson Resilience Scale (CD-RISC 10) (Connor & Davidson, 2003; Notario-Pacheco et al., 2011) was used to assess university students' resilience. This questionnaire has demonstrated acceptable reliability (Cronbach's α = .85) and high internal consistency, with an intraclass correlation test-retest coefficient of .71 when validated in Spanish population (Notario-Pacheco et al., 2011). The questionnaire consists of 10 items rated on a 5-point Likert scale ranging from 0 ("Never") to 4 ("Almost Always"). The resilience variable was calculated based on the sum of the scores of the 10 items, resulting in a range from 0 to 40 points, with higher score indicating higher levels of resilience.

Emotional intelligence

We used the Spanish version of the Trait Meta-Mood Scale (TMMS) to measure students' emotional intelligence (Fernandez-Berrocal et al., 2004; Salovey et al., 1995). This questionnaire has been validated in a Spanish sample and has demonstrated adequate reliability and internal consistency (Cronbach's α = .90). It consists of 24 items rated on a 5-point Likert scale ranging from 1 ("Strongly disagree") to 5 ("Strongly agree"). The 24 items were divided into 3 dimensions of 8 items each: attention to feelings (the ability to identify and recognize one's own feelings), clarity of feelings (the ability to understand and clearly describe one's own feelings), and emotional regulation or repair (the ability to control one's own emotions, both positive and negative). The scores for each dimension ranged from 8 to 40 points (summatory). For this study, a three-category variable was calculated for each dimension of emotional intelligence, with different cutoff points for women and men. Accordingly, attention to feelings was classified as "low," "adequate," or "excessive," whereas clarity and emotional regulation were each classified as "low," "adequate," or "excellent."

Statistical Analysis

The descriptive characteristics of the sample are presented based on to the pre-intervention measurements and are expressed as means and standard deviations (*SDs*) for continuous variables and as frequencies and percentages for the categorical variables. Prior to the inferential analyses, the normality of the dependent variables was assessed through visual inspection of histograms and the Kolmogorov-Smirnov test (Lilliefors, 1967). Since the variables followed a normal distribution, Student's *t*-test for related samples and the McNemar-Bowker test (Bowker, 1948) were used to examine the effect of the *Black Mirror* intervention on continuous and categorical variables, respectively.

Specifically, Student's *t*-test was used to examine pre- and post-intervention differences in the different dimensions of critical thinking, as well as in resilience. In addition to *p* values, effect sizes were reported using Cohen's *d* to evaluate the practical relevance of the observed changes. According to the conventional criteria (Cohen, 1988), values close to 0.2 indicated a small effect, values around 0.5 indicated a medium effect, and values of 0.8 or higher indicated a large effect.

For the ordinal categorical variables corresponding to the dimensions of emotional intelligence (attention, clarity, and regulation), the McNemar-Bowker test was used to evaluate the pre- and post-intervention changes in the distribution of frequencies across categories (e.g., between low, adequate, and excessive categories for the attention to feelings dimension). All statistical analyses and graphs were performed using *RStudio* software (v2023.12.1 + R 4.4.3, R Foundation for Statistical Computing, Vienna, Austria).

Results

Table 1 presents the descriptive characteristics of the total sample, segmented by sex. The only dimension that showed a significant difference between sexes (p = .039) in the pre-intervention assessment was emotional clarity, from the emotional intelligence questionnaire.

Figure 2 presents the changes in the dimensions of critical thinking and in overall critical thinking after participating in the *Black Mirror*-based gamification activity. Student's t-test analysis for related samples showed meaningful improvements in all dimensions of critical thinking after the intervention, as well as in overall critical thinking (all $p < .001$). The largest effect size was found for the recognition of assumptions dimension, with students reporting an initial score of 26.7 ± 2.0 which increased to 32.1 ± 3.6 (t = 12.6; $p < .001$; d = 2.5), and for overall critical thinking, with students reporting an initial score of 73.3 ± 4.82 which increased to 86.4 ± 6.4 (t = 11.8; $p < .001$; d = 2.3). A large effect size was also observed for the evaluation of arguments dimension (pre-score = 13.8 ± 2.4, post-score = 18.0 ± 2.2; t = 7.6; $p < .001$; d = 1.5), and for interpretation (pre-score = 12.4 ± 1.6, post-score = 14.6 ± 1.8; t = 4.4; $p < .001$; d = 0.9). In terms of descriptive statistics, 100% of the students improved their pre- post-intervention scores in the recognition of assumptions dimension and in overall critical thinking, 92.3% (24 out of 26) improved their scores for the evaluation of arguments dimension, as did 70% (18 out of 26) in the interpretation dimension. The item-by-item analysis (Supplementary Figure 2) revealed that, within the recognition of assumptions dimension, the items showing the greatest post-intervention improvement were item 17 ("Sometimes I think about my own thoughts and question them") and item 15 ("I try to maintain an overall attitude of critical thinking") with a difference of 1.5 points. These findings suggest that the gamification project based on *Black Mirror* encouraged the students to adopt a more reflective attitude and to question their own ideas and beliefs, which is a key aspect of self-reflection. In the evaluation of arguments dimension, item 1 ("I question the veracity of opinions that many people accept as true") and item 5 ("Being objective is 'cold'; it is better to let your feelings guide you") showed the greatest improvement (1 point), indicating an increasing tendency among participants to think skeptically and analytically about the information they receive, as well as to prioritize critical reasoning over emotions when making judgments. Finally, in the interpretation dimension, item 3 ("I try to find the truth rather than be right") showed the greatest change (1 point), indicating that participants shifted toward prioritizing rigorous analysis and openness to new evidence rather than reaffirming their prior opinions.

Table 1
Descriptive characteristics of the total sample segmented by sex from the gamification project based on Black Mirror

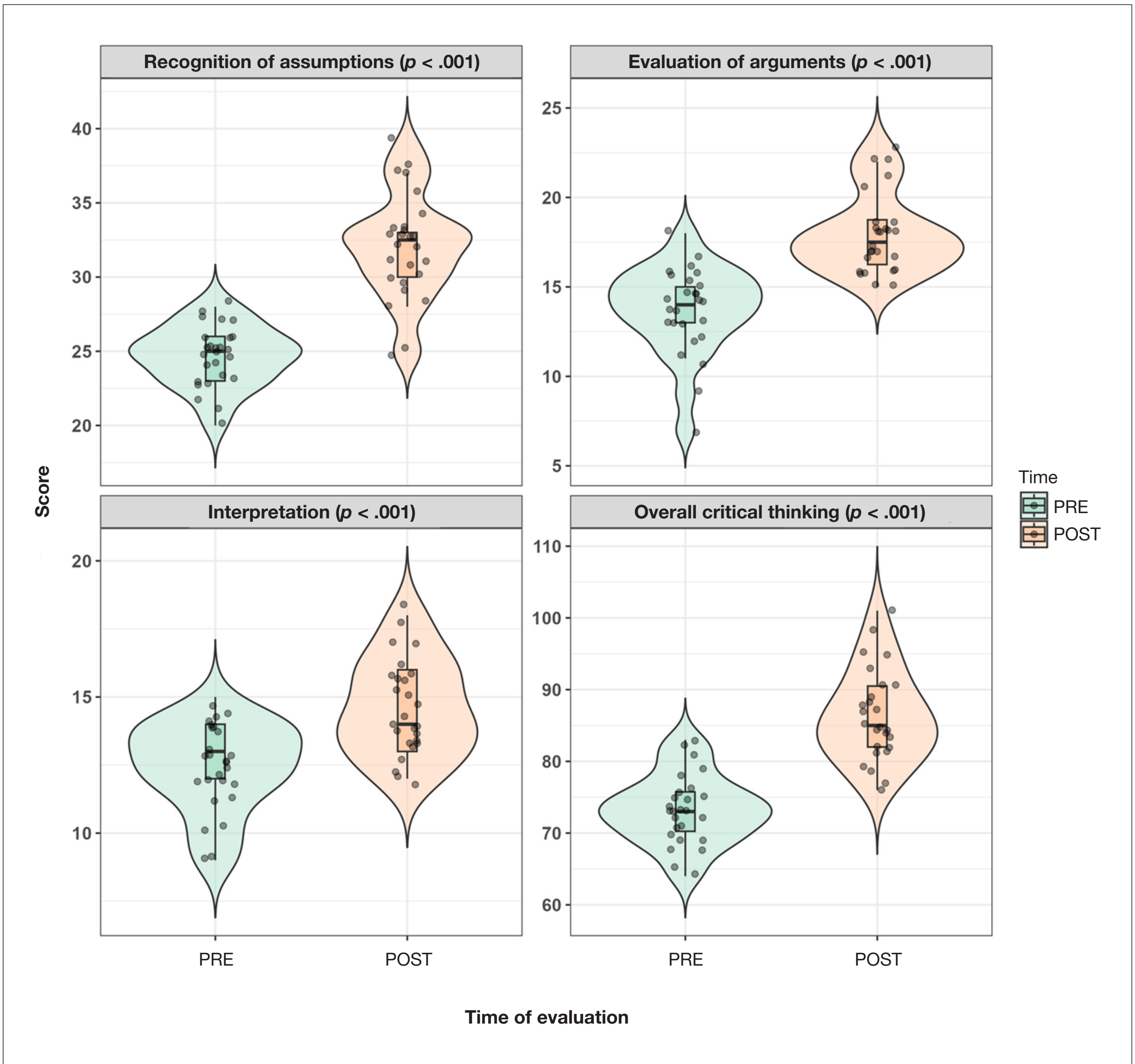
	Total (N = 26)	Female (n = 12)	Male (n = 14)	p-sex
	Mean ± *SD*	Mean ± *SD*	Mean ± *SD*	
Age ± years	23.17 ± 1.89	23.74 ± 2.67	22.68 ± 0.53	.203
Critical thinking				
Recognition of assumptions [7 - 42]	24.65 ± 2.02	23.92 ± 1.73	25.29 ± 2.09	.080
Evaluation of arguments [4 - 24]	13.77 ± 2.44	13.08 ± 2.64	14.36 ± 2.17	.198
Interpretation [3 - 18]	12.42 ± 1.63	12.92 ± 1.62	12.00 ± 1.57	.158
Overall critical thinking [20 - 120]	73.27 ± 4.82	71.83 ± 2.79	74.50 ± 5.88	.147
Resilience [0 - 40]	23.62 ± 3.94	24.67 ± 3.92	22.71 ± 3.87	.215
Emotional intelligence				
Attention to feelings [8 – 40]	28.85 ± 5.71	29.17 ± 7.09	28.57 ± 4.47	.805
Clarity [8 – 40]	28.69 ± 2.91	27.42 ± 2.97	29.79 ± 2.46	.039
Regulation [8 – 40]	26.85 ± 4.56	25.50 ± 4.40	28.00 ± 4.52	.167

*Note.*The values are expressed as mean ± standard deviation (*SD*). The minimum and maximum scores for each variable are listed inside the square brackets ([ ]). The p value refers to the comparison between sexes using Student's t-test.

The project also had a significant effect on the students' reported resilience levels, which increased from 23.6 ± 3.9 before the intervention to 30.5 ± 2.6 after the experience (Figure 3; $t = 9.6$, $p < .001$, $d = 1.9$). Specifically, 96.2% of the students (25 out of 26) improved their initial scores.

In terms of emotional intelligence, the McNemar-Bowker test was used to analyze changes in the distribution of the students' responses across categories (low, adequate, and excessive/excellent) for each dimension. As shown in Figure 4, the *Black Mirror*-inspired educational activity had a significant effect on the attention to feelings dimension (McNemar-Bowker $\chi^2 = 13.0$, $p = .005$). Specifically, more than half of the students (54%) improved from reporting either low or excessive attention to feelings before the intervention to reporting adequate attention after participation. No significant changes were found across response categories in the clarity and emotional regulation dimensions (both $p > .050$).

Figure 2
Pre- and post-intervention differences in the dimensions of critical thinking and overall score

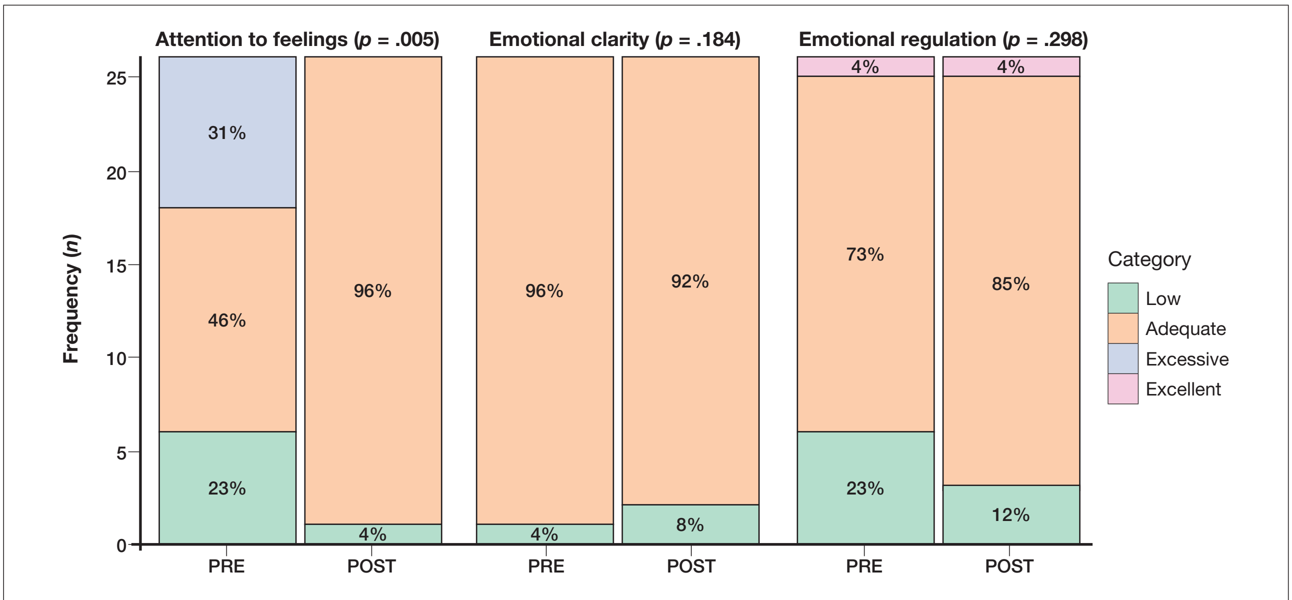


Note. The gray dots represent the individual scores pre- and post-intervention for the dimensions of critical thinking and the overall score. The box indicates the interquartile range, the bold horizontal line represents the median, and the vertical lines (whiskers) represent the minimum and maximum values. The statistical analysis was conducted using Student's *t*-test for related samples.

Figure 3
*Differences in resilience between pre- and post-*Black Mirror *intervention*

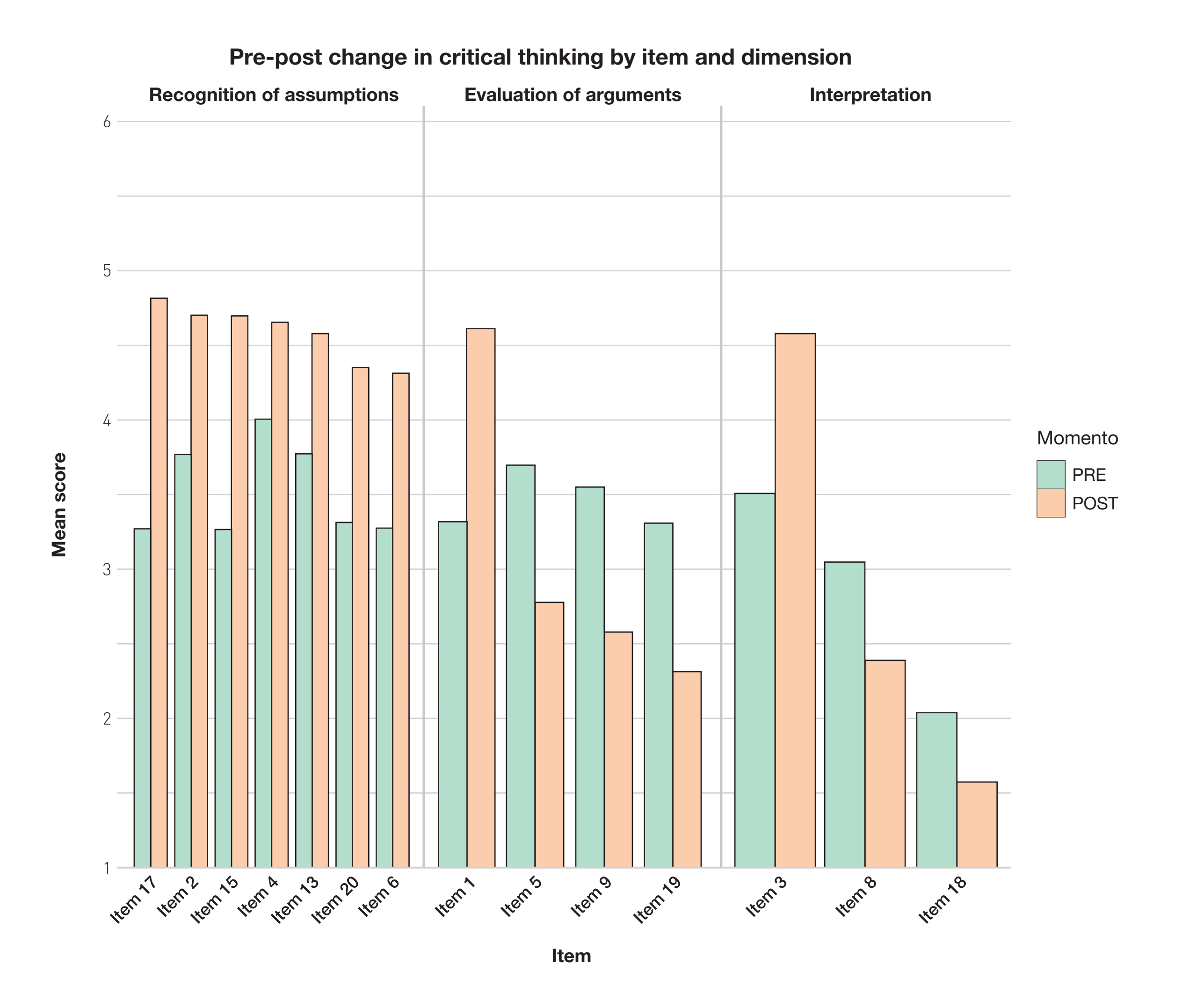
Note. The gray dots represent the individual scores for resilience pre- and post-intervention. The box indicates the interquartile range, the bold horizontal line represents the median, and the vertical lines (whiskers) represent the minimum and maximum values. The statistical analysis was conducted using Student's *t*-test for related samples.

Figure 4
*Differences between pre- and post-*Black Mirror *intervention among categories of the dimensions of emotional intelligence*



Note. The data are expressed as frequencies (number of cases) and percentages (within each category). We used the McNemar-Bowker test to determine significant changes between response categories that occurred when comparing the pre- and post-intervention evaluations.

Supplementary figure 2
Pre-post comparison of mean score per critical thinking questionnaire item, grouped by dimension



*Note.*The y axis shows the mean score on a scale from 1 (strongly disagree) to 6 (strongly agree). The items with reversed score were recoded to maintain interpretative coherence.

Discussion

The results of this study show the significant and positive impact of the *Black Mirror*-inspired gamification project on critical thinking, resilience, and attention to feelings, all of which are essential competencies in early teacher training and are transferable to their future teaching practice. These findings are consistent with previous research highlighting the value of active methodologies and gamification as high-impact strategies for promoting meaningful changes in behavior and learning (Pérez-López et al., 2024; Navarro-Mateos & Pérez-López, 2024). These results further underscore the enormous potential of such approaches in higher education. A good example of this is an intervention conducted with young adults that reported significant improvements in the group participating in a gamification activity, specifically in interest, inspiration, and engagement, compared with a control group (Kelders et al., 2018). Another example is the study conducted by Navarro-Mateos et al. (2024), in which a *Star Wars*-inspired gamification intervention improved emotional intelligence, personal initiative, entrepreneurial attitude, and resilience among college students. Although it is important for the narrative to be meaningful to students, technology is another element that may enhance the effectiveness of programs aimed at improving health outcomes. Cobb and Poirier (2014) reported similar findings in their intervention, concluding that technology helped strengthen participants' connection to and commitment to the project, thereby positively influencing their psychological well-being.

One of the most notable findings of this study was the significant improvement observed across all dimensions of critical thinking after the intervention, as well as in overall critical thinking. The effect size observed for these dimensions suggest not only statistically significant improvements, but also substantial changes in the way students process information and critically examine their own beliefs. Improvements in items such as "I think about my own thoughts and question them" reinforce the hypothesis that the intervention benefits not only cognitive skills, but also critical thinking and reflective capacity, both of which are typically difficult to develop though traditional teaching practices (Bietenbeck, 2014). These attitudinal changes may be associated with greater intrinsic motivation and stronger commitment to learning, which are particularly important for training future teachers (Eales-Reynolds et al., 2013). The development of self-reflection and skepticism is essential in a higher education context characterized by large volumes of information and the need to critically evaluate and filter it (Martínez-Mares & Risco-Lázaro, 2023). Previous research with college students in Spain has shown that individuals with a stronger disposition toward critical thinking also tend to be more receptive to diversity and challenges and to have a stronger creative self-concept, which positively contributes to their self-confidence (Álvarez-Huerta et al., 2022).

Regarding the resilience variable, the results also showed a notable increase in students' ability to cope with adverse situations post-intervention. This change was observed in 96% of participants and may be explained by the chosen narrative, which exposes the students to complex situations and creates the need to work on their emotional regulation and develop adaptive strategies. These findings are consistent with previous studies that have associated resilience with improvements in academic performance and student engagement (Romano et al., 2021). In higher education specifically, various interventions have shown than an appropriate approach can enhance student resilience and psychological well-being, thereby reducing stress and anxiety levels (You, 2016; van Breda, 2018).

In terms of emotional intelligence, within the attention to feelings dimension, 54% of students adjusted their levels to a more appropriate level of attention to feelings after participating in the intervention. This suggests that the intervention may have fostered greater emotional awareness; however, a longer intervention would be needed to produce significant changes in other dimensions of emotional intelligence, such as clarity or regulation (Paraguay-Delgado & Teves-Quispe, 2024).

Based on these results, the importance of emotional education in teacher training should be emphasized, as it contributes to improving teaching quality and fostering healthier and more empathetic learning environments (Paraguay-Delgado & Teves-Quispe, 2024). Therefore, higher education institutions should develop strategies that expose students to diversity and challenges within a safe environment, with the aim of training active and responsible professionals (Álvarez-Huerta et al., 2022).

Conclusions

The gamification project inspired by the television series *Black Mirror* and implemented in a Master's in Education program had a significant and positive impact on the development of key competencies in teacher training, such as critical thinking, resilience, and attention to feelings. The results show improvements across all dimensions of critical thinking, indicating enhanced reflective skills relevant to teaching practice. Likewise, the observed increase in resilience suggests that immersive and emotionally challenging learning experiences, when contextualized within narratives that are meaningful to students, may foster the development of resilience. Regarding emotional intelligence, although significant changes were observed only in the attention to feelings dimension, these findings point to the emerging development of emotional awareness, which could be further enhanced through a longer implementation period.

Overall, the results of this intervention support the impact of gamification, when integrated with fiction and technology, on students' holistic learning. These findings reinforce the need to strengthen higher education through projects that promote the development of social and emotional skills as well as critical thinking, fostering more resilient educational environments and learning that can be transferred to real-life contexts.

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Teachers' (De)motivating Styles in Physical Education from a Circumplex Approach: An Analysis of the Gap Between Theory and Practice

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Abstract

This theoretical article integrates Self-Determination Theory and the Circumplex Model to examine didactic interaction in physical education, questioning whether abstract constructs can delimit an inherently messy reality. The central aim is to evaluate the capacity of this bidimensional framework to organize dynamic and interpersonal teaching practices. The paper makes contributions in four key directions: (i) it identifies diffuse conceptual boundaries and overlaps between the eight proposed teaching approaches; (ii) it reveals critical perceptual discrepancies between teachers' intentions and students' experiences; (iii) it contrasts theory with practice by observing that reality manifests itself in asymmetric structures (oval or rhomboid) rather than perfect circles; and (iv) it proposes the model as a reflective framework for teachers to adjust their directiveness and support for basic psychological needs in a contextualized way. The study's main contribution lies in moving beyond mere technical classification, offering a tool to understand how subtle variations in teacher behavior impact students' motivation and learning. It is concluded that the circumplex model should not become a rigid system, but rather an essential heuristic tool for teacher training, facilitating a dynamic and sensitive calibration of didactic practice.

Keywords: circular model, motivating styles, need-supportive styles, need-thwarting styles, physical education, teaching style

Introduction

In the educational context, the teaching style adopted by the teacher is a determining factor in promoting students' motivation and learning, both in general education and, more specifically, in school physical education (PE) (Vasconcellos et al., 2020). PE teachers occupy a central position in the classroom in guiding students through their learning process (White et al., 2021). Research on teaching styles has had significant historical relevance in the field of PE, exemplified by the continuing influence of Muska Mosston's Spectrum of Teaching Styles (see Spectrum Institute for Teaching and Learning, n.d.) since the mid-1960s (Mosston, 1966). This research tradition has highlighted the complexity of educational reality, underscoring the need to move beyond reductionist conceptions of styles as mere techniques (Sicilia-Camacho, 2001).

Teacher–student interaction in the classroom is the most concrete expression of pedagogical practice, where abstract constructs, such as teaching style, seek to address its inherent complexity (Sicilia-Camacho & Delgado-Noguera, 2002). Nevertheless, no classification system can capture this reality in its entirety. In this context, Self-Determination Theory (SDT) (Deci & Ryan, 1985; Ryan & Deci, 2017) and, more particularly, the Circumplex Model of (De)motivating Styles (Aelterman et al., 2019) emerge as robust theoretical models for analyzing this complex classroom interaction, highlighting the importance both of supporting basic psychological needs (BPN) and of teacher directiveness. However, the plurality of existing models and divergent interpretations between teachers and researchers hinder their coherent implementation in educational practice.

This limitation is not so much due to a theoretical weakness inherent to the SDT-based circumplex model as it is to the dynamic, contextual and interpersonal nature of didactic interaction, which defies any attempt at exhaustive delimitation. From this perspective, theoretical proposals should be understood as analytical frameworks that make it possible to describe teachers' motivating tendencies and interaction patterns, rather than as rigid or mutually exclusive categories (Sicilia-Camacho, 2001). Consequently, although they constitute necessary theoretical models for interpreting educational reality, they inevitably simplify a complex, variable and contextualized teaching practice.

In light of SDT, the present theoretical study aims to analyze the complexity of didactic interaction in the PE classroom by integrating SDT and the circumplex model of (de)motivating styles. Through this analysis, it seeks to examine the capacity of this bidimensional framework to organize and identify teaching practices characterized by their dynamism and interpersonal nuance, questioning the extent to which these abstract constructs can delimit an educational reality that is, by nature, "messy." This work aims to provide a mapping that highlights the gap between the model and the reality of interaction in the PE classroom. To this end, the study will identify the existence of diffuse conceptual boundaries between the eight teaching approaches, as well as the perception gap between the teacher's didactic intentions and the student's experiences. By showing that educational reality often manifests itself in structures that are not perfectly circular and in overlaps between adjacent styles, this work moves beyond mere theoretical classification to offer a reflective framework on the limited usefulness of the circumplex model for capturing classroom reality.

To address the objective, the theoretical assumptions of SDT are first reviewed, and then, based on empirical evidence, tensions, overlaps and discrepancies are highlighted. The paper concludes by discussing the implications for teacher training, didactic intervention and future lines of research in the field of PE.

Self-Determination Theory

SDT, formulated by Richard M. Ryan and Edward L. Deci (Deci & Ryan, 1985; Ryan & Deci, 2017), is a motivational macrotheory that emerged in the 1980s. A fundamental postulate of SDT is that all human activity takes place in a social context, such as a class (Ryan & Deci, 2017). Unlike theories that prioritize the quantity of motivation, SDT emphasizes its quality. In this regard, the theory distinguishes three qualities of motivation, located along a *continuum* of self-determination, according to the level of autonomy present in each one. At one end of this *continuum* would be autonomous motivation, which, as the prototype of human motivation, refers to the performance of a behavior guided by experiences based on enjoyment, curiosity and the search for new challenges, as well as by its alignment with the person's system of values and goals, and by the recognition of the benefits it entails. In the central part would be controlled motivation, which implies that behavior is regulated by experiences based both on self-imposed pressure to improve self-esteem and avoid negative feelings, and on social pressure to obtain rewards or avoid punishments. At the opposite end, and in contrast to forms of autonomous and controlled motivation, would be amotivation, which reflects the absence of regulation and self-determination when undertaking a behavior.

SDT proposes a dual-process model based on the distinguishable perception between satisfaction and frustration of the BPN of autonomy, competence and relatedness (Vansteenkiste et al., 2020). Thus, satisfaction of the need for autonomy (feeling initiative and choice in one's own actions), competence (feeling effectiveness and mastery in the activities performed), and relatedness (feeling connection and security in interpersonal relationships with others) would represent the heart of the *bright* side of human existence, fostering autonomous motivation. By contrast, frustration of the need for autonomy (feeling pressured and pushed toward unwanted directions), competence (feeling ineffective and clumsy when engaging in activities), and relatedness (feeling lonely and excluded in interpersonal interactions) would constitute the heart of the *dark* side, facilitating controlled motivation and amotivation. According to SDT, a person's perception of the satisfaction and frustration of their BPN is formed from their interpretation of their social environment in general and, more specifically, of the combination of the styles of each socializing agent present in that environment.

Circumplex Model of (De)motivating Styles

The circumplex model represents a conceptual and methodological advance in the understanding of teachers' motivating and demotivating styles (Aelterman et al., 2019). This perspective provides a more integrated and refined view of teachers' classroom styles, moving beyond the traditional tendency to examine teaching styles (such as autonomy support, structure, control and chaos) categorically, through a black-and-white perspective based exclusively on their BPN-supportive or BPN-thwarting nature.

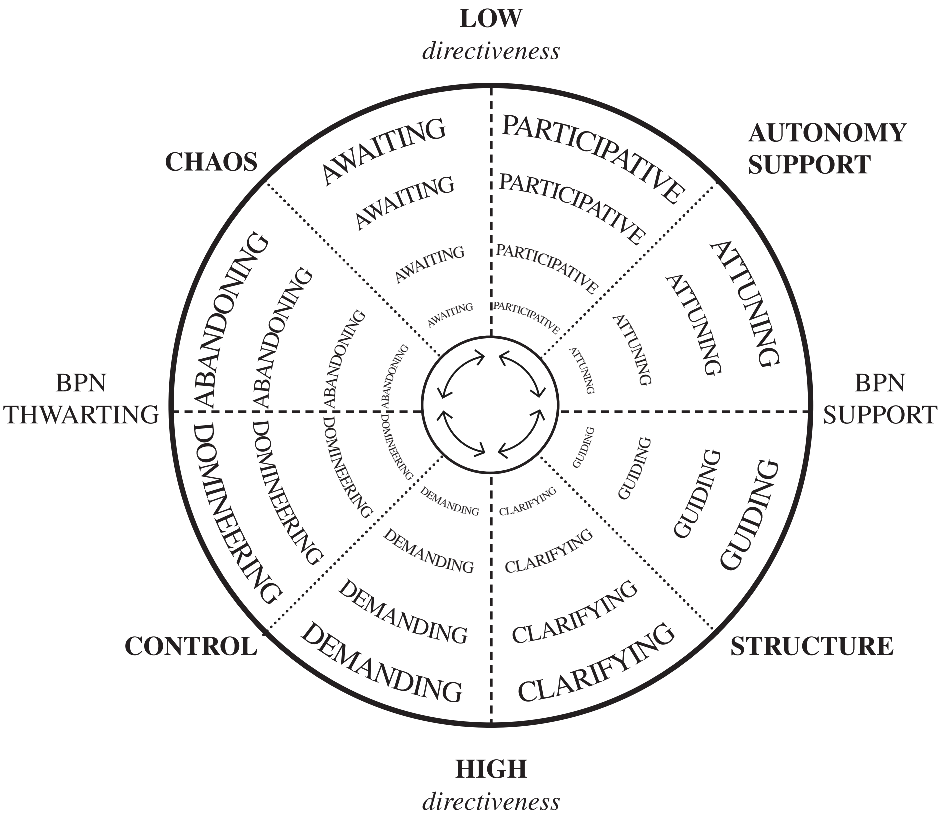
The circumplex model has substantially advanced the understanding of the effects of teaching styles by recognizing the need for a more integrative and detailed perspective that clarifies how the different styles relate to one another and allows for more precise differentiation. To this end, it uses a descriptive analytical strategy based on multidimensional scaling (Aelterman et al., 2019), which makes it possible to visualize the similarities and differences between various teaching practices in the PE classroom by placing them within a multidimensional structure. The underlying rationale is that teaching practices are not simply "supportive" or "thwarting" of students' BPN, but also vary according to the level of teacher directiveness.

This multidimensional scaling analysis led Aelterman et al. (2019) to suggest that teachers' styles could be optimally represented through a bidimensional configuration. The model defines each style not only in terms of the degree to which it supports or thwarts BPN, but also according to the degree of high or low directiveness that the teacher assumes in the classroom (Aelterman et al., 2019; Escriva-Boulley et al., 2021a). Figure 1 shows a graphical representation of the circumplex model and illustrates this structure with two perpendicular axes, making it possible to identify in an integrated way the degree of support for or thwarting of BPN and the level of teacher directiveness.

When observing Figure 1, the horizontal axis that crosses the circle (x-axis) reflects the teacher's capacity to support or thwart students' BPN. Within this axis, on the right-hand side (positive coordinates) would be the styles that support BPN (autonomy support and structure), while on the left-hand side of this axis (negative coordinates) the styles that thwart BPN are represented (control and chaos). It should be borne in mind that this axis reflects the degree of support or thwarting of BPN in general, regardless of the combination of the three needs that exist in each case. The vertical axis that crosses the circle (y-axis) represents teacher directiveness, that is, the degree to which teachers assume leadership or give students space to take the initiative in didactic interactions. In the upper coordinates would be teaching styles that imply low directiveness on the part of teachers (autonomy support and chaos), while in the lower coordinates would be teaching styles that imply high directiveness (structure and control).

Considering the two axes described above, relative to the vertical plane, the model identifies autonomy support and structure as motivating styles, insofar as both are BPN-supportive in nature, but qualitatively different, the former (autonomy support) being low in directiveness and the latter (structure) highly directive (Aelterman et al., 2019). On the other hand, the model labels control and chaos as

Figure 1
Graphical representation of teachers' (de)motivating styles and approaches in the circumplex model



Source: Translated and adapted from Aelterman et al. (2019).
Note. BPN = basic psychological needs. The dashed contour lines mark the four main styles. The more discreet dotted lines subdivide each style into its two specific approaches, suggesting less rigid boundaries between the components of the same style. The curved double arrows in the center indicate possible transitions between the approaches that make up the same style, evidencing the dynamism of teaching practices and the difficulty of precisely delimiting the contours of each approach.

demotivating styles, given that both are BPN-thwarting in nature, but qualitatively different, in the sense that the former is high in directiveness and the latter is low in this dimension (Aelterman et al., 2019). In this way, the proposal is located in coordinates diametrically opposed to the autonomy-supportive and controlling styles and, on the other hand, to the structure and chaos styles.

Beyond the four teaching styles identified by the model, a key contribution of this approach is the identification of eight more precise subareas or approaches within the four broader styles (Aelterman et al., 2019). These approaches are articulated around the circular structure, allowing for a more refined understanding of teaching practices. The logic of the model proposes that, for example, not all autonomy-supportive practices are identical; some may be more related to structure, while others lean more toward chaos (Van Doren, 2025).

Considering the four main teachers' (de)motivating styles, each could be addressed through two more specific teaching approaches, resulting in a total of eight. Table 1 presents each of the four teachers' (de)motivating styles and their respective specific teaching approaches, defined on the basis of concrete teaching behaviors to facilitate their identification in the real context of the PE classroom.

The circumplex model makes an important contribution to previous proposals in SDT. First, it integrates different proposals in such a way that it provides a unified proposal of teaching styles previously studied in isolation or in less detail, offering a more precise conceptual description. Second, the model helps to understand, at least conceptually, how the different ways of approaching PE teaching may be related. Third, by defining forms of teaching as a continuum, the model aligns better with a complex view of classroom reality. Fourth, and in line with the previous point, the model makes it possible to name classroom reality and thus constitutes a conceptual tool for teacher training. Fifth, it establishes a coherent theoretical framework for classroom research into teacher behavior and its outcomes in student learning.

At a practical level, and within initial and continuing PE teacher training, the circumplex model can be used as a reflective tool that helps teachers identify habitual patterns of motivating interactions in the classroom, as well as analyze possible variations and shifts between motivating approaches, and become aware of how subtle variations, both in the degree of directiveness and in the promotion of BPN, can have a significant impact on students' learning variables in PE (García-Cazorla et al., 2024a; Mayo-Rota et al., 2025).

Table 1
Teachers' (de)motivating styles and their respective teaching approaches described in the circumplex model

(De)motivating style	Approach	Observable teaching behaviors	Level of BPN support	Level of directiveness
Autonomy support: Refers to the teacher's adoption of an interpersonal tone of understanding, receptivity and flexibility toward students' educational needs and learning-related interests.	Participative	• The teacher gives students a voice. • Fosters joint decision-making in the learning process. • Offers opportunities for choice. • Takes their interests into account.	BPN facilitator	Low to medium
	Attuning	• The teacher adapts content to students' interests and preferences. • Accepts negative expressions. • Explains the importance of learning activities.	BPN support	Medium
Structure: Refers to the teacher's use of an interpersonal tone focused on progress and process, showing confidence in the student's capacity to develop their abilities and skills.	Guiding	• The teacher provides both useful and detailed initial information and constructive feedback. • Adjusts the difficulty of the activities to the student's capacities. • Encourages students to complete the activities successfully.	BPN support	High
	Clarifying	• The teacher clearly communicates expectations and objectives. • Consistently supervises the process.	BPN facilitator	High
Control: Refers to when the teacher displays a tone of pressure and coercion not only to prioritize their class agenda, but to make students think, feel and act according to the predetermined way.	Demanding	• The teacher uses orders, shouting and threats. • Uses rewards and punishments. • Uses an authoritarian tone.	BPN deprivation	Very high
	Domineering	• The teacher induces guilt and shame. • Uses expressions of disapproval. • Uses personal attacks.	BPN thwarting	Extremely high
Chaos: Refers to when the teacher adopts a laissez-faire style, behaving unpredictably and inconsistently, which not only confuses the student but also hinders the development of their skills.	Abandoning	• The teacher gives up after several attempts. • Does not provide help when needed.	BPN thwarting	Very low
	Awaiting	• The teacher passively waits for the student to act. • Does not initially intervene or guide.	BPN deprivation	Low

Note. BPN = basic psychological needs.

Conceptual Delimitation and Assessment of Teaching Styles

To assess perceptions of teachers' (de)motivating styles within the circumplex structure, Aelterman et al. (2019) developed the Situations in School questionnaire (SIS; *Situations-In-School*). This instrument, originally designed for secondary students and teachers, has been adapted to various contexts, including sport and higher education (Delrue et al., 2019; Vermote et al., 2020). In the specific context of PE, a modified version called SIS-PE, *Situations-In-School-Physical Education*; Escriva-Boulley et al., 2021a) was developed. It has been validated in various languages and contexts (Burgueño et al., 2024a; Escriva-Boulley et al., 2021a; Tilga et al., 2023), and showed a good level of reliability in the four (de)motivating styles, making it possible to measure the complex reality of teacher behavior in the PE classroom.

Studies based on SDT have documented the importance of teachers' motivating and demotivating styles in students' outcomes in PE (Vasconcellos et al., 2020; White et al., 2021). The results of these studies have shown that a motivating, highly structured and autonomy-supportive style is associated with positive outcomes such as autonomous motivation, engagement, learning and well-being (Vasconcellos et al., 2020; White et al., 2021). By contrast, a controlling style has been related to negative outcomes (Abós et al., 2022; Haerens et al., 2015; Vasconcellos et al., 2020), with the chaos style being the most harmful for students' experiences in the PE classroom (Bouten et al., 2025; García-Cazorla et al., 2024b). Intervention research has shown that teachers can be trained to adopt both an autonomy-supportive and a structured style, which benefits both the teachers themselves and their students (Aelterman et al., 2014; García-Cazorla et al., 2026; Reeve, 2016). Teachers generally recognize the benefits of autonomy support, although they sometimes fear that too much support may generate chaos, and that too much structure may be perceived as control (Aelterman et al., 2014; Reeve, 2016).

The approaches of each teaching style—motivating and demotivating—are manifested in concrete behaviors. In particular, an autonomy-supportive teacher may ask for suggestions (participative), or help make tasks interesting (attuning). A structuring teacher may offer individual progressions (guiding), or communicate clear expectations (clarifying). A controlling teacher may use authoritarian language (demanding), or induce guilt (domineering). A chaotic teacher may leave students alone (abandoning), or wait for them to lead the class (awaiting) (Van Doren et al., 2025). By way of example, in the PE classroom, a guiding approach may be put into practice when the teacher adapts the learning progressions of a specific activity to different levels of student competence throughout a learning unit, supporting competence satisfaction. By contrast, a demanding approach may be implemented when the teacher imposes a strict way of completing the activity in question, with little room for students to make decisions, especially in situations of motor competence assessment, which increases the teacher's controlling didactic tone.

The circumplex model provides a detailed view of teacher behavior, which plays an important role in students' experiences (Escriva-Boulley et al., 2021a). However, research indicates that not all motivating styles nurture BPN to the same extent, nor do all demotivating styles produce a similar effect of BPN frustration (Aelterman et al., 2019; Vansteenkiste et al., 2019). Specifically, the attuning and guiding approaches are theorized to be better representatives of BPN support, while the participative and clarifying approaches are hypothesized to facilitate BPN (Burgueño et al., 2024a), in the sense that both approaches create the necessary conditions for students to perceive that satisfaction of their BPN is supported (Aelterman et al., 2019; Vansteenkiste et al., 2019). On the other hand, the domineering and abandoning approaches are believed to thwart students' BPN, while the demanding and awaiting approaches undermine them (Burgueño et al., 2024a), since, although they do not directly thwart them, they do hinder and obstruct the potential support of these needs (Aelterman et al., 2019; Vansteenkiste et al., 2019).

In general terms, the empirical data support, among students, the theorized relationships between teachers' (de)motivating teaching approaches and the perception of their BPN in the PE classroom (Burgueño et al., 2024a; Diloy-Peña et al., 2024b, 2025, 2026). The autonomy-supportive and structuring approaches are related to students' BPN satisfaction, with a stronger association for the attuning and guiding approaches than for the participative and clarifying approaches. On the other hand, controlling and chaotic approaches are associated with BPN frustration, with a stronger relationship for the domineering and abandoning approaches than for the demanding and awaiting approaches. Nevertheless, the distinctive role played by the demanding approach in PE class should be highlighted, as it may also be positively associated with students' competence satisfaction in the short term (Diloy-Peña et al., 2024b, 2025). This could explain why the teacher adopts a tunnel perspective when introducing the task; that is, the teacher limits the way to perform it successfully to such an extent that it helps students feel that they are performing it well. However, as a counterpart, this entails a cost to their autonomy (Vansteenkiste et al., 2019). In contrast with the hypothesized relationships between teaching approaches and BPN experiences, one line of research suggests that the clarifying and awaiting approaches could, in some way, represent a type of neutral approach insofar as they have no relationship with either perception of BPN in the eyes of PE students (Diloy-Peña et al., 2026; Van Doren et al., 2025). For PE teachers, the growing evidence base indicates that teachers' use of (de)motivating styles in the PE classroom is conditioned by their perception of their own BPN at work (Burgueño et al., 2024a; García-Cazorla et al., 2025). In general, teachers' BPN satisfaction is associated with the use of the four motivating approaches in the classroom, just as frustration of their BPN is linked to the implementation of the four demotivating approaches in the PE classroom (García-Cazorla et al., 2025). It is also worth noting that teachers' use of the demanding approach was preceded not only by frustration of their BPN, but also by satisfaction of their BPN (Burgueño et al., 2024a).

The circumplex model thus seeks to identify which autonomy-supportive or structuring practices could come close to more demotivating approaches, as well as to detect which rigorously controlling practices could come close to more motivating approaches. This offers clear clues as to how teachers can modify and calibrate their classroom strategies to obtain optimal results with groups of students with different characteristics (Van Doren, 2025; Vansteenkiste et al., 2019). This perspective highlights that didactic intervention should not be understood as the implementation of "pure" (de)motivating styles, but rather as a dynamic and contextualized calibration of teaching practices throughout both the class and the learning units, and according to the characteristics of the group (García-Cazorla et al., 2026; Ocete et al., 2025). In this regard, the need to combine autonomy-supportive and structuring styles in teaching in a balanced way is highlighted, avoiding both excessively controlling practices and chaotic practices, characterized by a lack of guidance or teacher involvement (Burgueño et al., 2024b).

From Theory to Practice: Problems, Criticisms and Tensions

Despite the theoretical and methodological advances contributed by the circumplex model, there is an inherent tension between theoretical abstraction and the complexity of pedagogical practice. Theoretical models are abstract constructs that represent ideal extremes, which may hinder their application to the multifaceted reality of the classroom (Sicilia-Camacho & Delgado-Noguera, 2002). The diversity of styles adopted by teachers, influenced by variables such as students' profile, teachers' beliefs, the school environment and resources, can generate confusion in didactic practice. Thus, despite the theoretical coherence presented by the circumplex model, some limitations should be highlighted that evidence the discrepancy between theoretical models and classroom complexity.

Diffuse boundaries and collapse between approaches

A central problem in the circumplex model seems to lie in the difficulty of clearly conceptualizing and empirically delimiting the four teaching styles and, especially, the eight approaches, both for teachers and for students (Van Doren, 2025). Although the theory suggests a "thin line" between adjacent teaching approaches (García-Cazorla et al., 2026), the empirical evidence shows an inherent difficulty in maintaining clear separations in real practice in the PE classroom.

Several multidimensional scaling studies have failed to reproduce a perfect circle, instead producing oval or rhomboid structures (Burgueño et al., 2024a; Escriva-Boulley et al., 2021a). These alternative structures reflect asymmetric patterns in the organization of styles, possibly conditioned by the degree of perceived directiveness and by its impact on BPN satisfaction or frustration. Moreover, certain approaches show unexpected correlations: for example, from the students' perspective, the attuning approach is more closely related to the clarifying approach (within the structure style) than to the participative approach (within the autonomy-supportive style) (Burgueño et al., 2024a; Vansteenkiste et al., 2019). Similarly, in pre-service or in-service teachers, the domineering approach (within the control style) shows stronger associations with the abandoning approach (within the chaos style) than with the demanding approach (within the control style), which blurs the expected boundaries between styles. This evidence points to conceptual overlap between adjacent approaches and calls into question the discriminant validity of the model in its current form.

When observing the conceptualization of the approaches, it can be seen that some of them appear to overlap with one another. For example, the attuning and guiding approaches are often perceived very similarly, which makes them difficult to differentiate statistically (Van Doren et al., 2025). The thin line between styles becomes evident when observing the gray area formed in the transition between need support and need thwarting. Approaches that act as facilitators (e.g., participative, clarifying) can easily shift toward deprivation and thwarting (e.g., awaiting, demanding) if the teacher does not calibrate their intervention well (Van Doren, 2025). For example, offering too much freedom (which can be framed as a participative approach) may be interpreted by students as a lack of guidance or negligence (more in line with the chaos style and the awaiting approach) if they do not have sufficient competence to decide.

Discrepancies in the perception of the different actors

Another of the main tensions in the circumplex model is the perception gap between what the teacher believes they are doing and what students experience. Thus, perceptual discrepancies between the different educational actors add further tension to the connection between the theoretical model and practical reality (Coterón et al., 2025; Van Doren et al., 2026).

What a teacher considers a structured practice may be perceived by students as a form of control (Van Doren, 2025). For example, a teacher may feel that they are being clarifying by establishing strict rules for the proper functioning of the class, but students may perceive this as a demanding approach (García-González et al., 2023). This can be interpreted based on the ambiguous role that demandingness may have, given that the demanding approach (control) presents a certain paradox. In certain contexts, such as the Spanish context, it has been observed that it may be positively associated with competence satisfaction in the short term, since students interpret high directiveness as a sign of teacher commitment and concern for their learning, although this entails a cost to their autonomy (Tilga et al., 2023; Van Doren et al., 2026). Along these lines, it should be recalled that some studies have suggested that the clarifying and awaiting approaches sometimes function as neutral approaches that predict neither BPN satisfaction nor BPN frustration, which calls into question their direct motivational weight in the model (Diloy-Peña et al., 2026; Tilga et al., 2023).

Differences in the way teachers and students understand classroom reality constitute a limitation faced by any proposal of teaching styles. This happens because, as Sicilia-Camacho and Brown (2008) had already argued, while the teacher or the curriculum may want to follow or propose a variety of styles, classroom reality shows that students are not passive recipients of a universal learning framework, but often show resistance or negotiate teaching styles based on what is familiar or normal to them. The gap occurs because theories that seek to predict classroom reality often bracket out interpersonal interaction and students' capacity to influence class dynamics, which causes theoretical prescriptions to move away from what actually happens in everyday classroom practice.

The teacher as a flesh-and-blood subject. Pressures and personal well-being

Theoretical teaching models, such as the circumplex model, which attempt to reflect classroom reality, often ignore that the teacher's style is the result of an ecosystem of pressures. Along these lines, it should be recalled that research has emphasized that a teacher's capacity to be motivating depends on the satisfaction of their own BPN at work (Burgueño et al., 2024a; García-Cazorla et al., 2025). If teachers feel frustrated at work, whether due to a lack of resources or institutional support, they are much more likely to resort to controlling and chaotic styles (Escriva-Boulley et al., 2021b; Franco et al., 2025). It should not be overlooked that, although teachers may have theoretical knowledge about active methodologies and believe in them, they may come to adopt traditional (reproductive) approaches due to a lack of time, limitations in working with large groups, or feeling some pressure to maintain authority in the face of disruptive student behaviors (Escriva-Boulley et al., 2021b; Franco et al., 2025).

Methodological and Assessment Limitations of Teacher Behavior

Finally, in addition to the limitations noted above, it should be borne in mind that, in most cases, assessment of reality is subordinated to psychometric instruments such as the SIS-PE. This raises certain criticisms about the model's capacity to represent classroom reality for several reasons.

First, teachers' self-reports are often biased, so what is probably considered "good teaching" is that in which they report more autonomy support and less control than their students actually perceive (Coterón et al., 2025; Van Doren et al., 2026). This distortion makes it difficult to interpret their true practices or beliefs accurately. Second, there is a certain quantitative reductionism, given that existing instruments quantify behaviors but render invisible the creativity, adaptability and affective nuance of didactic interaction. Finally, most studies on the circumplex model proposal are limited to the perception of only one of the parties. It is evident that this can only represent one segment of reality, and progress is needed to obtain measures from different agents. In this regard, future research could integrate objective observations (such as the SIS-PE-Coder) to contrast teaching intentions with experiences (García-Cazorla et al., 2026; Van Doren et al., 2025).

Conclusions and Future Perspectives

The circumplex model has become established as a robust and very useful theoretical framework for unraveling the complexity of interactions in the PE classroom (Aelterman et al., 2019; White et al., 2021). By integrating the dimensions of both BPN support and teacher directiveness, this model allows for a detailed understanding of eight teaching approaches, moving beyond traditional categorical black-and-white views (Burgueño et al., 2024a). The evidence suggests that, while autonomy-supportive and structuring styles activate the *bright* side of motivation, the chaos, style, especially through the abandoning approach, emerges as the *dark* or most harmful side for students' BPN satisfaction, sometimes exceeding the negative impact of the controlling style. Nevertheless, the role of the demanding approach (one of the controlling style approaches) reveals a relevant paradox: its high directiveness may be interpreted by students as a sign of teacher commitment and be associated with competence satisfaction in the short term, although the risk of frustrating autonomy persists (Diloy-Peña et al., 2024a).

The transition from theory to practice shows that the teacher is a flesh-and-blood subject whose style is intrinsically linked to their own well-being. Research confirms that a teacher's capacity to be motivating depends on the satisfaction of their own BPN in the school environment. Thus, if teachers feel frustrated by institutional pressures or a lack of resources, they are more likely to drift into controlling or chaotic styles. Continuing education programs such as *MotivaDosEF* (García-Cazorla et al., 2026) have shown that it is possible to transform these tendencies, generating bidirectional benefits that improve both the student experience and teachers' performance and job satisfaction. These findings reinforce the idea that teacher training should not be limited to the transmission of techniques, but should foster awareness of the changing action of their practice.

Despite the robustness of the model, the present work has highlighted methodological tensions and perception gaps that will shape the future research agenda. There is a critical disconnect between the teacher's intention and the student's experience, where what the former designs as structure may be experienced by the latter as coercive control. Furthermore, classroom reality often overflows the geometry of the model, manifesting itself in empirical oval or rhomboid structures rather than perfect circles, due to the overlap of adjacent approaches such as attuning and guiding. For this reason, it is essential that future studies move beyond self-reports and use a type of methodological triangulation, integrating subjectivities and objective observations (such as the SIS-PE-Coder) to capture the transactional nature of teaching, in which students are not passive recipients, but agents who also shape the teacher's style.

In conclusion, based on the arguments presented in this theoretical review, we understand that the circumplex model should be used fundamentally as a heuristic tool and as a framework for professional reflection. Its value lies in providing a map for teachers to identify their interaction patterns and learn to move toward more nurturing approaches, recognizing that pedagogical effectiveness depends on implementation that is contextualized and sensitive to the needs of the group. Research should continue to explore these reciprocal dynamics and the weight of cultural factors to close the gap between theoretical prescriptions and the messy but vibrant reality of the PE classroom.

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When Passion Turns to Pressure: Psychological Predictors of Burnout in Adolescent Elite Swimmers

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Artistic swimmers performing a synchronized figure with technical precision and postural control.
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Abstract

Physical and emotional exhaustion, regarded as the core component of burnout, has been insufficiently explored in relation to its impact on sport performance. This study aimed to examine its progression among adolescent high-level swimmers over a competitive season and its relationship with competitive anxiety and sport commitment. A total of 297 high-level swimmers, training at least six times per week and/or enrolled in High Performance Sports Centers, initially consented to participate in the study. Of these, 247 completed the first assessment (T1), 218 provided valid data at T2, and 188 at T3. Employing a longitudinal design, participants completed the same set of questionnaires at three time points during the competitive season: T1 (October-November), T2 (February-March), and T3 (early July). Results indicated a significant reduction in physical and emotional exhaustion at T2 compared to T1, followed by a notable increase at T3 relative to T2. Across the season, physical and emotional exhaustion showed a positive correlation with somatic anxiety, worry, concentration disruption, and enthusiastic commitment. These findings underscore the potential impact of these variables on athletic performance and the risk of premature dropout, highlighting the practical relevance of the results. Ultimately, this research provides valuable insights for coaches to better manage their athletes' well-being and performance throughout the season.

Keywords: competitive anxiety, competitive swimming, exhaustion, sport commitment

Introduction

High-performance adolescent swimming is a physically and psychologically demanding discipline that requires intensive training, competition preparation, and considerable mental resilience. Athletes at this level are frequently exposed to elevated stress, which may contribute to physical and emotional exhaustion, a central dimension of athlete burnout (McDonough et al., 2013). While the physiological demands of competitive swimming have been widely studied, increasing attention is being paid to the psychological burden, including sport-related anxiety and varying levels of sport commitment (Berki et al., 2020). This introduction examines the interrelationship among physical and emotional exhaustion, sport commitment, and anxiety in adolescent swimmers, emphasizing their potential implications for both performance and well-being.

Physical and Emotional Exhaustion in Adolescent Swimmers

Physical and emotional exhaustion is widely regarded as the core and most sensitive dimension of athlete burnout, particularly among high-performance adolescent athletes (Raedeke & Smith, 2001; Gustafsson et al., 2018). In the present study, this centrality is reflected in the decision to focus specifically on physical and emotional exhaustion as the primary indicator of burnout across the competitive season. Burnout is characterized by intense fatigue, a diminished sense of personal accomplishment, and a detached or devalued attitude toward sport. This condition has been identified as a critical factor that negatively affects athletes' motivation and long-term involvement in sport (Morano et al., 2022). Swimmers, in particular, are highly susceptible to burnout due to early specialization, repetitive high-volume training routines, and elevated expectations from coaches and family environments (Giusti et al., 2020).

A systematic review conducted by Corrales and Olaya-Cuartero (2022) on school-age dropout in endurance sports identified emotional exhaustion as a major contributor to early sport disengagement. The review emphasized that the demanding training loads placed on young swimmers frequently result in both physical and psychological fatigue, thereby undermining their capacity to maintain consistent engagement throughout a competitive season. Given that competitive swimming requires long-term dedication, understanding the antecedents of emotional exhaustion becomes essential for enhancing athlete retention and optimizing performance outcomes.

The Role of Sport Commitment in Burnout and Performance

Commitment in sport has been conceptualized as a dual construct, encompassing both enthusiastic and coerced commitment (Scanlan et al., 2016). Enthusiastic commitment reflects intrinsic motivation, where athletes participate in swimming due to enjoyment and passion for the sport. Conversely, coerced commitment occurs when athletes feel obligated to continue due to external pressures, such as parental expectations, financial investment, or fear of disappointing coaches and teammates (Trinidad, 2024).

Previous studies have linked coerced commitment with higher levels of burnout in adolescent athletes. For instance, Tian and Sun (2024) investigated the relationship among self-concept clarity, mental toughness, and athlete burnout in swimmers during and after the COVID-19 pandemic. Their findings revealed that athletes who perceived their commitment as forced exhibited higher levels of emotional exhaustion and were more likely to consider sport dropout. Enthusiastic commitment, on the other hand, was associated with lower stress levels and greater resilience, enabling swimmers to endure the physical demands of their sport without experiencing burnout (Ponseti et al., 2016).

Given these findings, understanding the motivational climate surrounding young swimmers is crucial. If commitment is largely coercive, it can result in negative psychological outcomes such as anxiety and depression, which further fuel emotional exhaustion. In contrast, fostering an environment that supports autonomy and intrinsic motivation may help mitigate burnout symptoms.

Sport Anxiety and Its Impact on Emotional Exhaustion

A major concern regarding sport anxiety in high-level swimmers is its cyclical nature. Elevated anxiety levels can impair performance, which in turn amplifies stress and perpetuates a negative feedback loop that intensifies emotional exhaustion. In a longitudinal study, Vacher et al. (2017) observed that fluctuations in swimmers' recovery–stress balance significantly influenced their emotional states, including anxiety and dejection, highlighting the importance of early psychological intervention. If left unaddressed, this cycle can result in stagnation of athletic progress, psychological withdrawal, or even premature sport dropout. As such, the implementation of psychological strategies—such as mindfulness-based training, cognitive restructuring, and stress regulation techniques—may be essential in supporting both the well-being and competitive longevity of adolescent swimmers (Zhang et al., 2025).

The Seasonal Progression of Physical and Emotional Exhaustion

Competitive swimming is organized around structured seasonal training cycles, during which athletes experience fluctuations in psychological stress and physical fatigue. Typically, physical and emotional exhaustion evolves over the course of the season, beginning with increased motivation at the outset, followed by mid-season fatigue, and peaking in stress levels during key competitions (Dobson et al., 2020).

In a longitudinal study, Martin et al. (2022) tracked NCAA collegiate swimmers throughout a full competitive season and reported that burnout symptoms were most acute in the latter stages of the year. In line with these patterns, Curran et al. (2011) found that emotional exhaustion increased as athletes approached key competitions, particularly among those reporting high external pressure and low psychological need satisfaction. These results suggest that both internal psychological factors and external stressors—such as performance expectations and the timing of competitive events—may influence the emotional state of young swimmers as the season progresses.

Recognizing these seasonal patterns is crucial for designing effective prevention strategies. Coaches and sport psychologists are encouraged to integrate periodization models that include scheduled psychological recovery phases alongside physical tapering to reduce the risk of burnout (Karlsson, 2022). Moreover, moderating training intensity during mid-season phases may help alleviate emotional exhaustion while preserving performance readiness.

Influence of Age, Sex, and Competitive Level

Age, sex, and competitive level are critical variables that influence physical and emotional exhaustion, sport commitment, and competitive anxiety in adolescent swimmers. These factors shape athletes' psychological responses to training and competition demands, with distinct patterns observed across different demographic groups.

Age plays a pivotal role in both coping strategies and vulnerability to burnout. Younger swimmers (13–14 years) often show greater susceptibility to emotional exhaustion due to their developmental stage and limited experience managing sustained training loads (Martin et al., 2022). In contrast, older adolescents (15–16 years) may demonstrate greater physical resilience but also encounter increased psychological pressure linked to performance expectations and future sporting prospects (Morano et al., 2022).

Sex differences have also been consistently identified in the literature. Female swimmers tend to report higher levels of competitive anxiety and emotional exhaustion compared to males (Giusti et al., 2020). These disparities may be attributed to a greater sensitivity to external evaluation, differences in emotional regulation, and sex-based variations in coping strategies (McDonough et al., 2013). While male swimmers may report lower levels of anxiety, they may still experience notable physical fatigue, particularly during intensive training phases.

Competitive level further modulates these dynamics. Athletes participating in high-level competitions—such as national championships—are exposed to greater physical demands and heightened psychological stressors (Pan et al., 2024). This pressure is often associated with elevated levels of emotional exhaustion, particularly among those whose commitment is externally driven. Conversely, swimmers at lower competitive levels may face fewer external stressors but remain vulnerable to burnout through intrapersonal challenges and team-related dynamics (Trinidad, 2024).

In sum, these demographic and competitive variables underscore the need for individualized psychological support tailored to age, sex, and level of competition. Implementing developmentally appropriate coping strategies, fostering supportive training environments, and recognizing sex-based differences in stress perception may enhance resilience and reduce the risk of burnout in adolescent swimmers.

Study Aims and Hypotheses

The present study aimed to examine the evolution of physical and emotional exhaustion in high-level adolescent swimmers throughout a full competitive season and to explore its associations with competitive anxiety and sport commitment. Furthermore, variables such as age, sex, competitive category, and competitive level were incorporated to provide a comprehensive understanding of these relationships. Based on these objectives, the first hypothesis proposed that physical and emotional exhaustion would increase as the season progresses. The second hypothesis proposed that anxiety would be positively correlated with physical and emotional exhaustion, whereas enthusiastic commitment would be negatively associated with both aspects.

Method

Participants

A total of 297 high-level swimmers, regularly engaged in training programs with a minimum of six sessions per week in the swimming pool and/or integrated into high performance sports centers, were initially recruited. To ensure that only high-level swimmers were included in the sample, participants needed to have already competed in the Spanish National Championship or be qualified for the next one. A third selection criterion was based on the coaches' judgment, whereby swimmers could be included based on their projection and attitude. Of the 297 swimmers who consented to participate, 247 completed the first assessment (T1), 218 completed T2, and 188 completed T3. Fifty-one percent were male, aged between 13 and 16 years (M = 14.56, SD = 1.05). Table 1 presents the characteristics of the participants at the three data collection times conducted throughout the season. Sample characteristics did not differ significantly between participants at baseline and subsequent measurement points, except for age, with younger participants remaining in the later collection points. The variable *category* grouped the swimmers according to the categories established by the Spanish Swimming Federation at the time of the study and refers to: 1st year (13–14 years), 2nd year (14–15 years) and 3rd year (15–16 years). Regarding the variable *competitive level*, swimmers were categorized into two groups: high competitive level and low competitive level. This distinction was based on whether or not swimmers had ever participated in the Spanish National Championships. Although all items in the online questionnaire were configured as mandatory, the demographic questions corresponding to competitive category and competitive level were presented as open-response fields. In a small number of cases, particularly at T2 and T3, participants entered information in a non-standard format, which resulted in some responses being recorded as missing or non-interpretable for these two variables. Importantly, these issues affected only these secondary demographic variables; the main psychological variables of interest (physical and emotional exhaustion, competitive anxiety, and sport commitment) were complete and valid for all cases included in the analyses. The research followed a longitudinal group evolution design (Goodwin & Goodwin, 2016). The study received ethical approval from the Research Ethics Committee for Medicinal Products of the Principality of Asturias (248/18).

Table 1
Characteristics of the Participants at the Three Data Collection Times

	T1 (*n* = 247)	T2 (*n* = 218)	T3 (*n* = 188)	χ^2/F	*p*
Sex, *n (%)*				2.576	.276
Male	126 (51.0)	98 (44.9)	83 (44.1)		
Female	121 (49.0)	120 (55.1)	105 (55.9)		
Age, *M (SD)*	14.61 (1.06)	14.56 (.96)	14.36 (1.05)	3.36	.035
Category, *n (%)*				0.999	.910
1st year	59 (33.3)	70 (36.1)	48 (38.4)		
2nd year	70 (39.5)	64 (33.0)	42 (33.6)		
3rd year	48 (27.1)	60 (30.9)	35 (28.0)		
Competitive level, *n (%)*				0.122	.941
Higher	120 (48.6)	92 (48.4)	76 (46.9)		
Lower	127 (51.4)	98 (51.6)	86 (53.1)		
Years of experience, *M (SD)*	6.30 (1.80)	6.31 (1.90)	6.24 (1.82)	0.079	.924

Note. *M* = mean value; *SD* = standard deviation.

Procedure

Informed consent was obtained from all participants and, where required, from their legal guardians. High-performance centers and sports clubs were contacted directly via telephone or email for participant recruitment. Organizations that agreed to collaborate provided a list of eligible swimmers. Both athletes and their parents were informed about the study's aims, data confidentiality, and the voluntary nature of participation. Participants were encouraged to ask questions and reminded of their right to withdraw from the study at any time without consequences. Completing the questionnaires required less than five minutes.

Data collection was conducted online, either via email or telephone, at three time points over an eight- to nine-month period: Time 1 (T1): mid-October to early November, approximately 11–15 weeks into the competitive season; Time 2 (T2): late February to early March; and Time 3 (T3): early July. For each measurement wave, participants (and, when applicable, their legal guardians) received an initial invitation link to complete the questionnaires, followed by two reminders within a 7–10-day interval. Because participation was anonymous, it was not possible to conduct individual follow-up; therefore, all reminders were sent in a general, non-personalized way. Consequently, some swimmers did not respond at subsequent time points, which contributed to the natural attrition observed between T1 and T3, a common phenomenon in longitudinal research with adolescent athletes.

The intervals between measurement points ranged from four to five months. This timeline was designed to minimize the effects of motivational and psychological fluctuations typically associated with competitive events. To further reduce bias, T2 and T3 assessments were administered at least two to three weeks prior to the main championship events of the spring and summer seasons.

Measurements and Instruments

Physical and Emotional Exhaustion. Physical and emotional exhaustion (PEE) was assessed using the Athlete Burnout Questionnaire (ABQ; Raedeke & Smith, 2001), adapted to the Spanish context by Arce et al. (2010). The ABQ is a 15-item instrument that evaluates three dimensions of athlete burnout, but only the Physical and Emotional Exhaustion (PEE) subscale was used in this study. This choice reflects the central theoretical status of physical and emotional exhaustion as the core and most sensitive component of athlete burnout, particularly in adolescent athletes (Raedeke & Smith, 2001; Gustafsson et al., 2018). Accordingly, PEE was treated as the primary indicator of burnout across the competitive season. This subscale includes five items (e.g., "Swimming makes me too tired"), which are rated on a 5-point Likert scale (1 = almost never, 5 = almost always). The internal consistency of this subscale, as measured by Cronbach's alpha, was .87, .87, and .89 for Time 1 (T1), Time 2 (T2), and Time 3 (T3), respectively.

Competitive Anxiety. Competitive anxiety was measured using the Sport Anxiety Scale-2 (SAS-2; Smith et al., 2006), validated for the Spanish context by Ramis et al. (2010). The SAS-2 consists of 15 items divided into three subscales: somatic anxiety (e.g., "I feel my body is tense"), worry (e.g., "I worry that I am not performing well"), and concentration disruption (e.g., "I find it hard to concentrate on what I am supposed to do"). All items are introduced with the statement: "Before or while training or competing...". Responses are recorded on a 4-point Likert scale (1 = not at all, 4 = very much). Cronbach's alpha values for somatic anxiety were .83, .83, and .83; for worry, .87, .89, and .86; and for concentration disruption, .79, .80, and .84, across T1, T2, and T3.

Sport Commitment. Sport commitment was assessed using the Sport Commitment Questionnaire-2 (SCQ-2; Scanlan et al., 2016), adapted to the Spanish context by Sánchez-Miguel et al. (2019). The SCQ-2 includes 12 subscales, but this study focused on the two subscales related to commitment types: enthusiastic and coerced. Enthusiastic commitment consists of six items (e.g., "I will continue swimming as much as I can"), while coerced commitment includes five items (e.g., "I feel forced to continue swimming"). Participants rated their responses on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Cronbach's alpha values for enthusiastic commitment were .85, .63, and .91, and for coerced commitment were .66, .62, and .75, across T1, T2, and T3.

Data Analyses

Hierarchical linear models (HLMs) were employed to examine changes in physical and emotional exhaustion across the three data collection points. This method was selected because it avoids the underestimation of standard errors—thereby reducing the risk of Type I error—and effectively accommodates missing data (Field, 2024). The outcome variables at Level 1 (repeated measures; $N = 654$) were nested within Level 2 units (participants; baseline $N = 247$). Linear mixed-effects models were estimated using maximum likelihood (ML) procedures, following the guidelines of Snijders and Bosker (2011).

An initial intercept-only (null) model was specified for physical and emotional exhaustion to partition the total variance across the two levels. The intra-class correlation coefficients (ICC) were calculated to determine the proportion of variance attributable to each level, confirming the appropriateness of a multilevel modeling approach (Hofmann et al., 2000).

Predictor variables included linear time, sex, age, competitive category, participation in Spanish national championships, and years of swimming experience. These were added sequentially using a hierarchical model-building strategy. Variables that did not yield statistically significant estimates across all model iterations were excluded from the final model (West et al., 2014).

Finally, constrained cubic spline functions were incorporated to model the non-linear associations between physical and emotional exhaustion and all statistically significant predictors. Repeated-measures linear mixed models were adjusted for covariates identified in the previous steps. Four knots were used to produce a smooth, continuous fitted curve. Statistical significance was set at $p < .05$, and all analyses were performed using Stata/MP version 15.0 (StataCorp LP, College Station, TX, USA).

Results

Tested Models With Physical and Emotional Exhaustion as Dependent Variables

The results from the preliminary analysis (null model, Model 1), shown in Table 2, indicate that physical and emotional exhaustion varied significantly both between participants (inter-individual variability) and within participants over time (intra-individual variability). Specifically, 9.6% of the total variance was attributed to inter-participant differences, while 90.4% corresponded to within-participant changes.

Model 2, which included only data collection time points as predictors, revealed a decrease in physical and emotional exhaustion at mid-season (T2), followed by an increase at the end of the season (T3). This model accounted for a 5.3% reduction in intra-participant variability.

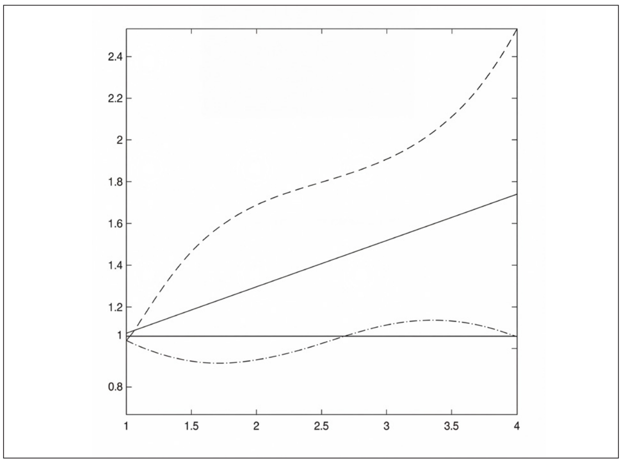
Model 3 incorporated all significant predictors. When these variables were included, the previously observed differences across time points disappeared, suggesting that the included predictors accounted for the longitudinal changes. Notably, age, somatic anxiety, worry, concentration disruption, and enthusiastic commitment explained a large portion of inter-individual variability, which was no longer significant in this model.

Table 2
Repeated Measures Linear Mixed Models With Physical and Emotional Exhaustion as Dependent Variable

	Physical and emotional exhaustion					
	Model 1		Model 2		Model 3	
	Estimate	*SE*	Estimate	*SE*	Estimate	*SE*
Fixed effects						
Intercept	2.52***	0.07	2.72***	0.06	2.52***	0.04
Time					n.s.	
T1 (*Baseline*)			-			
T2			-0.45***	0.09		
T3			-0.16	0.09		
Sex					n.s.	
Age					0.15***	0.04
Years of experience					n.s.	
Category					n.s.	
Competitive level					n.s.	
Somatic anxiety					0.10*	0.04
Worry					0.11**	0.04
Concentration disruption					0.15***	0.04
Enthusiastic commitment					0.16***	0.04
Coerced commitment					n.s.	0.04
Random effects						
Within-level variance	0.94***	0.06	0.89***	0.06	0.82***	0.06
Between-level variance	0.10*	0.05	0.12*	0.05	0.09	0.05
ICC	0.09		0.11		0.09	

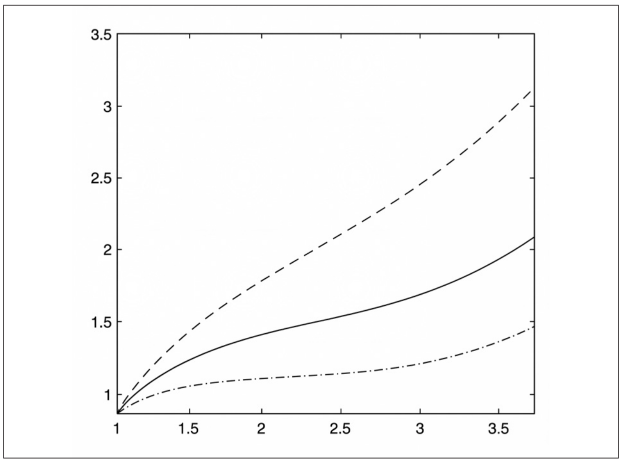
Note. Estimates are unstandardized coefficients. *SE* = standard error; ICC = intraclass correlation coefficient. *$p < .05$, **$p < .01$, ***$p < .001$. n.s. = not significant.

Figure 1
Adjusted odds ratio with a 95% confidence interval for the association between somatic anxiety and physical and emotional exhaustion



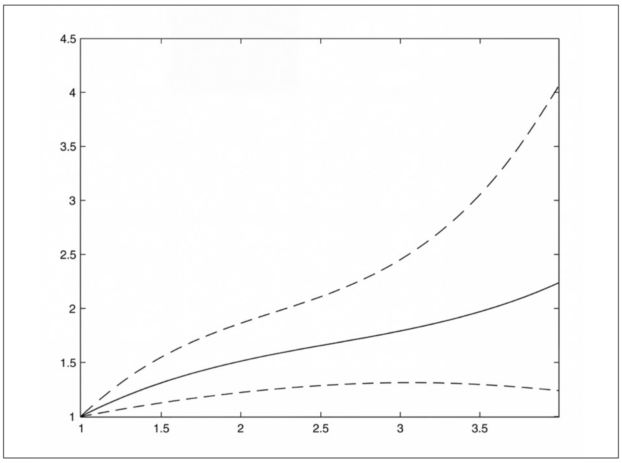
Note. Physical and emotional exhaustion was modelled by restricted cubic splines using a repeated measures linear mixed model and adjusted by the variables *worry, concentration disruption*, and *enthusiastic commitment*.

Figure 2
Adjusted odds ratio with a 95% confidence interval for the association between worry and physical and emotional exhaustion



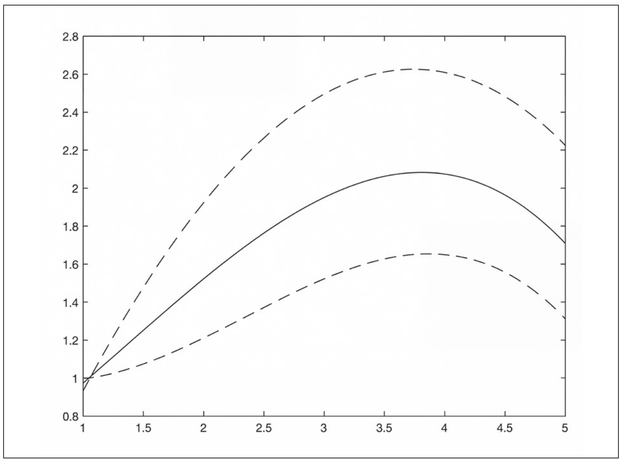
Note. Physical and emotional exhaustion was modelled by restricted cubic splines using a repeated measures linear mixed model and adjusted by the variables *somatic anxiety*, *concentration disruption*, and *enthusiastic commitment*.

Figure 3
Adjusted odds ratio with a 95% confidence interval for the association between concentration disruption and physical and emotional exhaustion



Note. Physical and emotional exhaustion was modelled by restricted cubic splines using a repeated measures linear mixed model and adjusted by the variables *somatic anxiety*, *worry* and *enthusiastic commitment*.

Figure 4
Adjusted odds ratio with a 95% confidence interval for the association between enthusiastic commitment and physical and emotional exhaustion



Note. Physical and emotional exhaustion was modelled by restricted cubic splines using a repeated measures linear mixed model and adjusted by the variables *somatic anxiety*, *worry* and *enthusiastic commitment*.

Cubic Splines

Figures 1 through 4 present the non-linear associations between physical and emotional exhaustion and the key predictors, modelled using constrained cubic splines. Figure 1 – Somatic Anxiety (range 1–4): displays a progressive upward trend that becomes statistically significant at point 3 (OR = 1.35, 95% CI [1.03, 1.78]). Figure 2 – Worry (range 1–4): shows a steep increase between points 1 and 2 (OR = 1.45, 95% CI [1.13, 1.87]) and again between points 3 and 4 (OR = 2.05, 95% CI [1.37, 3.07]). Figure 3 – Concentration Disruption (range 1–4): follows a similar pattern, with a sharp incline near point 4 (OR = 2.24, 95% CI [1.23, 4.09]). Figure 4 – Enthusiastic Commitment (range 1–5): Displays a marked increase up to point 3.5 (OR = 2.10, 95% CI [1.65, 2.68]), followed by a gradual decline toward point 5 (OR = 1.75, 95% CI [1.34, 2.30]).

Discussion

This study explored the progression of physical and emotional exhaustion among high-level adolescent swimmers throughout a competitive season and its associations with competitive anxiety and sport commitment. A secondary aim was to examine how demographic (age, sex) and performance-related factors (category and competitive level) moderated these dynamics. The findings provide valuable insights into how motivation, stress, and fatigue interact in elite youth sport, offering both theoretical and practical implications for long-term performance and athlete well-being.

Longitudinal Patterns of Exhaustion

As expected in the first hypothesis, physical and emotional exhaustion fluctuated over the season. A decrease was observed mid-season (T2), followed by a notable increase by the end (T3). These trends reflect the cumulative effects of training intensity and competitive stress. Mid-season reductions may relate to tapering, workload adjustments, or improved coping, while the spike at season's end likely stems from increased psychological pressure and physical load during key competitions. These seasonal fluctuations in exhaustion are broadly consistent with recent evidence linking burnout trajectories to competitive performance indicators in youth and adult samples (Olsson et al., 2025), reinforcing the idea that monitoring exhaustion over time is crucial for both performance optimization and athlete retention.

These findings align with the cumulative stress and recovery model (Kellmann, 2002). Initial motivation may serve as a psychological buffer, but sustained exposure without sufficient recovery leads to fatigue accumulation. This reinforces the importance of integrating psychological recovery phases, not just physical tapering, into seasonal training plans.

Anxiety, Commitment, and Exhaustion

The second hypothesis was partially supported. Somatic anxiety and worry were significantly linked to higher exhaustion, whereas concentration disruption showed a weaker association. These results indicate that physical tension and cognitive rumination—more than attentional lapses—exert greater pressure on an athlete's energy reserves.

Multidimensional models of anxiety (Martens et al., 1990) support this distinction. Somatic symptoms and worry appear to fuel exhaustion through psychophysiological mechanisms involving sleep disruption, elevated cortisol levels, and muscular tension (Tossici et al., 2024). These findings highlight the importance of psychological strategies—such as mindfulness, relaxation, and cognitive restructuring—to mitigate the effects of anxiety and protect athletes from fatigue.

A notable outcome concerns sport commitment. Enthusiastic commitment—typically viewed as protective—was positively associated with physical and emotional exhaustion. This supports the *passion paradox* (Vallerand et al., 2008), where athletes driven by strong intrinsic motivation may overexert themselves, neglecting recovery and well-being in the pursuit of performance.

In this context, enthusiastic commitment becomes a double-edged sword. While it fosters engagement and resilience, it can promote unhealthy overtraining if not managed with appropriate rest. Highly committed athletes may train through pain or ignore warning signs of fatigue. Coaches must recognize that high motivation does not equal immunity from burnout.

Interestingly, coerced commitment—often associated with external pressure—did not significantly correlate with exhaustion. This suggests that external demands alone may not result in sustained energy depletion unless internalized. It is possible that athletes who feel externally pressured disengage earlier or invest less energy, avoiding the same cumulative fatigue patterns.

Taken together, anxiety, commitment, and exhaustion form a dynamic triangle. Competitive anxiety elevates stress, whereas excessive motivation without recovery amplifies fatigue. Interventions should therefore be holistic, addressing both psychological and motivational sources of exhaustion.

Influence of Demographics and Competition Level

Age, sex, and competitive level significantly influenced exhaustion. Younger athletes (13–14 years) reported higher early-season exhaustion, possibly due to limited experience and resilience. Older swimmers (15–16 years) showed sharper increases at season's end, reflecting accumulated stress and rising competitive expectations.

Sex differences were also evident. Female swimmers consistently reported higher levels of exhaustion throughout the season. These results align with existing literature on adolescent female vulnerability to emotional stress, influenced by hormonal, social, and psychological factors (Wilczyńska et al., 2022). Such differences highlight the importance of sex-sensitive coaching and mental health support.

Swimmers at national competitive levels exhibited greater exhaustion, particularly at the end of the season. High-performance contexts involve greater physical demands and psychological pressure, requiring well-planned recovery protocols and emotional support systems. These findings suggest that elite adolescent athletes face similar psychological risks to adult professionals, despite being in developmental stages.

Practical Implications

These findings offer several practical applications. First, fatigue should be monitored multidimensionally using both physical indicators and psychological assessments. Regular mood check-ins, well-being scales, and discussions with athletes can help identify early signs of exhaustion before performance declines or dropout occurs.

Second, coaches and support staff must understand that enthusiasm can conceal underlying fatigue. High-commitment athletes are not necessarily low-risk; in fact, their strong internal drive may predispose them to silent overtraining. Encouraging open communication and normalizing recovery is essential.

Third, sport organizations should embed psychological support into youth training programs. Access to mental skills coaching, mindfulness workshops, and education on emotion regulation may reduce the burden of competitive anxiety and improve athletes' self-management.

Moreover, motivational balance should be cultivated. Athletes must learn to align ambition with self-care, recognizing that sustainable progress depends on both effort and recovery. Coaches should foster environments where personal development is valued alongside performance.

Lastly, age- and sex-specific interventions are necessary. Younger athletes benefit from guidance and stress-coping training. Older swimmers may need support in managing the cumulative demands of competition. Female athletes may require emotional support strategies tailored to their specific stress responses. Competitive level should also inform recovery planning, especially for athletes facing elite demands.

Limitations and Future Research

This study has some limitations. The use of self-report instruments, while common in psychological research, can introduce bias. Future studies should incorporate objective physiological markers of fatigue, such as HRV, sleep patterns, or biochemical indicators, to provide a more robust understanding of exhaustion.

Additionally, the sample consisted solely of Spanish swimmers, which may limit generalizability. Cultural, structural, and coaching differences across countries could affect how adolescent athletes experience stress and burnout. Comparative international studies are needed to clarify how these factors vary by context.

The study covered a single competitive season. While this longitudinal design offers strength over cross-sectional studies, extending the analysis across multiple seasons would allow examination of whether fatigue patterns persist, evolve, or diminish over time. Such data could help identify critical windows for intervention.

Further research is needed to explore how external factors—such as academic load, family dynamics, or social support—interact with psychological variables. A biopsychosocial framework could capture the complex realities of young athletes' lives and inform more personalized intervention models.

In addition, although the Athlete Burnout Questionnaire assesses three dimensions, the present study focused exclusively on physical and emotional exhaustion. This choice is consistent with the central role of exhaustion in burnout theory and research (Raedeke & Smith, 2001; Gustafsson et al., 2018), but it restricts the scope of our conclusions to this core component and future studies should examine whether similar patterns emerge for reduced sense of accomplishment and sport devaluation.

The longitudinal design was also affected by natural attrition between T1 and T3. Despite our efforts to minimize dropout through repeated reminders and clear communication, some swimmers did not complete all waves, and a small number of demographic responses (competitive category and level) were recorded in a non-interpretable format due to the open-response nature of these items. Although the main psychological variables were complete and mixed-model procedures are relatively robust to missing data, the results should be generalized to all initially eligible swimmers with appropriate caution. Finally, the study was not designed as a specific pre-post comparison between T1 and T3, but rather as a multi-wave analysis of trajectories; future research may integrate both types of analysis to provide a more complete picture of seasonal changes.

Conclusions

This longitudinal study offers valuable insights into the progression of physical and emotional exhaustion among high-level adolescent swimmers, underscoring the dynamic interplay between psychological, motivational, and demographic factors throughout a competitive season. The findings highlight the need for a nuanced, athlete-centered approach to managing fatigue and promoting well-being in youth sport.

First, the results confirmed a cyclical pattern of exhaustion, where energy levels improve briefly mid-season but increase sharply as competition intensifies. This seasonal fluctuation emphasizes the importance of timely intervention, not only during peak phases but throughout the training calendar.

Second, competitive anxiety—particularly somatic symptoms and worry—emerged as key predictors of exhaustion. Interventions that address both physical stress responses and cognitive rumination may help buffer athletes against chronic fatigue.

Third, the paradox of enthusiastic commitment challenges traditional assumptions about motivation. While intrinsic motivation fosters persistence, it may also increase the risk of overtraining if not accompanied by structured recovery strategies. Coaches must be attentive to signs of *invisible fatigue* in highly driven athletes.

Fourth, demographic and competitive factors, including age, sex, and competitive level, significantly influenced exhaustion trajectories. These findings call for tailored support frameworks that reflect each athlete's specific developmental and performance context.

Finally, this study offers clear practical recommendations. Coaches and sport psychologists should collaborate to create psychologically informed training programs that balance performance with recovery. Mental health literacy, stress management education, and individualized monitoring can contribute to healthier and more sustainable athletic development.

By addressing these factors holistically, support teams can foster environments where young athletes not only perform but thrive.

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SPORT TRAINING

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Goalkeeper Competitive Level and the Organization of Spanish Futsal Attacks: An Exploratory Observational Study

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Artistic swimmers performing a synchronized figure with technical precision and postural control.
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Abstract

This observational study explored how competitive level relates to the organization of futsal attacking actions involving the goalkeeper in Spain. We analyzed 773 interventions (professional: 529 from the *Liga Nacional de Fútbol Sala*; amateur: 244, from the 2nd and 3rd divisions) from the 2023–2024 season. A Random Forest model classified competitive level with 71.1% accuracy, identifying game moment (e.g., M30), pass type (short vs. long), and action outcome (progression/possession) as key discriminators. Logistic regression indicated that foot receptions and short, precise passes were positively associated with professional status (e.g., M30 coefficient = 0.41; progression = 0.23; possession = 0.19). Principal Component Analysis showed partial separation of profiles, while K-Means yielded two clusters: Cluster 1 contained 66.8% professional players and was characterized by teammate-origin receptions, foot control, and short passes under low pressure; Cluster 0 included 52.9% amateur players, with earlier-phase actions (M10), hand receptions, and bowling passes. Professional goalkeepers exhibited greater adaptability by acting under pressure and facilitating structured build-up, whereas amateur goalkeepers favored conservative, low-risk choices. These findings underscore the goalkeeper's evolving offensive role and offer practical insights for talent identification, tactical training, and performance assessment across competition levels; interpretations are exploratory and bounded by the observational design and league-specific context.

Keywords: competitive standard, logistic regression, match analysis, team sports

Introduction

Although futsal goalkeepers are traditionally the last line of defense, research shows that 67% of their interventions have offensive intentions (Oszmaniec & Szwarc, 2015). Historically, their main function was to block shots and prevent goals. However, in modern futsal, their role has expanded significantly to include active participation in the team's offensive phase. The evolution of the game, alongside regulatory changes by FIFA allowing goalkeepers to act as field players during live play (5vs4+GK), has prompted coaches and analysts to reconsider the tactical potential of goalkeepers, not only as defenders but also as auxiliary outfield players who can contribute to attack construction and ball circulation. This shift has been particularly evident in scenarios where the opponent applies high pressure during the build-up phase. In such cases, using the goalkeeper as an additional field player can help to break the press and create numerical superiority (Corrêa et al., 2014; Vicente-Vila & Lago-Peñas, 2016). Their increasing technical proficiency with their feet has facilitated this change, as observed in elite-level futsal (Amatria et al., 2021). In this vein, Méndez et al. (2019b) highlighted that although 5v4+GK strategies are more effective at maintaining possession, they do not necessarily translate into more goal-scoring opportunities, indicating that, while the tactic aids in controlling play, its offensive yield may be limited. Beyond these FIFA regulatory changes, evidence from stakeholders in Spain suggests that the post-2006 harmonization of futsal rules—particularly in sideline and corner restart procedures—diminished perceived spectacle and constrained adaptive behaviors of players, coaches, and referees, as shown in a descriptive cross-sectional study combining questionnaires and field diaries (Cachon Zagalaz, et al., 2014).

The link between space, numerical balance, and pressure is crucial in understanding the success of offensive strategies in futsal. Similar dynamics have been observed in football, where teams facing low defensive resistance were more successful at creating scoring chances, and ball possession improved when teams were able to manage opponent pressure effectively (Schulze et al., 2019; Forcher et al., 2024). Recent futsal-specific studies provide deeper insight into this phenomenon. Vicente-Vila and Lago-Peñas (2016) concluded that the inclusion of the goalkeeper as a fifth field player significantly improves possession effectiveness, especially in short possessions under low defensive pressure. Silva et al. (2021) similarly observed that the primary offensive role of goalkeepers in both professional and amateur games is to support ball retention, with direct contributions to goal scoring remaining sporadic. Furthermore, Szwarc and Oszmaniec (2020; 2021) found that, among top-level teams, most goalkeeper actions during offensive play were aimed at gaining territory and initiating build-up phases. Interestingly, their studies noted that the game's score (winning, drawing, or losing) had minimal impact on the style and frequency of these actions, suggesting a consistent offensive role regardless of match context. Additionally, the tactical decision to use an outfield goalkeeper alters the physical dynamics of play. According to De Jong et al. (2022), teammates of an outfield goalkeeper covered less distance at high intensity (above 15.4 Km/h), indicating a more positionally oriented offensive structure during such scenarios. This reinforces the idea that involving the goalkeeper in outfield roles is not merely a reactive tactic, but a deliberate strategy requiring coordination, technical execution, and tactical awareness. Moreover, classic time–motion analysis in elite futsal quantified the spatial–temporal demands on players, demonstrating alternating bouts across five displacement rhythms (walking, jogging, medium speed, high speed, and sprint), with frequent lateral and backward movements and ball-carrying runs—constraints that heighten the need for rapid perception—action coupling, including for goalkeepers (Hernández, 2001).

Collectively, the reviewed evidence reinforces the evolving perception that futsal goalkeepers are no longer limited to defensive responsibilities within their own third of the court. Rather, they are emerging as dynamic contributors to the offensive phase, particularly in structured build-up play and in maintaining possession under high pressure. While their direct involvement in goal-scoring opportunities may remain secondary, their participation is increasingly recognized as critical for establishing and sustaining favorable attacking conditions in contemporary futsal. In this vein, we explicitly foreground the contextual variables that most strongly constrain goalkeeper behavior, thus considering the time of play, operationalized in four 10-min segments, the match status (draw, winning, or losing), and strategic situation, in terms of the immediate game context captured through defensive pressure on the ball and numerical configuration, including goalkeeper-as-outfield (5v4+GK). These variables are not ancillary; they are primary constraints shaping the timing, risk profile, and technique of goalkeeper interventions in possession. Empirically, the interaction of match time and scoreline is decisive. Coaches more frequently adopt 5v4+GK under adverse scorelines in late, 'critical' minutes, and goals scored or conceded in this configuration are tightly conditioned by these situational factors, with short and precise attacks being most effective (Méndez-Domínguez et al., 2019; 2021; Vicente-Vila & Lago-Peñas, 2016). Defensive pressure further moderates goalkeeper effectiveness because ball possession success increases when pressure is low and sequences are brief, conditions under which goalkeepers more profitably act as facilitators in build-up (Vicente-Vila & Lago-Peñas, 2016; FIFA Technical Study Group, 2021). Numerical superiority with an outfield goalkeeper also reconfigures physical and positional demands, reducing teammates' high-intensity running while requiring greater locomotor output from the goalkeeper and supporting a more stable positional structure (De Jong et al., 2022). Furthermore, match status alone does not always determine an elite goalkeeper's style across all actions, but situational clusters emerge when scoreline is considered jointly with time and pressure, which justifies considering these contextual factors (Szwarc & Oszmaniec, 2021; Méndez-Domínguez et al., 2019). Therefore, to fulfil this expanded role, goalkeepers must possess not only traditional defensive competencies but also technical proficiency with the ball comparable to that of outfield players. However, this dual skill set is relatively rare and likely restricted to players competing at the highest levels of the sport. Accordingly, the aim of the present study was to examine the differential impact of goalkeeper involvement on offensive effectiveness, specifically in terms of goal-scoring opportunities, goals scored, and team ball possession, between professional (*Liga Nacional de Fútbol Sala*) and amateur (2nd and 3rd division) Spanish futsal leagues during the same competitive season. It was hypothesized that goalkeeper participation in attacking phases would have a distinct influence across competition levels, contributing more significantly to ball possession and the creation of scoring opportunities and goals in professional futsal compared to amateur levels.

Methods

Observational Design

This investigation employed a nomothetic, punctual, and multidimensional observational design, consistent with the canonical framework of systematic observational methodology. This design typology ensures scientific rigor when analyzing naturally occurring behaviors in complex sport settings.

Following Anguera & Hernandez-Mendo (2014), a nomothetic approach was adopted to capture behavioral variability across a broad set of goalkeepers; a punctual structure was selected, as observations were confined to a single competitive season; and a multidimensional configuration was used to incorporate several interacting behavioral dimensions including contextual, spatial, technical, and outcome-related variables. The study adhered to established observational principles regarding ecological validity, perceptual exhaustiveness, and systematic coding structures recommended for mixed-methods observational sport research.

Participants

A total of 26 goalkeepers were included in the analysis. Across the 2023–2024 season, these goalkeepers accounted for 529 goalkeeper-outfield participations in the Spanish *Liga Nacional de Fútbol Sala* (LNFS) and 244 participations in Spanish amateur futsal leagues (2nd and 3rd divisions). A formal *a priori* power analysis was not feasible because the study did not prospectively recruit participants from a defined population; instead, it exhaustively included all available observations (convenience census) from the target competitions during the observation period. Consistent with current recommendations on transparent sample size reporting, we explicitly justify this choice and delineate the inferential scope of our analyses (i.e., estimation, pattern detection, and hypothesis-generating insights rather than confirmatory hypothesis testing with prospective power guarantees). As outlined by Lakens (2022), acceptable justifications include (a) collecting data from (almost) the entire available population and (b) explicitly acknowledging when a traditional *a priori* power analysis is not applicable due to design constraints. The league permitted the use of images for research purposes. The Blanquerna Research Committee approved the protocol and procedures with reference number 2425006D and granted that the study complies with the European data protection regulation (General Data Protection Regulation) regarding the processing of publicly available team-sport data.

The matches were systematically analyzed following the systematic observational methodology (Anguera et al., 2011). LINCE PLUS software (Soto et al., 2021) was used for notational analysis, and the data were transferred to Microsoft Excel (Microsoft Excel 2016, Microsoft Corporation, Redmond, WA, USA) and SPSS (IBM SPSS Statistics Version 30.0, IBM Corp., Armonk, NY, USA) for further analysis. All data were recorded using concurrent time-based (Type IV) observational recording, allowing multiple dimensions to co-occur within the same behavioral event. Content validation followed the criterion of authority within systematic observational methodology. Four experts (national futsal coach of the *Real Federación Española de Fútbol*) independently rated the conceptual adequacy and clarity of each criterion and category (response options: YES/NO). An item was included if ≥ 3 experts responded YES; otherwise, it was excluded or revised. Following Aixa-Requena et al. (2025), we computed the percentage of positive coincidences by counting YES–YES agreements across all expert pairs for every item (with six pairs per item) and dividing by the total possible pairs. We then derived a two-sided exact binomial 95% confidence interval for the overall agreement rate. This authoritybased validation procedure conforms to the canonical prescriptions of the systematic observational methodology for developing ad hoc instruments (Anguera & Blanco, 2003; Anguera et al., 2011).

Two experienced observers (8 years of experience in the notational analysis of futsal events using LINCE), participated in the intra- and inter-rater reliability process using 10% of the sample. The observers' data were compared using Cohen's Kappa index (κ) (Robinson & O'Donoghue, 2007), obtaining a very good agreement between both independent observers.

Observational Instrument. Criteria and Categories

Table 1 shows the criteria, the categories, the codes and a description of the observational tool.

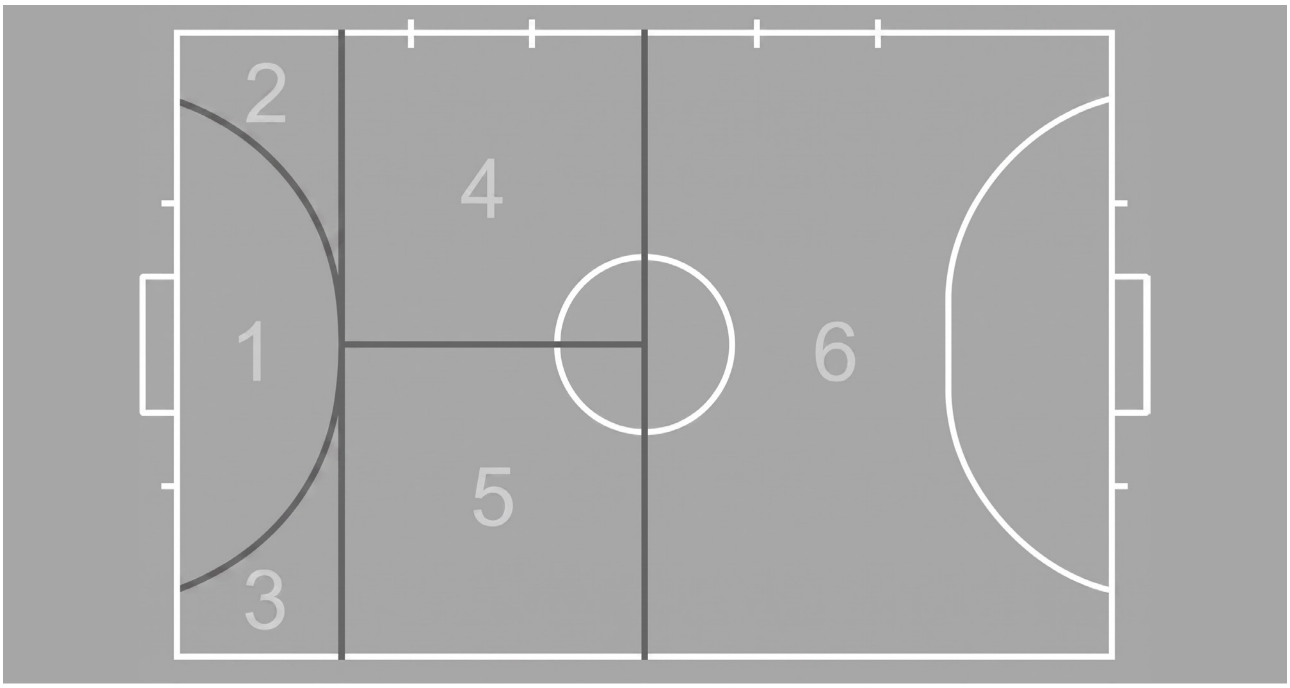
Table 1
Observational Tool for the Analyses

Criteria	Category	Code	Description
Score	Winning 2 goals	W2	Goalkeeper's team winning by 2 goals or more
	Winning 1goal	W1	Goalkeeper's team winning by 1 goal
	Draw	D	Draw
	Losing 1 goal	L1	Goalkeeper's team losing by 1 goal
	Losing 2 goals	L2	Goalkeeper's team losing by 2 goals or more
Moment of the match	Moment 0-10	M10	Time from 0 to 9:59 min
	Moment 10-20	M20	Time from 10 to 19:59 min
	Moment 20-30	M30	Time from 20 to 29:59 min
	Moment 30-40	M40	Time from 30 to 40 min
Pressure on the ball	No pressure	NOPR	No-possessing team does not apply pressure
	Pressure players	PRPL	No-possessing team applies pressure to all outfield players, but not to the goalkeeper
	Pressure all	PRALL	No-possessing team applies pressure to all opposing players (including the goalkeeper)
Receiving technique	Hand reception	HAND	Goalkeeper takes the ball with the hands
	Foot reception	FOOT	Goalkeeper takes the ball with the foot
Origin of the ball	Partner	PART	Partner passes the ball to the goal-keeper
	Opponent	OPP	Ball arrives at the goalkeeper from an opponent
Reception zone (see figure 1)	Reception zone 1	R1	Goalkeeper receives the ball in zone 1
	Reception zone 2	R2	Goalkeeper receives the ball in zone 2
	Reception zone 3	R3	Goalkeeper receives the ball in zone 3
	Reception zone 4	R4	Goalkeeper receives the ball in zone 4
	Reception zone 5	R5	Goalkeeper receives the ball in zone 5
	Reception zone 6	R6	Goalkeeper receives the ball in zone 6
Action zone (see figure 1)	Action zone 1	A1	Goalkeeper executes the action in zone 1
	Action zone 2	A2	Goalkeeper executes the action in zone 2
	Action zone 3	A3	Goalkeeper executes the action in zone 3
	Action zone 4	A4	Goalkeeper executes the action in zone 4
	Action zone 5	A5	Goalkeeper executes the action in zone 5
	Action zone 6	A6	Goalkeeper executes the action in zone 6

Table 1 (Continuation)
Observational Tool for the Analyses

Criteria	Category	Code	Description
Goalkeeper action	Bowling pass	BOW	Goalkeeper performs a bowling pass
	Baseball pass	BAS	Goalkeeper performs a baseball pass
	Parabolic pass	PAR	Goalkeeper performs a parabolic pass
	Short pass	SHORT	Goalkeeper performs a short pass
	Long pass	LONG	Goalkeeper performs a long pass
	Head hit	HEAD	Goalkeeper hit the ball with the head
	Dribbling an opponent	DRIB	Goalkeeper performs a dribble against an opponent
	Shot to target	SHOT	Goalkeeper shots to the target
	Ball refuses	REF	Goalkeeper refuses the ball
Action outcome (positive)	Goal goalkeeper	GOG	Goalkeeper scores
	Goal goalkeeper's team	GOT	Goalkeeper's team scores
	Chance created	CHA	Goalkeeper's team creates a chance to score
	Possession ball	POSS	Goalkeeper's team keep the ball
	Progression ball	PROG	Goalkeeper's team progresses 1 line of pressure (1 line = 10 m)
	Ball out	OUT	Ball out of the court in favor of the goalkeeper's team
Action outcome (negative)	Opponent's goal	OPSC	Opponent team scores
	Opponents chance	OPCH	Opponent team creates a chance to score
	Recuperation goalkeeper	RECG	Opponent team regains possession following a goalkeeper error
	Recuperation player	RECP	Opponent team regains possession following an outfield player error
	Ball out goalkeeper	OUTG	Ball out of the court favoring the opponent team following a goalkeeper intervention
	Ball out player	OUTP	Ball out of the court favoring the opponent team following an outfield player intervention

Figure 1
Court Zones (Vicente-Vila & Lago-Peñas, 2016)



Procedures

Video footage of the professional matches was obtained from the official website of the *Real Federación Española de Fútbol*. Amateur matches were registered in agreement with the local teams and the corresponding federative authorities. Goalkeeper interventions were observed frame-by-frame from a side view of the court. Two experienced observers, each with eight years of specialist experience in futsal notational analysis using LINCE and LINCE Pro, independently coded 32 interventions from professional futsal matches (11% of the total sample, randomly selected), and 25 interventions from amateur futsal matches (10% of the total sample, randomly selected) under identical viewing conditions and blinded to each other's work and to the study hypotheses, following frame-by-frame procedures. To assess inter-rater reliability, both observers coded the same video subset concurrently, and their coding was compared using Cohen's kappa (κ), which yielded values ranging from .87 to 1, indicating very good to almost perfect agreement according to established benchmarks in performance analysis research. For intra-rater reliability, the principal observer re-coded the same clips after a 10–15-day washout interval, consistent with validated temporal stability protocols described in observational methodology, again producing κ values between .89 and 1, demonstrating strong stability of coding decisions over time. Cohen's kappa was calculated using IBM SPSS Statistics Version 30.0.0.

Statistical Analysis

To test the hypothesis that the behavior of amateur and professional futsal goalkeepers differs across multiple observed categories, a multi-step advanced statistical analysis was conducted. Firstly, a Principal Component Analysis (PCA) was applied to one-hot encoded categorical data to explore underlying patterns and visualize potential differentiation in goalkeeper behaviors based on competitive level (Standard 1 for amateur, Standard 2 for professional). Although PCA is not inherently designed for categorical data, it was used here as a surrogate for Multiple Correspondence Analysis (MCA), which could not be implemented in the current computational environment. Then, a supervised classification approach using a Random Forest classifier was employed to evaluate the predictability of goalkeeper level based on game-action variables. Model performance was assessed using classification accuracy, a confusion matrix, and a variable importance ranking. Furthermore, a multinomial logistic regression was used to identify which variables significantly contributed to distinguishing between amateur and professional goalkeepers. Due to convergence issues in full models, a reduced model using the top 10 most important predictors (from the Random Forest model) was fitted to obtain interpretable coefficients. Finally, unsupervised clustering was performed using the k-means algorithm on the encoded dataset to identify natural groupings of goalkeeper behaviors without using level labels. The resulting clusters were cross-tabulated with goalkeeper type to assess alignment with known classifications. All statistical procedures were executed using Python (version 3.11), with libraries including scikit-learn, statsmodels, pandas, and matplotlib.

Results

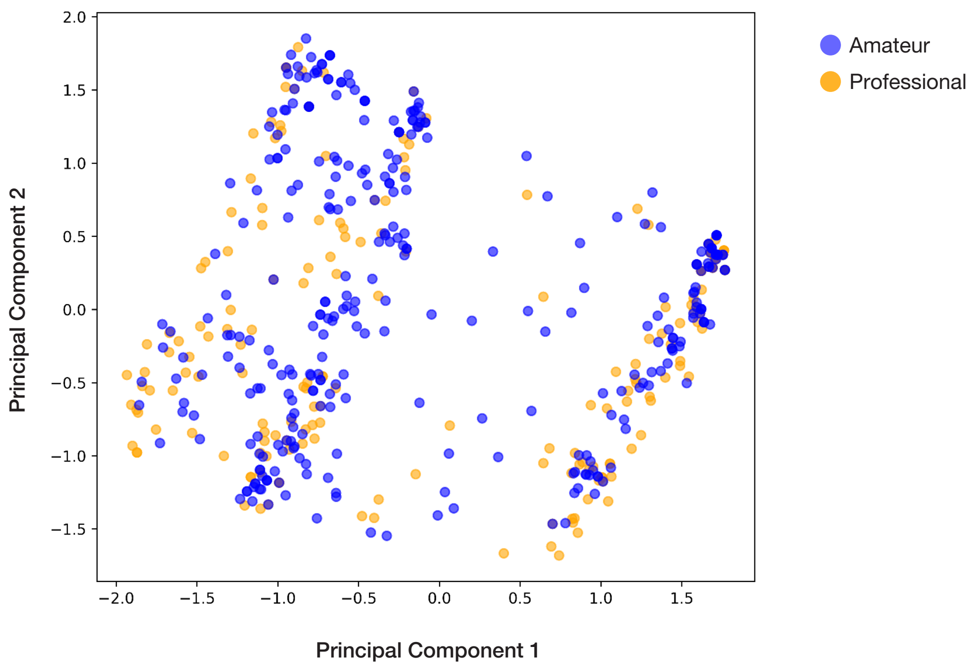
Figure 2 presents a Principal Component Analysis biplot showing the first two components derived from categorical game data. A partial visual separation was observed between amateur and professional goalkeepers, with some overlap, suggesting underlying behavioral distinctions. The Random Forest classifier achieved an overall classification accuracy of 71.1%, with higher precision for professional goalkeepers (77.7%) compared to amateurs (61.5%). The confusion matrix is shown in Figure 3.

Table 2 lists the top 10 most important features for classification based on Gini importance scores from the Random Forest model. Variables such as "Moment of the match: M30" and "Action outcome: PROG" were prominent discriminators. Due to multicollinearity limitations, the multinomial logistic regression was conducted using only the top predictors. Table 3 displays the estimated coefficients, where positive values indicate a higher likelihood of professional goalkeeper classification.

k-means clustering resulted in two groups, with Cluster 1 composed of 66.8% professional goalkeepers and Cluster 0 composed of 52.9% amateur goalkeepers. Figure 4 depicts the cluster composition. Table 4 summarizes the modal characteristics of each cluster, highlighting distinct behavioral profiles for each group.

Figure 2

Principal Component Analysis (PCA) Differentiating Amateur and Professional Futsal Goalkeepers Based on Encoded Contextual, Technical, and Outcome Variables



Note. Data were one-hot encoded prior to PCA, producing two principal components that summarize multivariate behavioral patterns across goalkeeper interventions.

Figure 3

Confusion Matrix Depicting the Classification Performance of the Random Forest Model Differentiating Amateur and Professional Goalkeepers

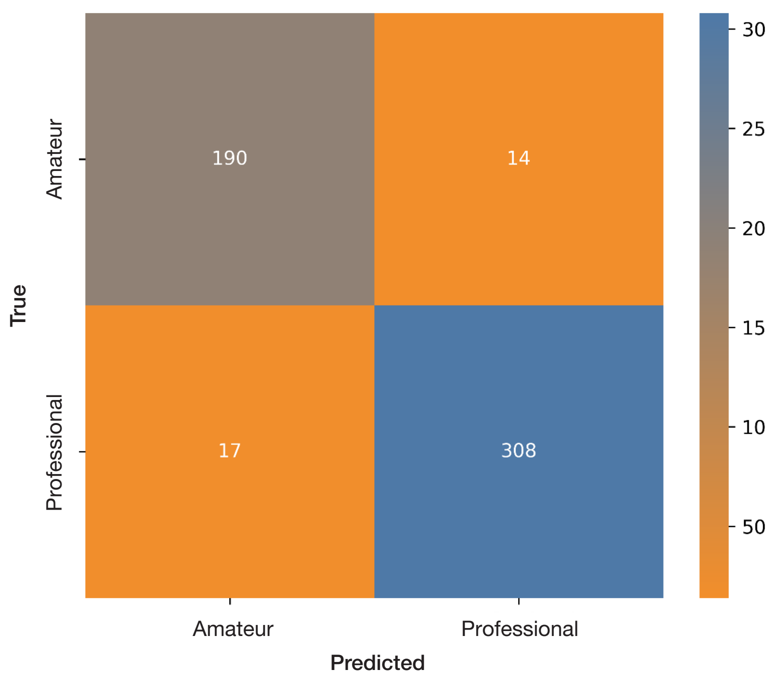


Table 2
Top 10 Most Important Variables (Random Forest)

Feature (Encoded Category = Value)	Importance
Score _W2	0.0537
Moment of the match_M10	0.0457
Moment of the match_M30	0.0444
Moment of the match_M40	0.0413
Score _D	0.0391
Pressure on the ball_NOPR	0.0373
Action outcome_PROG	0.0354
Moment of the match_M20	0.0348
Score _L2	0.0335
Action outcome_POSS	0.0326

Note. Score: D = Draw, W1 = Win by 1, W2 = Win by 2+, L1 = Lose by 1, L2 = Lose by 2+; Moment of the match: M10 = 0-10 min, M20 = 10–20 min, M30 = 20–30 min, M40 = 30–40 min; Pressure on the ball: NOPR = No pressure, PRPL = Pressure to players, PRALL = Full pressure; Receiving technique: HAND = Hands, FOOT = Foot; Origin of the ball: PART = Partner, OPP = Opponent; Reception/Action zone: R1 and A1 (see Figure 1); Goalkeeper action: BOW = Bowling pass, SHORT = Short pass; Action outcome: POSS = Keep possession.

Table 3
Logistic Regression Coefficients (Professional vs Amateur)

Feature (Encoded Category = Value)	Importance
const	0.7105
Moment of the match_M30	0.4123
Action outcome_PROG	0.2317
Action outcome_POSS	0.1939
Moment of the match_M20	0.1911
Moment of the match_M10	0.1764
Pressure on the ball_NOPR	0.1665
Moment of the match_M40	-0.0692
Score _D	-0.5641
Score _L2	-0.9335
Score _W2	-1.2566

Note. Score: D = Draw, W1 = Win by 1, W2 = Win by 2+, L1 = Lose by 1, L2 = Lose by 2+; Moment of the match: M10 = 0-10 min, M20 = 10–20 min, M30 = 20–30 min, M40 = 30–40 min; Pressure on the ball: NOPR = No pressure, PRPL = Pressure to players, PRALL = Full pressure; Receiving technique: HAND = Hands, FOOT = Foot; Origin of the ball: PART = Partner, OPP = Opponent; Reception/Action zone: R1 and A1 (see Figure 1); Goalkeeper action: BOW = Bowling pass, SHORT = Short pass; Action outcome: POSS = Keep possession.

Figure 4
Distribution of Amateur (orange) and Professional (blue) Goalkeepers Within Each K means Cluster: Cluster Composition Reflects Similarity of Encoded Behavioral Profiles

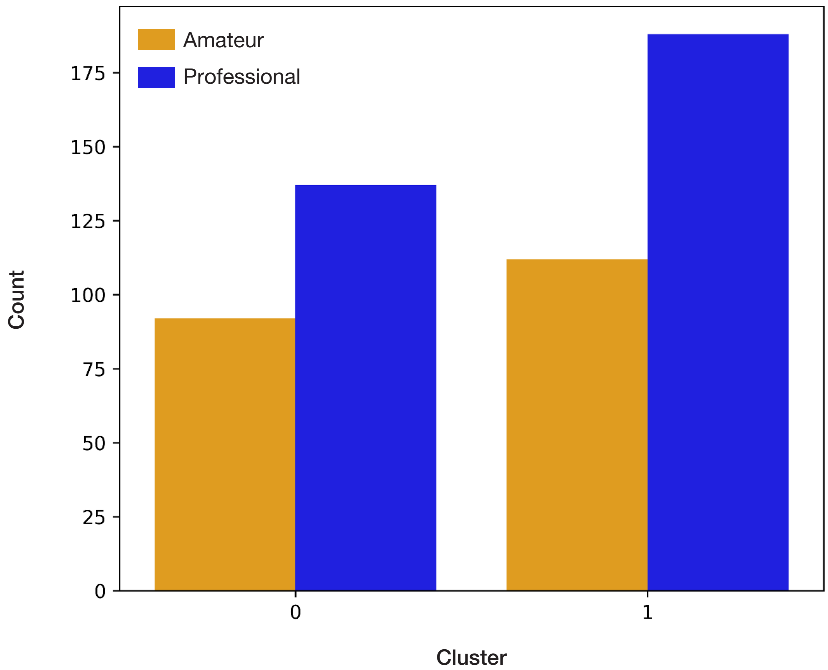


Table 4
Dominant Characteristics (Codes) per Cluster (K-means)

Cluster	Score	Moment of the match	Pressure on the ball	Receiving technique	Origin of the ball	Reception zone	Action zone	Goalkeeper action	Action outcome
0	D	M10	NOPR	HAND	OPP	R1	A1	BOW	POSS
1	D	M20	NOPR	FOOT	PART	R1	A1	SHORT	POSS

Note. Score: D = Draw, W1 = Win by 1, W2 = Win by 2+, L1 = Lose by 1, L2 = Lose by 2+; Moment of the match: M10 = 0–10 min, M20 = 10–20 min, M30 = 20–30 min, M40 = 30–40 min; Pressure on the ball: NOPR = No pressure, PRPL = Pressure to players, PRALL = Full pressure; Receiving technique: HAND = Hands, FOOT = Foot; Origin of the ball: PART = Partner, OPP = Opponent; Reception/Action zone: R1 and A1 (see Figure 1); Goalkeeper action: BOW = Bowling pass, SHORT = Short pass; Action outcome: POSS = Keep possession.

Discussion

The aim of this study was to investigate the offensive behaviors of futsal goalkeepers at different levels of competition, with the expectation that professional and amateur goalkeepers would demonstrate distinctive tactical profiles. The findings confirm this hypothesis, suggesting clear and systematic differences in behavior based on competitive level. These differences are manifested in the timing, type, and purpose of goalkeeper interventions during offensive phases.

The Principal Component Analysis (Figure 2) demonstrated a partial but notable separation between amateur and professional goalkeepers. This spatial divergence suggests an underlying structure of behavioral traits that correspond to player level. As observed in previous studies, elite goalkeepers in futsal are expected to participate more actively in offensive sequences, not only by initiating play but also by adapting their actions to evolving game contexts (Vicente-Vila & Lago-Peñas, 2016; Méndez et al., 2019b). The separation detected through PCA echoes findings from 11-a-side football, where similar analyses revealed differentiated spatial and temporal positioning of goalkeepers across competition levels (Lamas et al., 2018; Bassek et al., 2025). Supervised classification using a Random Forest model (Table 3) provided further support for this separation, achieving 71.1% accuracy in classifying goalkeeper level based solely on offensive action descriptors. Among the most predictive variables were contextual elements such as the “moment of the match: M30” and tactical outcomes such as progressive action. These variables correspond to behaviors previously described in the literature as indicative of strategic involvement, where elite goalkeepers operate as facilitators in build-up sequences rather than mere distributors (Paz-Franco et al., 2014; Szwarc & Oszmaniec, 2020). Professional goalkeepers were more likely to receive the ball from teammates and engage in short, precise passes under pressure, actions that demand high technical execution and rapid decision-making (Vilar et al., 2014). These findings are consistent with the work of Paz-Franco et al. (2014), who emphasize that tactical decision-making under pressure is a key differentiator between elite and sub-elite performers. Conversely, amateur goalkeepers tended to rely more on safer options such as hand receptions and bowling passes, particularly in early match stages (M10), reflecting a risk-averse and less versatile behavioral pattern. This rigidity was also observed in the work of Szwarc and Oszmaniec (2020), who argued that amateur goalkeepers generally engage in low-risk actions to retain possession rather than to generate offensive advantage. These results align with Méndez et al. (2019a), who found that top-ranked futsal teams adopt highly coordinated attacking profiles that often rely on the goalkeeper as an active component of the attacking structure, contributing to numerical superiority and facilitating dynamic positional rotations. This may explain the increased prevalence of progressive and context-aware actions observed in professional goalkeepers. Moreover, Corrêa et al. (2014) demonstrated that when goalkeepers assume outfield roles, the opposing team’s defensive organization is directly impacted, often leading to spatial disorganization. The strategic use of the goalkeeper as an additional attacker, therefore, is not just a technical or tactical choice but a systemic adaptation that reshapes team dynamics on both ends of the court. Additionally, Méndez-Domínguez et al. (2021) demonstrated that the strategic use of the fly goalkeeper, particularly in the final moments of elite futsal matches, is influenced by game status and match context, showing that goals scored using this strategy are highly dependent on situational conditions. This supports our finding that professional goalkeepers are not only technically skilled but tactically adaptive, deploying offensive interventions selectively in response to time-sensitive and score-sensitive match demands. Their study underscores that fly goalkeeper use is not random but governed by shared patterns in critical phases, which may explain the structured yet flexible actions observed in our elite participants.

The logistic regression analysis (Table 3) further substantiated the Random Forest findings, showing that technical actions such as foot reception, short passing, and receiving from teammates were positively associated with professional level. These elements suggest a higher degree of tactical integration, as supported by De Jong et al. (2022), who described the elite goalkeeper as a positional support in modern offensive schemes. The offensive role of the goalkeeper in futsal is not limited to restarting play but involves real-time problem-solving and the manipulation of space, often under pressure, to preserve or improve positional advantage (Travassos et al., 2012).

The k-means clustering (Figure 3, Table 4) suggests two clear profiles: one dominated by professional goalkeepers (Cluster 1), and the other more associated with amateurs (Cluster 0). Cluster 1's dominant behaviors included receiving the ball from a teammate, acting in later phases of the game (M20+), and opting for short or progressive passes. This aligns with previous characterizations of professional behavior as 'strategically delayed,' allowing for better interpretation of space and coordination with teammates (Szwarc & Oszmaniec, 2020; Vilar et al., 2014). By contrast, Cluster 0 behaviors, dominated by early-match actions and simpler passes, reflects more reactive and less structurally informed participation, which may stem from limited tactical training or reduced perceptual capacity (Wilkins et al., 2018). It is particularly noteworthy that amateur goalkeepers show a narrower behavioral repertoire. This might indicate that sub-elite futsal goalkeepers prioritize ball retention over dynamic offensive engagement. The supposed reduced tactical adaptability noted here may also stem from a lack of shared offensive patterns in amateur teams, as emphasized by Travassos et al. (2012), where synchronized decision-making across lines might be less developed.

From a methodological perspective, this study indicates the value of combining observational data with advanced mixed methods to investigate tactical behaviors in futsal (Camerino, Castañer & Anguera, 2012). Thus, stable tactical behaviors are best identified via repeated observations, context-sensitive analyses, and complementary analytical approaches rather than causal inference. This perspective supports interpreting our multivariate results (Random Forest, logistic regression, clustering) as convergent evidence of robust, recurring patterns in goalkeeper-in-possession behaviors across contexts, strengthening coherence between design, analysis, and claims while avoiding over-attribution of effects (Pompa et al., 2024). The analytical process follows key principles in performance analysis, notably the use of contextualized notational systems, multidimensional coding schemes, and multi-method triangulation as outlined by O'Donoghue (2010) and Hughes et al. (2019). The consistent use of categorical variables rooted in competition-relevant game situations strengthens the ecological validity of the dataset, a criterion emphasized by Anguera et al. (2011) in observational methodology. The integration of dimensionality reduction (PCA), supervised classification (Random Forest, logistic regression), and unsupervised clustering (k-means) offers a comprehensive framework that aligns with recent methodological trends in sports science. These techniques are particularly suitable for exploring complex interaction patterns without imposing restrictive *a priori* assumptions, a necessity in team sports where behaviors are emergent and nonlinear (Weiwei, 2021). In addition, methodological rigor is enhanced through reliability criteria consistent with the standards proposed by Anguera et al. (2017), such as the definition of exhaustive and mutually exclusive categories and the use of expert consensus during the design of the observational tool. The study also reflects the observational principles proposed by Lapresa et al. (2013), with a clear distinction between structural patterns and contextual dimensions, a feature necessary to properly account for tactical variability. These criteria are essential to ensure internal validity and the interpretative power of the conclusions drawn from coded game behavior. As demonstrated by Wilkins et al. (2018), combining qualitative and quantitative perspectives in sports analysis maximizes explanatory depth, especially when analyzing player-environment interactions such as those involving the goalkeeper. The current study adheres to these guidelines by using statistical models not only to classify but also to explain performance differences rooted in game context, tactical function, and temporal distribution of actions. This mixed strategy reflects best practices in contemporary performance analysis research, where the interaction between technical-tactical actions, game context, and player decision-making is analyzed as a dynamic system rather than a sequence of isolated events (Travassos et al., 2013; McLean et al., 2017).

Limitations

This study is observational and relies on a convenience census of goalkeeper offensive actions drawn from Spanish professional and amateur leagues within a single season; as such, causal inferences cannot be made, and the findings should be interpreted as exploratory associations rather than effects. The sampling frame (specific competitions, 2023–24 season) and contextual constraints (e.g., league styles, tactical norms, and scheduling) may limit generalizability to other countries, competition formats, or future seasons. In addition, although we implemented rigorous coding procedures with very high inter- and intra-rater agreement and used multivariate models to detect patterns, model outputs (e.g., variable importance, clustering structure) remain contingent on the selected categories, the one-season window, and the ecological variability of match contexts; unmeasured factors (e.g., team tactics, coaching instructions, player fatigue), could partly account for the observed profiles. Together, these limitations recommend caution in interpretation and underscore the need for multi-season, multi-league replications and confirmatory designs before deriving prescriptive conclusions beyond settings similar to those analyzed.

Conclusions

To conclude, the data confirm that professional futsal goalkeepers not only possess superior technical abilities but are also tactically integrated actors who influence the game's offensive flow. Their decision-making is more contextually tuned, their actions more temporally distributed, and their role better aligned with positional play principles. These attributes are consistent with the increasing complexity and multifunctionality required at elite levels and should inform both scouting and training practices moving forward.

The findings of this study offer actionable guidance for coaches and practitioners seeking to optimize the offensive contribution of futsal goalkeepers across competitive levels. Professional teams can enhance their attacking structure by further integrating the goalkeeper into controlled build-up play, emphasizing foot-based receptions, short passing under pressure, and coordinated positional rotations that exploit numerical superiority and facilitate progression. In contrast, amateur teams should prioritize foundational technical work, particularly first-touch quality, body orientation, and simple short-passing connections, to reduce reliance on low-risk hand distributions and encourage tactical involvement beyond the early phases of play. Across levels, designing training tasks that incorporate contextual constraints such as match moment, defensive pressure, and ball origin can foster more adaptive, context-sensitive behaviors. By incorporating goalkeeper-inclusive positional play circuits, pressure-resistance drills, and structured support patterns, coaches can cultivate decision-making, technical precision, and tactical synergy, enabling goalkeepers to act not only as defenders but also as meaningful contributors to their team's offensive organization.

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Assessing Power, Kinematic, and Muscle Oxygenation Asymmetries Between Legs During Incremental 400-m Track Running in Triathletes

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Abstract

Running on a 400-m track may induce asymmetries in power output (PWR), kinematics, or muscle oxygen saturation (SmO_2). This study primarily aimed to determine whether 400-m track running induces measurable differences in power output, kinematics, and muscle oxygen saturation between the inner and outer legs. The secondary aim was to evaluate the extent of asymmetries in power output, kinematics, and muscle oxygen saturation in triathletes during track running. PWR and kinematic data were collected using Stryd sensors placed on both shoes, while SmO_2 data were obtained via near-infrared spectroscopy (NIRS) devices positioned on the vastus lateralis (VL) muscles of both legs. Although SmO_2, PWR, and kinematic parameters showed changes corresponding to increased velocity during the VAM-EVAL test, an incremental running protocol in which speed increases by 0.5 $km{\cdot}h^{-1}$ every minute until exhaustion, repeated-measures ANOVA revealed significant main effects of leg (inner vs. outer) for power output (PWR), step length (SL), ground contact time (GCT), and vertical oscillation (VO). However, post hoc analyses identified significant inter-limb differences only for PWR at 80% of maximal aerobic speed (MAS), and for SL at 70% and 80% MAS. Regarding asymmetries, repeated-measures ANOVA showed no significant differences across intensities, except for SmO_2, with significant changes observed between 60–90% and 70–90% MAS. These findings highlight the potential of SmO_2 asymmetries measured via NIRS to non-invasively detect disparities in oxygen utilization between the legs, particularly at high intensities (90% MAS). This technology could assist athletes and coaches in identifying imbalances in oxygen delivery and utilization between legs, a critical factor for optimizing muscle performance.

Keywords: inter-limb asymmetry, kinematic analysis, muscle oxygen saturation, near-infrared spectroscopy, power output, VAM-EVAL test

Introduction

Running on a 400-m track is fundamental for training and performance assessment, providing a controlled setting for evaluating endurance and kinematic efficiency (Léger & Boucher, 1980). These tracks feature two straight sections (approximately 84.39 m each) and two curved sections with a radius of around 36.5 m (World Athletics, 2019). The curves present unique biomechanical challenges, requiring runners to manage continuous leftward turns. This asymmetrical movement places different mechanical and physiological demands on the inner and outer legs due to variations in loading, with potential implications for performance and injury risk (Alt et al., 2015). Supporting this perspective, Gilgen-Ammann et al. (2017) found that gait asymmetry was significantly greater in runners with a history of injury than in uninjured counterparts, suggesting that persistent asymmetries may reflect underlying vulnerabilities. This raises the question of whether pre-existing asymmetries may be the reason for these injuries (Knapik et al., 1991; Vasquez-Bonilla et al., 2022, 2023).

To better understand the origin of these asymmetries, it is essential to examine how curved-track running affects specific kinematic variables such as cadence (CAD), stride length (SL), and ground contact time (GCT). In response to the centrifugal forces generated during turning, athletes typically exhibit a shorter SL and longer GCT in the inner leg compared with the outer leg, particularly at higher running speeds. The inner leg serves as a stabilizer under increased compressive forces, while the outer leg provides greater propulsion to meet the biomechanical demands of the curve (Chang & Kram, 2007). In the study by Chang and Kram (2007), asymmetries between the inner and outer legs were observed during sprinting on a 6-m radius curve. The outer leg demonstrated a significantly greater SL compared to the inner leg (1.70 ± 0.10 m vs. 1.53 ± 0.02 m; $p < .05$). Although differences were also noted in step frequency (SF) (3.88 ± 0.13 steps s^{-1} vs. 3.56 ± 0.12 steps s^{-1}) and GCT (0.203 ± 0.008 s vs. 0.190 ± 0.006 s), these differences were not statistically significant. Hamill et al. (1987) investigated how runners adjusted lower-extremity function when navigating the curves of a 400-m track. Their study revealed significant asymmetries between the right and left limbs during curved running, particularly in the initial phase of foot contact. Notably, differences were observed in touchdown angles, maximum pronation angles, and mediolateral ground reaction forces. These findings suggest that transitions between curved and straight sections of the track require runners to adapt their gait patterns dynamically. Continuous leftward turning on curves imposes distinct mechanical and physiological demands on each leg, potentially affecting variables such as vertical oscillation (VO) and CAD (Hamill et al., 1987).

Over time, these asymmetrical mechanical loads may contribute to the development of inter-limb asymmetries, particularly in athletes who frequently train on curved tracks. This concept refers to performance imbalances between the opposing limbs of the body (Bishop et al., 2017, 2022; Fox et al., 2023). Although inter-limb asymmetries have traditionally been studied in multidirectional sports involving explosive actions and rapid changes of direction (Bishop et al., 2017; Loturco et al., 2019), recent research has also examined these imbalances in endurance-based and linear disciplines such as running and triathlon (Helme et al., 2021; D'Hondt et al., 2024; Jacques et al., 2021). These findings suggest that asymmetries are relevant not only in team sports but also in activities characterized by continuous and repetitive motion. Asymmetries in lean mass distribution, muscle strength, or power output (PWR) have been linked to performance inefficiencies and an increased risk of injury (Bell et al., 2014; Knapik et al., 1991).

Systematic reviews have underscored the complex relationship between inter-limb asymmetry and sports performance. For example, Bishop et al. (2017) concluded that inter-limb asymmetries observed across a variety of tasks often have a negative impact on physical performance. However, their findings highlighted significant variability, with some studies reporting minimal or no association between asymmetry and performance outcomes. Similarly, D'Hondt et al. (2024) reported high methodological heterogeneity in studies on inter-limb asymmetry and endurance running, making it difficult to draw definitive conclusions. Although some asymmetry metrics, such as unilateral countermovement jump (UCMJ) asymmetries exceeding 10% or inter-limb differences in strength, may negatively affect running performance (Bishop et al., 2017), the evidence is not universally consistent, emphasizing the need for high-quality research to determine thresholds and actionable training implications.

In triathlon, kinematic asymmetries may be more strongly influenced by the prolonged and repetitive mechanical demands of cycling than by the transition itself. Accumulated fatigue from cycling can alter neuromuscular control during subsequent running, potentially exacerbating inter-limb asymmetries (Millet & Vleck, 2000). Heiden and Burnett (2003) demonstrated that muscle activation patterns in the legs during running are significantly altered following the cycling segment, with notable changes in key lower-limb muscles such as the biceps femoris and vastus lateralis. Similarly, Connick and Li (2015) reported increased stride-time variability and reduced stride length during post-cycling running, indicating a disruption in locomotor control likely linked to prior fatigue. Olcina et al. (2019) observed a decrease in stride length following cycling, suggesting impaired neuromuscular recruitment as a contributing factor.

In addition to kinematic and muscle activation variables, muscle physiology parameters are also relevant for better understanding limb asymmetries. Muscle oxygen saturation (SmO_2) provides valuable information for assessing potential inter-limb differences. A decrease in SmO_2 reflects a greater imbalance between oxygen delivery and utilization, indicating increased muscular oxygen extraction during exercise (van der Zwaard et al., 2016). Using near-infrared spectroscopy (NIRS), researchers have been able to evaluate whether variability or asymmetries in oxygen utilization exist between the legs during activities such as cycling (Sendra-Pérez et al., 2025; Skotzke et al., 2024). Olcina et al. (2019) examined the effect of prior cycling on running performance, stride length, and muscle oxygen saturation (SmO_2) in triathletes, and their results indicated that high-intensity cycling before running can impair performance by reducing stride length and limiting the peripheral utilization of oxygen in muscles exhibiting elevated SmO_2 levels. These findings suggest that pre-fatigue induced by cycling not only compromises biomechanical efficiency but also leads to localized oxygenation imbalances, potentially exacerbating muscle asymmetries during the subsequent running segment. Similar findings have been reported in other sports such as football and rugby, where SmO_2 asymmetries correlate with reduced performance efficiency and increased injury risk (Vasquez-Bonilla et al., 2022, 2023).

Wearable technology now allows real-time monitoring of kinematic variables, PWR, and SmO_2 to assess asymmetries. Devices such as the Stryd sensor provide detailed data on PWR, SL, GCT, and VO, supporting performance analysis (van Rassel et al., 2023). These tools help athletes and coaches identify inter-limb differences in mechanical output and SmO_2, enabling targeted training to optimize performance and reduce injury risk. Prior studies have demonstrated their usefulness in this context. For example, Bini and Hume (2015) found notable pedal-force asymmetries during cycling time trials, whereas Yanci (2014) reported PWR asymmetries between dominant and nondominant legs in endurance athletes. Both studies suggest that addressing these imbalances may enhance performance and reduce injury risk.

Building on this foundation, inter-limb asymmetry is defined as the imbalance or difference between the lower limbs which can manifest in functional, kinematic, or kinetic dimensions. In endurance runners, research has reported functional asymmetries of approximately 16–17% and biomechanical differences ranging from 3% to 54%, depending on the task and metric used (D'Hondt et al., 2024). While data specifically quantifying its general prevalence in triathletes remain scarce due to a lack of prior investigations in this population, existing evidence has documented significant lateral differences in neuromuscular characteristics. Specifically, running after cycling has been shown to alter muscle activation patterns, such as reduced soleus activation in one limb, despite no observed differences in external kinetics or kinematics (Jacques et al., 2021). Given the biomechanical demands of track running and the documented presence of inter-limb asymmetries in endurance athletes and triathletes, this study aimed to address the following objectives:

1. To analyze whether running on a 400-m track induces measurable differences in power, kinematics, and muscle oxygen saturation between the inner and outer legs.
2. To evaluate the extent of power, kinematic, and muscle oxygen saturation asymmetries in triathletes during track running.

Materials and Methods

Participants

Fourteen national-level male triathletes voluntarily participated in this study (Table 1). Inclusion criteria were being licensed and actively competing in national triathlon events. Exclusion criteria included cardiac disorders, current injury, or injury within the previous two months. Furthermore, individuals with an adipose tissue thickness (ATT) greater than 7 mm were excluded to minimize interference with NIRS signal quality, as higher ATT can attenuate near-infrared light and compromise the accuracy of SmO_2 readings (McManus et al., 2018). ATT was calculated as 0.5 × the mean skinfold thickness. All participants provided written informed consent, and the study protocol was approved by the Clinical Research Ethics Committee of the Catalan Sports Administration (026/CEICGC/2023).

Table 1
Triathlete characteristics (n = 14)

Variables	Values
Age (years)	27.43 ± 8.55
Body mass (kg)	66.50 ± 5.30
Stature (cm)	175.07 ± 5.76
BMI (kg·m^{-2})	21.70 ± 1.49
Maximal aerobic speed (km·h^{-1})	18.53 ± 1.02
ATT RVL (mm)	3.29 ± 1.95
ATT LVL (mm)	3.47 ± 2.07

Note. Values are presented as mean ± standard deviation (SD). BMI = body mass index; ATT RVL = adipose tissue thickness of the right vastus lateralis; ATT LVL = adipose tissue thickness of the left vastus lateralis.

Materials

PWR and kinematic parameters were measured using the Stryd sensor (Stryd Inc., Boulder, CO, USA), which has been previously validated for running power estimation under controlled conditions (Cerezuela-Espejo et al., 2021). Stryd sensors were attached to the laces of each running shoe, centrally positioned on the dorsum of the foot, in accordance with the manufacturer's guidelines. The device sampled and exported processed data at 1 Hz, while internal inertial data were recorded at higher rates (up to ~100 Hz). SmO_2 was measured with a continuous-wave NIRS device (MOXY, Hutchinson, Minnesota, United States) using four wavelengths (680, 720, 760, and 800 nm). SmO_2 was measured as a percentage according to the following equation: SmO_2 = [oxy. hemoglobin (O2Hb) / (oxy. hemoglobin (O2Hb) + deoxy. Hemoglobin (HHb))] * 100 where O_2Hb represents oxyhemoglobin and HHb represents deoxyhemoglobin. The MOXY device is a portable, non-invasive NIRS system designed for field-based assessments of muscle oxygenation. Its validity and reliability for measuring SmO_2 during exercise have previously been established (Feldmann et al., 2019). The NIRS device was positioned over the belly of the vastus lateralis (VL) muscle on both legs, midway between the greater trochanter and the lateral femoral epicondyle (McManus et al., 2018). The sensors were secured with adhesive tape (Hypafix; BSN Medical, Hamburg, Germany). The sampling rate was set to the device's default mode, updating every two seconds with a 10-second smoothing window.

Procedures

The placement of the Moxy sensors was determined using a tape measure and a marker pen. In addition, skinfold thickness was measured at the site where the NIRS device was positioned using a Harpenden skinfold caliper (accuracy: 0.20 mm). The Stryd sensors were then attached to both running shoes.

All participants performed a VAM-EVAL test (García & Secchi, 2013) on a 400-m track. In accordance with the original protocol, no standardized warm-up was performed prior to testing, as the low initial running speed provided a progressive warm-up. Running speed was controlled by an acoustic signal. The initial velocity was set at 8.5 km·h^{-1} and increased by 0.5 km·h^{-1} each minute. Cones were placed every 20 m to help participants adjust their pace to the audio cues. The test was terminated when participants stopped due to exhaustion or failed to reach the marked cone on two consecutive occasions. Maximal aerobic speed (MAS) was defined as the velocity achieved during the last fully completed stage; incomplete stages were not considered (García & Secchi, 2013).

The testing sessions were conducted on an outdoor athletics' track in Barcelona between February 27 and April 23, 2024, under average environmental conditions of 21.1 ± 5.7 °C and 74.6 ± 16.6% relative humidity. Participants were instructed to refrain from high-volume or high-intensity training during the 24 hours preceding the test.

Statistical Analysis

Kinematic and SmO_2 data were filtered every 2 seconds before analysis and temporally aligned to time zero (t = 0) for synchronization. Time zero was defined as the start of the VAM-EVAL test, identified by the first increase in running speed indicated by the acoustic signal, and synchronized across devices using the internal timestamps of the recording systems. Descriptive statistics (mean ± standard deviation [*SD*]) were calculated for all variables.

The intensity levels (60%, 70%, 80%, and 90% of maximal aerobic speed [MAS]) were determined from the results of the VAM-EVAL test. Mean values for both legs were obtained from the central 20 seconds of each one-minute interval at every intensity level.

Normality was evaluated using the Shapiro–Wilk test. With the exception of some asymmetry indices (PWR ASYM, CAD ASYM, VO ASYM, GCT ASYM, and SL ASYM), all variables met the assumption of normality. Consequently, a two-way repeated-measures analysis of variance (ANOVA) was conducted to compare differences between legs (inner leg vs. outer leg) and intensity levels (60%, 70%, 80%, and 90% of MAS) for PWR, kinematic parameters (CAD, VO, GCT, and SL), and SmO_2.

A separate one-way ANOVA was performed to examine differences in asymmetry indices for PWR, kinematic parameters (CAD, VO, GCT, and SL), and SmO_2 across intensity levels. Asymmetry (%) for each variable was calculated according to the following equation:

$$ASI\,\% = \left(\frac{X_r - X_l}{\frac{1}{2}(X_r + X_l)}\right) \cdot 100$$

where X_r represents the SmO_2 recorded from the right leg and X_l represents the corresponding SmO_2 recorded from the left leg. This approach follows established protocols (Karamanidis et al., 2003; Knapik et al., 1991).

In both the two-way repeated-measures ANOVA and the one-way ANOVA for asymmetry indices, post hoc pairwise comparisons were conducted using Holm's correction method to control the family-wise error rate due to multiple testing, and adjusted *p*-values are reported. For pairwise comparisons following the two-way ANOVA, effect sizes were calculated using Cohen's *d*, with values of 0.2, 0.5, and 0.8 interpreted as small, medium, and large effects, respectively (Cohen, 1988). For the one-way ANOVA applied to normally distributed asymmetry indices (e.g., SmO_2 ASYM), effect sizes were estimated using partial eta squared (η^2_p), with thresholds of .01, .06, and .14 considered small, medium, and large effects, respectively (Richardson, 2011). In contrast, for asymmetry indices that did not meet the normality assumption (e.g., PWR ASYM, CAD ASYM, VO ASYM, GCT ASYM, and SL ASYM), the Friedman test was applied, followed by Wilcoxon signed-rank tests with Holm's correction for pairwise comparisons; in these cases, effect sizes were calculated using Kendall's *W*, interpreted as small (.1), moderate (.3), and large (.5) levels of agreement (Tomczak & Tomczak, 2014).

All statistical analyses were performed using Microsoft Excel (version 16.81, 24011420) and JASP (version 0.18.3). Statistical significance was set at $p < .05$ for global effects.

Results

The participants (n = 14) achieved a maximal heart rate (HR_{max}) of 183.5 ± 15.6 bpm and a MAS of 18.53 ± 1.02 km·h^{-1} during the VAM-EVAL test. SmO_2, PWR, and kinematic parameters showed progressive changes in response to the increasing running velocity throughout the test.

Table 2
Descriptive data for both legs in PWR, CAD, VO, GCT, SL, and SmO₂ during the VAM-EVAL test (n = 14; significant differences (p < .05) across intensity levels are indicated)

	60% MAS		70% MAS		80% MAS		90% MAS
PWR-IL (W)	228.6 ± 29.3	A B C	259.6 ± 27.5	B C	293.8 ± 29.4	C *	324.5 ± 31.8
PWR-OL (W)	225.2 ± 27.5	A B C	256.6 ± 27.3	B C	285.4 ± 30.6	C	319.5 ± 29.4
CAD-IL (spm)	81.8 ± 2.8	A B C	83.5 ± 2.8	B C	85.3 ± 3.0	C	88.2 ± 3.1
CAD-OL (spm)	82.0 ± 2.9	A B C	83.4 ± 2.8	B C	85.4 ± 3.1	C	88.5 ± 3.3
VO-IL (cm)	81.7 ± 10.3	B	84.6 ± 8.3		85.7 ± 8.1		82.2 ± 6.9
VO-OL (cm)	80.1 ± 10.1	B	83.8 ± 8.2		84.7 ± 8.4		81.5 ± 7.4
GCT-IL (ms)	251.9 ± 10.8	A B C	227.3 ± 7.0	B C	207.6 ± 9.2	C	193.5 ± 6.6
GCT-OL (ms)	255.2 ± 10.5	A B C	230.2 ± 8.2	B C	209.8 ± 8.5	C	193.9 ± 6.6
SL-IL (cm)	1199.5 ± 101.3	A B C	1363.5 ± 92.2	B C *	1519.8 ± 100.5	C *	1641.4 ± 89.8
SL-OL (cm)	1173.9 ± 95.3	A B C	1328.8 ± 87.0	B C	1476.0 ± 93.5	C	1613.1 ± 78.5
SmO_2-IL (%)	40.2 ± 9.4	C	40.5 ± 9.9	C	36.7 ± 9.9	C	26.6 ± 10.0
SmO_2-OL (%)	42.7 ± 13.6	C	40.3 ± 16.0	C	36.4 ± 18.6	C	24.9 ± 18.1

Note. Values are presented as mean ± standard deviation (SD). Letters (A, B, C) indicate significant differences between intensity levels compared with 70%, 80%, and 90% of MAS, respectively. Significant differences between legs ($p < .05$) are marked with an asterisk (*). IL = inner leg; OL = outer leg; PWR = power output; CAD = cadence; VO = vertical oscillation; GCT = ground contact time; SL = step length; SmO_2 = muscle oxygen saturation; MAS = maximal aerobic speed.

Table 3
Results of the two-way repeated-measures ANOVA for PWR, CAD, VO, GCT, SL, and SmO_2 during the VAM-EVAL test (n = 14)

		F	df (effect, error)	*p*	η^2_p
PWR	Leg	13.62	(1, 13)	.003	.512
	Intensity	432.90	(3, 39)	< .001	.971
	Leg*Intensity	1.31	(3, 39)	.285	.001
CAD	Leg	1.10	(1, 13)	.313	.078
	Intensity	93.47	(3, 39)	< .001	.878
	Leg*Intensity	1.12	(3, 39)	.354	.079
VO	Leg	7.97	(1, 13)	.014	.380
	Intensity	4.78	(3, 39)	.006	.269
	Leg*Intensity	1.35	(3, 39)	.271	.094
GCT	Leg	6.51	(1, 13)	.024	.334
	Intensity	273.83	(3, 39)	< .001	.955
	Leg*Intensity	0.97	(3, 39)	.415	.070
SL	Leg	21.26	(1, 13)	< .001	.621
	Intensity	402.29	(3, 39)	< .001	.969
	Leg*Intensity	0.94	(3, 39)	.424	.068
SmO_2	Leg	0	(1, 13)	.976	.000
	Intensity	29.93	(3, 39)	< .001	.697
	Leg*Intensity	2.37	(3, 39)	.068	.154

Note. F = F statistic; df = degrees of freedom (effect, error); *p* = significance level; η^2_p = partial eta squared (effect size). PWR = power output; CAD = cadence; VO = vertical oscillation; GCT = ground contact time; SL = step length; SmO_2 = muscle oxygen saturation. Statistical significance was set at $p < .05$.

During the incremental stages of the VAM-EVAL test (60%, 70%, 80%, and 90% of MAS), PWR, CAD, and SL increased significantly in both legs at all intensities, whereas GCT decreased significantly across all intensities (all $p < .05$) (Table 2). A significant main effect of Leg was observed for PWR ($F(1,13) = 13.62$, $p = .003$, $\eta^2_p = .512$), VO ($F(1,13) = 7.97$, $p = .014$, $\eta^2_p = .38$), GCT ($F(1,13) = 6.51$, $p = .024$, $\eta^2_p = .334$) and SL ($F(1,13) = 21.26$, $p < .001$, $\eta^2_p = .621$). However, post hoc comparisons between inner and outer legs at each intensity level only reached statistical significance after Holm correction for PWR at 80% of MAS ($t(13) = -4.455$, $p = .003$, $d = -0.29$), SL at 70% of MAS ($t(13) = -6.298$, $p < .001$, $d = -0.37$) and SL at 80% of MAS ($t(13) = -4.717$, $p < .001$, $d = -0.47$) This suggests a consistent main effect of Leg in VO and GCT, with one leg systematically differing from the other across all intensities. However, the lack of a significant Leg × Intensity interaction indicates that the magnitude of this inter-limb difference remained stable, regardless of intensity level. No significant inter-leg differences were found for CAD ($p = .313$, $\eta^2_p = .08$) or SmO_2 ($p = .976$, $\eta^2_p = .00$).

Effect size analysis revealed moderate to large inter-limb differences for PWR, VO, GCT, and SL (η^2_p ranging from .33 to .62). In contrast, GCT, SL, and PWR exhibited marked intra-limb adaptations with increasing intensity, as reflected by highly significant intensity effects and partial eta squared values exceeding .95 (Table 3). Both the inner and outer legs exhibited very large within-limb effect sizes in response to increasing intensity, particularly for GCT, SL, and PWR. Effect sizes ranged from 1.07 to 3.26 for PWR, from 1.75 to 6.97 for GCT, and from 1.38 to 4.76 for SL. CAD and SmO_2 also showed within-limb changes, although with smaller magnitudes. Effect sizes ranged from 0.52 to 2.16 for CAD and from 0.08 to 1.15 for SmO_2, suggesting moderate to large intra-limb adjustments, particularly at higher intensity levels. In contrast, VO displayed only small and inconsistent effect sizes ($d = 0.08$ to 0.39), indicating limited responsiveness to increasing intensity.

Table 4
Descriptive data for asymmetry indices in PWR, CAD, VO, GCT, SL, and SmO_2 across intensity levels (60%, 70%, 80%, and 90% of MAS; significant differences between intensity levels (p < .05) are indicated)

	60% MAS		70% MAS		80% MAS	90% MAS
PWR ASYM (%)	3.87 ± 3.51		2.26 ± 1.47		3.08 ± 2.25	2.46 ± 1.36
CAD ASYM (%)	0.40 ± 0.48		0.25 ± 0.23		0.45 ± 0.46	0.54 ± 0.83
VO ASYM (%)	2.14 ± 2.29		1.31 ± 1.47		1.66 ± 1.30	1.76 ± 1.05
GCT ASYM (%)	2.11 ± 1.70		1.68 ± 2.17		1.74 ± 0.77	1.96 ± 1.82
SL ASYM (%)	3.71 ± 2.77		2.56 ± 1.46		2.93 ± 2.19	2.68 ± 1.25
SmO_2 ASYM (%)	24.44 ± 16.30	C	26.98 ± 21.98	C	35.38 ± 29.61	53.49 ± 48.53

Note. Values are presented as mean ± standard deviation (*SD*). Letters (A, B, C) indicate significant differences between intensity levels compared with 70%, 80%, and 90% of MAS, respectively. ASYM = asymmetry; PWR = power; CAD = cadence ; VO = vertical oscillation; GCT = ground contact time; SL = step length; SmO_2 = muscle oxygen saturation; MAS = maximal aerobic speed.

Table 5
Results of the statistical analyses for inter-limb asymmetry indices across intensity levels during the VAM-EVAL test

	χ^2 / F	df	*p*	Kendall's *W* / η^2_p
PWR ASYM	3.171	3	.366	.076
CAD ASYM	0.848	3	.838	.020
VO ASYM	4.114	3	.249	.098
GCT ASYM	5.143	3	.162	.122
SL ASYM	5.571	3	.134	.133
SmO_2 ASYM	5.653	3	.003	.303

Note. χ^2F = Friedman test statistic; F = F statistic; df = degrees of freedom; *p* = significance level; Kendall's *W* = effect size for Friedman test; η^2_p = partial eta squared (effect size). ASYM = asymmetry; PWR = power; CAD = cadence; VO = vertical oscillation; GCT = ground contact time; SL = step length; SmO_2 = muscle oxygen saturation; MAS = maximal aerobic speed. PWR ASYM, CAD ASYM, VO ASYM, GCT ASYM, and SL ASYM were analyzed using the Friedman test, whereas SmO_2 ASYM was analyzed using a repeated-measures ANOVA. Statistical significance was set at $p < .05$.

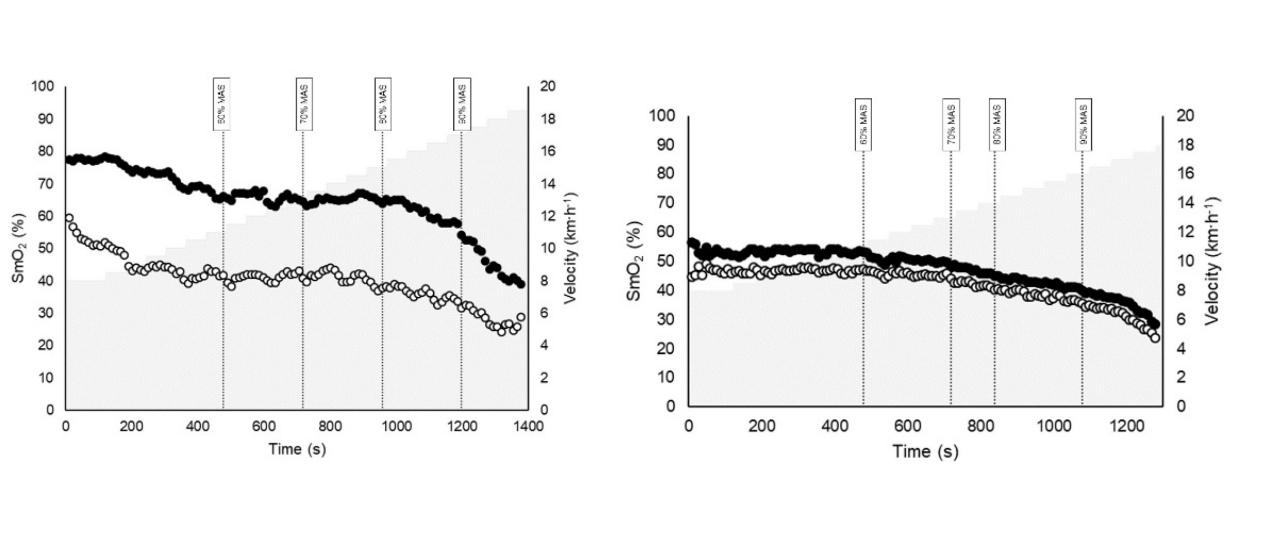
Regarding inter-limb asymmetry values, no significant differences were observed in PWR, CAD, SL, VO, or GCT across the different intensity levels (Table 4). However, asymmetry in SmO_2 showed significant differences between 60–90% and 70–90% of MAS ($p < .05$).

Effect size analysis revealed small to large effects for SmO_2 asymmetry across intensities, ranging from small (60–70% MAS: $d = 0.081$; 70–80% MAS: $d = 0.266$) to moderate (60–80% MAS: $d = 0.347$; 80–90% MAS: $d = 0.574$) and large (60–90% MAS: $d = 0.921$; 70–90% MAS: $d = 0.840$) (Table 4). These results suggest that SmO_2 asymmetry progressively increases as running intensity rises.

Figure 1 illustrates the SmO_2 patterns of both legs in two representative participants. The left panel showed a participant exhibiting marked asymmetries, whereas the right panel depicts one with no observable asymmetry. In the asymmetric participant, although the absolute SmO_2 values differ substantially between legs, the temporal saturation profiles remain notably similar across intensities.

Figure 1

Comparison of SmO_2 between a participant exhibiting legs' asymmetry (left panel) and a participant without legs' asymmetry (right panel) during the VAM-EVAL test



Note. SmO_2 values are expressed as percentages (%), and running velocity is expressed in kilometers per hour ($km{\cdot}h^{-1}$). The black line represents the outer leg, while the light-colored line represents the inner leg. MAS = maximal aerobic speed.

Discussion

This study is among the first to examine power, kinematic, and muscle oxygenation asymmetries between the inner and outer legs during incremental 400-m track running in an ecological outdoor setting. Most previous research in this area has been conducted under controlled indoor laboratory conditions, which may not fully capture the biomechanical and physiological complexities of real-world running.

The first aim was to determine whether running on a 400-m track induces measurable differences in PWR, kinematic variables (CAD, VO, GCT, SL), and SmO_2 between the inner and outer legs. The main findings revealed significant main effects of Leg for PWR, SL, VO, and GCT, indicating systematic inter-limb differences across all intensity levels. However, post hoc analyses identified statistically significant differences only at specific intensities (PWR at 80% of MAS, and SL at both 70% and 80% of MAS), while no significant inter-limb differences were observed for CAD or SmO_2. Furthermore, the absence of significant Leg × Intensity interactions suggests that these asymmetries remained stable throughout the incremental protocol rather than increasing with exercise intensity.

The second aim was to evaluate the extent and progression of inter-limb asymmetries as running intensity increased. The main findings showed that asymmetry indices for PWR, CAD, VO, GCT, and SL did not change significantly across intensity levels, suggesting stable mechanical symmetry throughout the test. In contrast, SmO_2 asymmetry increased progressively with intensity, with large effect sizes observed at 90% MAS. This physiological divergence suggests a growing imbalance in local muscle oxygenation between limbs under higher metabolic stress, highlighting SmO_2 as a sensitive and potentially early marker of load-dependent asymmetry during high-speed running.

These findings partially align with previous studies reporting kinematic alterations during curved running; however, important methodological differences must be considered when comparing results. For instance, the studies by Chang and Kram (2007) and Hamill et al. (1987) demonstrated that curved track running affects key kinematic variables such as CAD, SL, SF, VO, and GCT. It is important to acknowledge substantial differences in their experimental conditions compared with those of the present study. Specifically, Chang and Kram (2007) investigated running on curves with a much smaller radius (6 m) than that of a standard athletics track (36.5 m), and their participants ran at maximal sprinting speeds, in contrast to the submaximal intensities used in our protocol (up to 100% of MAS; $5.15 \pm 0.28\ m{\cdot}s^{-1}$). Similarly, Hamill et al. (1987) examined running at a considerably higher velocity ($6.31 \pm 5\ m{\cdot}s^{-1}$) than the pace maintained by the triathletes in our study. These methodological differences produced much greater centrifugal forces, thereby amplifying the kinematic disparities between the inner and outer legs observed in their findings.

We also observed that as running intensity increased, significant rises were observed in PWR, CAD, and SL in both legs across all intensity levels. Specifically, PWR in the IL increased by 13.6%, 13.2%, and 10.4% between 60–70%, 70–80%, and 80–90% of MAS, respectively. Similarly, PWR in the OL increased by 13.9%, 11.2%, and 11.9% across the same intervals. Regarding CAD, both legs exhibited moderate but consistent increases with intensity. CAD in the IL rose by 2.1%, 2.2%, and 3.4%, while the OL showed slightly smaller but progressive increments of 1.7%, 2.4%, and 3.6% across the corresponding intervals. SL also increased with intensity, although the rate of increase declined as it approached 90% of MAS. In the IL, SL rose by 13.7%, 11.5%, and 8.0%, while in the OL, increases of 13.2%, 11.1%, and 9.3% were observed. Conversely, GCT consistently decreased in both legs as intensity increased. For the IL, GCT declined by −9.8%, −8.7%, and −6.8% between 60–70%, 70–80%, and 80–90% of MAS, respectively. In the OL, the reductions were −9.8%, −8.9%, and −7.6% across the same intensity ranges. These findings align with those of Patoz et al. (2023), particularly regarding the consistency of biomechanical responses across increasing running intensities. Similar to their observations at 90%–120% of peak aerobic speed, our data revealed no significant Leg × Intensity interactions ($p > .05$), indicating a uniform adaptation pattern in both limbs. Additionally, both studies reported stable cadence (stride frequency) and vertical oscillation despite increasing fatigue, suggesting that runners prioritize maintaining movement rhythm and center-of-mass control. The significant effect of intensity observed in our ground contact time data also supports their interpretation that runners adopt spatiotemporal strategies, such as modulating contact time, to optimize load distribution during high-intensity efforts. While both studies focused on biomechanical responses to submaximal and near-maximal intensities, our protocol was slightly less demanding. In our study, athletes performed a continuous incremental test without rest periods, whereas Patoz et al. (2023) conducted four separate exhaustive trials at fixed percentages of each participant's peak speed, performed in randomized order.

In addition to the mechanical adjustments observed in spatiotemporal parameters, physiological responses at the muscular level also showed meaningful trends as intensity increased. In particular, muscle oxygen saturation (SmO_2) progressively decreased in both the inner and outer leg throughout the incremental protocol. This response is consistent with previous studies on muscle oxygenation during graded exercise, which reported a continuous decline in SmO_2 due to increased oxygen extraction demands (Grassi et al., 1999). The present findings confirm this pattern, especially at higher intensities such as 90% of MAS.

No significant differences were observed between the inner and outer leg ($p = .976$), nor was there a significant Leg × Intensity interaction ($p = .068$). However, there was a strong main effect of intensity ($p < .001$, $\eta^2_p = .697$), indicating that SmO_2 responded markedly to increases in running speed. These results suggest that the observed changes in SmO_2 reflect a global physiological adaptation to elevated metabolic demand, without clear evidence of functional imbalances between the inner and outer leg in terms of muscle oxygenation.

The secondary aim of this study was to evaluate the extent of asymmetries in PWR, kinematic variables (CAD, VO, GCT, and SL), and SmO_2 in national-level triathletes during a VAM-EVAL test. The main findings showed no significant differences across intensities, except for SmO_2, which exhibited significant changes between 60–90% and 70–90% of MAS. These results suggest that SmO_2 asymmetries become more pronounced at higher exercise intensities, particularly at 90% of MAS, indicating that as running intensity increases, oxygen utilization disparities between legs become more evident in triathletes.

To better contextualize these findings, it is essential to consider the underlying physiological mechanisms that may explain the observed asymmetries. The presence of significant SmO_2 asymmetry, despite symmetrical mechanical outputs such as power and stride length, points toward the role of intrinsic muscular factors. In particular, local variations in capillarization and vascular adaptations may contribute to these disparities. Capillarization is a key determinant of oxygen delivery and diffusion; specifically, parameters such as capillary density and the number of capillary contacts per fiber area (CC/FA) are associated with more efficient O_2 extraction, a relationship particularly robust in young populations (Chilibeck et al., 1997). Moreover, vascular adaptations induced by endurance training tend to be localized, with enhanced microvascular responsiveness occurring primarily in the tissues directly involved in the effort (Soares et al., 2018).

Internal physiological processes may remain asymmetric due to differences in local muscle perfusion or oxidative metabolism. In this context, circulatory adjustments mediated by autonomic reflexes, such as the exercise pressor reflex, may favor blood flow redistribution toward the most metabolically active muscles, potentially limiting oxygen delivery to non-active or synergistic muscles. These mechanisms are part of the broader autonomic response to increased metabolic demand and play a role in modulating limb-specific vascular responses during intense exercise (Orcioli-Silva et al., 2024).

Additionally, neuromuscular strategies such as muscle co-activation contribute to these internal asymmetries. At higher running speeds, global co-activation increases, occurring earlier and for shorter durations to enhance whole-limb stiffness and joint stabilization (Fiori et al., 2024). Importantly, the relationship between muscle excitation (RMS) and SmO_2 is not uniform across all muscles. While power-generating muscles like the vastus lateralis show a clear inverse pattern (RMS increases while SmO_2 decreases) due to higher metabolic demand, some stabilizers, such as the gastrocnemius medialis, maintain both stable SmO_2 and RMS levels throughout exercise (Sendra-Pérez et al., 2025). This reflects their distinct functional roles, as stabilizing muscles are more involved in load regulation than in force generation. These findings highlight the complex interplay of neuromuscular and vascular mechanisms that modulate SmO_2 dynamics. Since the present study focused exclusively on the vastus lateralis, examining additional muscles with diverse functional roles would provide a more comprehensive understanding of these physiological asymmetries.

While previous studies have typically assessed SmO_2 symmetry using statistical agreement methods and absolute inter-limb differences, our analysis employed a normalized asymmetry index (ASI%) to express the relative disparity between legs. In controlled laboratory settings, Sendra-Pérez et al. (2025) defined symmetry based on absolute SmO_2 differences ranging from 10% to 20%, while Skotzke et al. (2024) used Bland–Altman analysis to establish limits of agreement (LoA) of ± 20%, finding that such inter-limb differences are common and not linked to leg dominance. In contrast, our ASI% values during outdoor running ranged from 24.4% to 53.5%, exceeding both the laboratory thresholds and the minimal detectable change (MDC) of 18% reported by Skotzke et al. (2024) for SmO_2 in cycling.

However, it is important to note that the ASI% is mathematically sensitive to low absolute values. Since SmO_2 levels declined markedly at high intensities (e.g., ~25% at 90% MAS), even moderate absolute differences may yield disproportionately high ASI% values. To validate our findings, we conducted a Bland–Altman analysis across all intensities. The results revealed minimal systematic bias across 60%, 70%, and 80% of MAS (−2.6% ± 24.0%, +0.2% ± 24.3%, and +0.3% ± 28.3%, respectively), with relatively consistent limits of agreement. At 90% MAS, although SmO_2 values were lower, the bias remained small (+1.7%), and the LoA (± 25.68%) did not widen substantially compared to previous stages. Compared to Skotzke et al. (2024), who reported LoA of ± 20% during steady-state cycling, our results show slightly wider but still comparable levels of physiological asymmetry under more demanding, field-based running conditions. These results suggest that while physiological asymmetries in SmO_2, as captured by ASI%, do become more evident with increasing intensity, the magnitude of the relative asymmetry should be interpreted cautiously, especially under conditions of low oxygen saturation.

According to the recent systematic review by D'Hondt et al. (2024), the relationship between inter-limb asymmetry and endurance running performance is complex. Their findings indicate that some (but not all) functional, morphological, kinematic, and kinetic asymmetry metrics are negatively associated with, or show no significant relationship to, running performance. In the present study, despite exhibiting significant SmO_2 asymmetries, particularly at higher intensities, the triathletes achieved a performance level of 3 according to the classification proposed by De Pauw et al. (2013). To analyze asymmetries in greater depth, it would have been beneficial to perform a preliminary body composition assessment using dual-energy X-ray absorptiometry (DXA) to evaluate total body composition and identify potential differences in muscle mass between legs. Branski et al. (2010) demonstrated that lean mass asymmetry influences strength and power asymmetry during jumping tasks in collegiate athletes. In addition, conducting specific unilateral strength tests for runners could have provided insight into potential strength imbalances between limbs. Such an approach would have allowed for a more comprehensive interpretation of the observed differences in muscle oxygen saturation.

Limitations and Further Research

This study has some limitations that should be considered. First, the sample size was relatively small and included only male national-level triathletes, which may limit the generalizability of the findings to other populations, such as female athletes or recreational runners. Second, SmO_2 was measured exclusively in the vastus lateralis. Including additional muscles involved in running could have offered a broader view of inter-limb physiological asymmetries. Third, no direct measures of unilateral muscle strength, neuromuscular function, or body composition asymmetry, were included, which could have contributed to a deeper interpretation of the observed SmO_2 asymmetries. Finally, although conducting the test in an outdoor setting adds ecological validity, it may also have introduced more variability compared to laboratory-based conditions.

Future research should continue to emphasize ecological settings to more accurately reflect the demands of outdoor running. Moreover, integrating body composition analyses and specific strength assessments for both legs could help identify the physiological origins of SmO_2 asymmetries. Expanding these studies would contribute to a deeper understanding of the physiological and biomechanical mechanisms underlying inter-limb imbalances and their potential implications for athletic performance. Finally, future investigations should incorporate systematic observation and video analysis tools (Soto et al., 2019) to enhance the reliability of motion analysis in applied sport environments.

Conclusions

The findings of this study on national-level male triathletes performing an incremental 400-m track running test indicate that, although no asymmetries were observed in power output or kinematic parameters, muscle oxygen saturation asymmetries became evident as running intensity increased. These asymmetries were not attributable to the curved running trajectory, since no significant differences were found between the inner and outer legs, except for power output at 80% of maximal aerobic speed (MAS) and step length at 70% and 80% of MAS. While mechanical parameters remained largely symmetrical, the progressive divergence in SmO_2 values suggests a physiological imbalance that becomes more pronounced at higher intensities, highlighting SmO_2 as a sensitive marker of internal load-dependent asymmetries, even in the absence of mechanical discrepancies.

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SPORT PEDAGOGY

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Promoting Change: Traditional Model Versus Gamification in Physical Education Teacher Education

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Abstract

The aims of the study were to assess the impact of a pedagogical approach, gamification, in Physical Education Teacher Education (PETE) on students' satisfaction and on the perceptions of both students and professor after the experience. A total of 142 students (102 men, 40 women) aged between 19 and 41 years, with a mean age of 21.7 (*SD* = 2.5) enrolled in the Physical Activity and Sport Science degree at a public university agreed to participate. The study involved two groups: one following a traditional instructional approach (*n* = 64) and the other using a gamification approach (*n* = 78). A mixed methods design was employed, using a Student Satisfaction Questionnaire for quantitative data collection, consisting of 20 items on a 5-point Likert scale. For qualitative analysis, an individual videoreflection protocol was established, with each video recorded and submitted electronically via the virtual campus to ensure confidentiality. Within this framework, the participating professor completed a self-administered journal at the end of each week, while the students answered the questionnaire and recorded their video reflections at the end of the program. The quantitative results showed increased student satisfaction, which in turn promoted learning. Comparative analysis of the qualitative data revealed a consensus between students and the teacher regarding three positive themes: gamification, values, and academic learning; however, a negative aspect—high workload—was identified solely by the teacher. In conclusion, gamification constitutes an effective pedagogical approach in initial Physical Education Teacher Education, as it enhances student satisfaction and facilitates academic learning. However, its implementation requires acknowledging the increased workload for teaching staff as a necessary condition for success.

Keywords: active methodologies, educational technology, higher education, information and communication technologies, physical education didactics, sports pedagogy, tertiary education

Introduction

Student motivation is a key element in any educational context, and higher education is no exception, where higher levels of motivation have been linked to better academic performance (Morris & Usher, 2011). Unfortunately, there is a high degree of amotivation among college students, caused at least partially by traditional, highly controlling, teacher-centered methodological approaches (Vermote et al., 2020). To address this negative trend, the Integrative Model for Teacher Change (Kern et al., 2020) highlights the need for a framework to design reform-oriented initiatives, such as changes in teachers' pedagogical practices (e.g. resources, teaching strategies, assessment). Within this model, individuals are perceived as dynamic agents of their own change (Richards et al., 2019), but they need frameworks that empower them.

Gamification has been defined as the use of game elements in non-game contexts to make them more attractive, enjoyable, and motivating (Deterding et al., 2011). Kapp (2012) understands it as the use of game mechanics and game-thinking to capture people's attention and encourage action, thereby promoting learning and problem-solving. In the educational context, Codish and Ravid (2014) highlighted that gamification is based on the inclusion of game elements in classrooms, training materials, and learning management systems. The use of points, badges and leaderboards is the most commonly used gaming mechanics (Werbach & Hunter, 2012), but many other elements have also been used to design gamified systems, such as progress bars, performance graphs, quests, meaningful stories, avatars, profile development and teammates (Sailer et al., 2017).

In this context, several studies have analyzed the impact of gamification-based teaching on the training of university students (Alajaji & Alshwiah, 2021; Arufe et al., 2022) and more specifically, on future Physical Education teachers, enrolled in degree programs in Primary Education and Physical Activity and Sport Sciences. Regarding the former, research has shown that this methodological strategy is attractive (Pérez-López et al., 2017) and promotes student autonomy (Valero-Valenzuela et al., 2020) and motivation (Pérez-López & Rivera-García, 2017; Flores-Aguilar et al., 2023), leading to greater engagement in learning (Alajaji & Alshwiah, 2021; Arufe et al., 2022). Focusing on the Physical Activity and Sport Sciences undergraduate degree, Pérez-López and Rivera-García (2017) and Pérez-López et al. (2017) described successful experiences in which students increased their motivation, reported satisfaction with the class climate and their learning, increased their competencies, and believed they could transfer these to their future professional practice.

Based on the aforementioned evidence, the primary aim of the present study was to assess the impact of a gamified pedagogical approach, compared with a traditional instructional model, on the satisfaction levels of Physical Education Teacher Education students, specifically regarding their perceptions of the learning process and the relevance of the activities. The second aim was to analyze, from a qualitative perspective, the lived experiences and critical reflections of both students and the professor following the first implementation of gamification in this educational context.

Material and Methods

Participants

A total of 142 students (102 men, 40 women; *M* = 21.7, *SD* = 2.5) enrolled in the second year of the Physical Activity and Sport Science undergraduate program at a public university in southeastern Spain agreed to participate. The study involved two academic years: (a) 2017–18, in which 64 students experienced a traditional instructional approach, including 47 men (73.4%), and 17 women (26.6%), and (b) 2018–19, in which 78 students experienced a gamified approach, including 56 men (71.8%), and 22 women (28.2%), (this approach was totally new to them). Both programs are described in detail below. Convenience sampling was used because the same teacher, with more than 15 years of experience in Physical Education and Sport pedagogy, conducted both intervention programs and agreed to participate in the study. He received training in this pedagogical approach, as this was his first time implementing it.

Design and Procedure

The study followed a mixed methods research design (Anguera et al., 2012), integrating a quasi-experimental approach with nonequivalent groups (quantitative) and phenomenological analysis (qualitative). This methodological structure enabled data triangulation, where findings from the student questionnaires were contrasted with participants' video reflections to provide a comprehensive understanding of the intervention. First, approval to conduct the study was obtained from the University of Murcia Ethics Committee (ID: 2912/2018). Second, all participants completed the same program to develop Athletics' content knowledge and pedagogical content knowledge (e.g., history, basic rules, basic skills, progressions, techniques). In accordance with McMillan and Schumacher (2001), the project complied with the ethical values required for research involving human beings, and all participants provided written informed consent.

Intervention Program

Athletics is one of the compulsory subjects in the Physical Activity and Sport Science undergraduate program. It is taught over four months during the first semester of each academic year. Each week, students attend one hour of theoretical instruction and one hour of practical sessions (the latter in small groups of 20 students). Students were taught using either a traditional or a gamification approach in both theoretical and practical sessions. The main aim was to develop future teachers' athletics content knowledge and pedagogical content knowledge.

In particular, the objective of this course was to provide students with foundational technical, regulatory, and pedagogical knowledge of athletics, enabling them to effectively teach running, jumping, and throwing events through inclusive, educational, and evidence-based methodologies. The course covers the historical, technical, and pedagogical foundations of athletics, including the teaching and learning processes of track and field events, the use of facilities and equipment, and the adaptation of activities to diverse educational contexts and participant needs. Learning is structured through a combination of theoretical-practical lectures, on-track practical sessions, independent and collaborative tasks focused on technical analysis and instructional design, and continuous assessment through examinations, projects, and active participation.

In the 2017–18 academic year, a traditional instructional approach was implemented (Metzler, 2005), in which the teacher was the center of the learning process, making all decisions regarding task selection, pacing, and grouping. Teaching strategies positioned students as mere recipients and they did not address any dimension beyond cognitive and motor skills. The teacher used the command style to facilitate student learning and performance reproduction, the practice style in which students engaged in individual and private practice, and the reciprocal style in which students worked in partnership to support learning (Mosston & Ashworth, 2010). Students' content knowledge and pedagogical content knowledge were assessed throughout the course using apps and at the end through a final written examination.

In the 2018–19 academic year, the course was implemented through a gamified, student-centered approach entitled "Ludotechnicals' Rebellion", structured around a narrative in which students were challenged to become "Ludomasters" and teach athletics in physical education settings to promote a healthy lifestyle and positive values. The project included the three basic pillars of gamification previously introduced: dynamics, mechanics, and components (Werbach & Hunter, 2012), as well as key elements for creating a gamified context (Fernández-Río et al., 2020): (a) a powerful narrative: the *Hunger Games* plot was used to motivate students; a well-known, attractive story that was easy to adapt, in which students had to "defeat the villains" to earn points and become "Ludomasters" at the end of the semester (highest rank and highest qualification). In this system, the highest rank ("Ludomaster") corresponded to the highest possible course grade. However, points and ranks were aligned with the completion and quality of academic tasks and assessments (e.g., practical challenges, projects, and theoretical tests), ensuring that the gamified elements reflected students' actual learning and performance rather than functioning solely as a reward mechanism. (b) Challenging goals: students had several goals to achieve, linked to challenges and badges (e.g., beating a set time in a relay race or creating a video on the technical execution of hurdles); some tasks were performed individually and others in groups. (c) Mastery class climate: group and individual comparison were eliminated, and the teacher focused on personal or intragroup improvement. (d) Self-regulated learning: students paced themselves and decided which skills to perform; they knew in advance which tasks and challenges they had to complete to become "Ludomasters," and they decided when to perform them. (e) Immediate feedback: students received first-hand information about their performance to know if they needed to repeat a task to improve it; the teacher provided continuous feedback. (f) Visibly incremental success: tasks progressively increased in difficulty to support students success at the beginning, foster motivation, and encourage engagement with more difficult tasks and challenges towards the end. (g) Badges for achievements: the project incorporated badges that were awarded as physical credentials upon completion of specific tasks or learning milestones and served as formative indicators of progress and engagement. (h) Social connection: students worked in heterogeneous groups (based on sex and skill level) from the beginning of the semester to support one another's success. According to Gawrisch et al. (2020), Physical Education Teacher Education programs are encouraged to prepare teachers capable of delivering technology-integrated learning experiences. Therefore, following previously published studies (Mora-González et al., 2020), the program (Table 1) incorporated the use of information and communication technology (ICT) such as apps (e.g., Socrative, Kahoot, Edpuzzle, and Genially) and films (e.g., *The Hunger Games*, *Ready Player One*). The project finished with a Breakout EDU activity (Nicholson, 2018), in which students had to solve different problems related to athletics (e.g., long jump, shot put) integrating both content knowledge and pedagogical content knowledge (only in this academic year).

Table 1
Contents, Topics, Teaching Methodology and ICTs

Objectives	Contents	Topics	Teaching methodology				ICTs	
			Gamification approach			Traditional approach	GF	TA
			Components	Mechanics	Dynamics	Teaching strategies		
Acquiring foundational knowledge of athletics	Introduction: historical, rules and pedagogical foundations	Instructional framework	Points	Challenges, awards, feedback, competition, and cooperation *Challenge:* make playful proposals as trainee teachers	Narrative, emotions	Command style, practice style, reciprocal style	Kahoot, Google Forms, Genially, social media	Kahoot
Practicing and teaching the events associated with each discipline group	Runs	Running Relays Hurdles	Points, badges, levels, rankings	Challenges, awards, feedback, competition, and cooperation *Challenge:* analyze hurdle technique filmed with a high-speed video camera	Narrative, progression	Command style, practice style, reciprocal style	Kinovea, Kahoot, Edpuzzle, Socrative, Genially, Fluky	Kinovea, Edpuzzle, Socrative
	Jumps	Long jump High jump	Points, badges, jokers, totems, levels, rankings	Challenges, awards, feedback, competition, and cooperation *Challenge:* conduct a test on the technical elements of the High Jump	Narrative, discovery, unlocking challenges, progression	Command style, practice style, reciprocal style	Kinovea, Kahoot, Edpuzzle, Socrative, Genially, Fluky	Kinovea, Edpuzzle, Socrative
	Throws	Shot-put Javelin	Points, badges, jokers, totems, levels, rankings	Challenges, awards, feedback, competition, and cooperation *Challenge:* analyze the shot-put technique filmed with a high-speed video camera	Narrative, discovery, unlocking challenges, progression	Command style, practice style, reciprocal style	Kinovea, Kahoot, Edpuzzle, Socrative, Genially, Fluky	Kinovea, Edpuzzle, Socrative
Applying and adapting inclusive and educational methodologies	Ending: activities to diverse educational contexts and needs	Modification contests and activities	Points, rankings	Challenges, awards, competition, and cooperation *Challenge:* cover a distance overcoming several obstacles using the long jump, shot put, javelin throw, and sprint	Narrative, emotions, progression	Command style, practice style, reciprocal style; theoretical knowledge exam	Wallame, Genially, Google forms	-

Note. TA = Traditional approach; GF = Gamification framework; ICTs = Information and communication technologies.

Instruments

Student Satisfaction Questionnaire. This is a survey designed by the researchers of the Murcia University Quality Unit to assess students' satisfaction with the pedagogical approach. It is an original instrument that provides relevant data based on professional experience, although it has not undergone formal statistical validation. Trained external evaluators conduct it at the end of every semester during the last class session (before final grades are turned in). The aim is to obtain the students' views on the way the classes are designed and conducted. A total of 67 students completed the questionnaires. It includes 20 items grouped in three subscales: (a) students' sociometric characteristics (three items; e.g., age, gender), (b) professor satisfaction (12 items; e.g., "Tasks conducted during practical sessions are related to the information discussed in the theoretical sessions"), and (c) subject satisfaction (five items; e.g., "The class does not include topics discussed in other subjects"). Participants responded using a 5-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). It also includes a "no answer" option. Reliability coefficients were .94 for professor satisfaction and .65 for subject satisfaction. Overall student satisfaction had a reliability coefficient of .93.

Critical video reflection. At the end of the intervention, all students were invited to voluntarily participate in a video reflection activity, and nine agreed to contribute. Participation was not predetermined or selective, and the objective was to obtain rich, in-depth perspectives rather than a statistically representative sample. The number of participants was considered adequate once thematic saturation was reached and no new relevant themes emerged. They were asked to answer the following open-ended question: "Please try to recall what has happened in the course that you have just finished; how has it contributed to your Physical Education Teacher Education training?". Participants were instructed to record their responses in a distraction-free environment and submit them via the online campus platform. This visual method was selected to allow students to freely articulate their lived experiences, capturing nuances often lost in written surveys (Pink, 2007). Confidentiality was strictly guaranteed, and data were used solely for research purposes (Roulston, 2010). The aim was to foster a critical reflection on the intervention, allowing themes regarding positive or negative aspects of the training to emerge naturally (Cherrington & Loveridge, 2014; Curtner-Smith & Sofo, 2004).

Professor's diary. The university professor who conducted the intervention program completed an open-format diary (Hordvik et al., 2017). The teacher's diary was not anecdotal but followed a semi-structured protocol to ensure systematic data collection. Entries were made weekly, immediately after the lessons to minimize recall bias. The diary focused on three specific dimensions: (1) perceived student engagement and barriers to participation, (2) logistical and organizational challenges of the gamified approach compared with the traditional approach, and (3) instructor's emotional responses and critical reflections on the methodological implementation.

Data Analysis

Quantitative data (questionnaire responses and grades) were analyzed using IBM SPSS 24.0 software. The Shapiro-Wilk test showed that the data did not follow a normal distribution. Consequently, non-parametric statistics were used to assess differences between the 2018–19 (gamification approach) and 2017–18 (traditional approach) academic years: the Mann-Whitney U test. Cohen's d was used to determine effect sizes (0.2–0.5 = small, 0.5–0.8 = medium, ≥ 0.8 = large; Cohen, 1988).

Qualitative data (video reflections and diary entries) were analyzed using ATLAS.ti (v. 7.1.3) software for the qualitative analysis of large bodies of textual, graphical, audio, and video data (Morales-Sánchez et al., 2014) following a systematic deductive-inductive procedure. The analysis was structured in three hierarchical levels: 1. Textual level (quotes): identification of meaningful extracts ($n = 121$) from the primary documents. 2. Conceptual level (nodes/codes): grouping of quotes into specific codes based on their semantic meaning (e.g., 'narrative', 'challenges', 'autonomy', 'effort'). 3. Structural level (families/dimensions): aggregation of codes into four main thematic categories: (1) gamification, (2) values, (3) academic learning, and (4) workload. This coding tree allowed for the triangulation of the professor's and students' perspectives within each dimension. Thematic content analysis and constant comparison were used to analyze all data (Libarkin & Kurdziel, 2002). In accordance with Korstjens and Moser (2018), several standards were used to ensure quality and trustworthiness: (a) credibility: through observation, data triangulation, and review by two members of the research team; (b) transferability: through description of the whole process; (c) confirmability: through frequent meetings of the two members of the research team in charge of the qualitative data analysis to discuss data interpretation; and (d) reflexivity: through the previous standards.

Results

Quantitative Results

Regarding the Student Satisfaction Questionnaire (Table 2), most items in the first subscale, professor satisfaction, remained stable across both academic years, reaching scores very close to maximum. However, one item showed a significant increase in the 2018–19 academic year (gamification): "The selected activities promoted learning", increasing from 3.22 to 4.12 ($p = .04$) with a large effect size ($d = 0.80$). In most of the other items, there were increases from the 2017–18 to the 2018–19 academic year, although these differences were not significant. Nevertheless, three items are worth highlighting: "The professor increased my interest in the subject" which rose from 3.44 to 4.00, with a medium effect size ($d = 0.49$); "The professor demonstrated mastery of the subject"; and "Global score of the professor's performance" which increased from 4.22 and 3.67 to 4.67 and 4.25, respectively, and large effect sizes ($d = 0.64$ and $d = 0.65$).

Focusing on the third subscale, subject satisfaction (Table 3), no significant differences were found between the two academic years ($p > .05$). However, most items showed a positive trend from the 2017–18 to the 2018–19 academic year: "The subject does not overlap with content covered in other subjects" from 3.9 to 4.31 (medium effect size); "The class plan is appropriate for achieving the subject's objectives" increased from 3.8 to 4.03 (small effect size); "The references used are helpful for following the subject" increased from 3.91 to 4.05 (small effect size), and "The assessment system is appropriate for evaluating student progress" increased from 3.83 to 3.98 (small effect size).

Table 2
Subscale "Professor Satisfaction" of the Subject Assessment Questionnaire.

	Academic year					
	2017/2018		2018/2019		*p*-value	*d*
	M	*SD*	*M*	*SD*		
1. The professor complied with the teaching guide	4.44	0.73	4.40	0.72	.86	0.06
2. The professor used the assessment criteria included in the teaching guide	4.33	0.71	4.33	0.76	.93	0.00
3. Theory and practice were well coordinated	3.89	1.36	4.21	1.01	.53	0.30
4. The selected activities promoted learning	3.22	1.30	4.12	1.10	.04	0.80
5. The professor's explanations helped me understand the content	3.89	1.17	4.12	0.99	.59	0.23
6. The professor demonstrated mastery of the subject	4.22	0.97	4.67	0.66	.15	0.64
7. The professor promoted student participation in class	4.22	0.97	4.32	0.79	.83	0.12
8. The professor solved doubts and provided guidance	4.33	0.87	4.32	0.87	.96	0.01
9. The resources used were adequate for learning	4.22	1.39	4.24	0.90	.57	0.02
10. I am satisfied with the support provided by the professor	4.00	0.93	4.25	1.04	.34	0.24
11. The professor increased my interest in the subject	3.44	1.67	4.00	1.04	.43	0.49
12. Global score of the professor's performance	3.67	1.22	4.25	0.84	.17	0.65

Note. M = Mean; *SD* = Standard Deviation; *p*-value = Mann-Whitney U test; *d* Cohen = Effect size.

Table 3
Subscale "Subject Satisfaction" of the Subject Assessment Questionnaire

	Academic year					
	2017/2018		2018/2019		*p*-value	*d*
	M	*SD*	*M*	*SD*		
1. The teaching guide is helpful for planning my work	3.42	1.27	3.41	1.17	.69	0.01
2. The subject does not overlap with content covered in other subjects	3.90	1.08	4.31	0.94	.56	0.43
3. The class plan is appropriate for achieving the subject's objectives	3.80	1.00	4.03	0.94	.22	0.24
4. The references used are helpful for following the subject	3.91	1.07	4.05	1.00	.61	0.14
5. The assessment system is appropriate for evaluating student progress	3.83	1.29	3.98	0.98	.73	0.14

Note. M = Mean; *SD* = Standard Deviation; *d* = Effect size.

Qualitative Results

The triangulation of the professor's diary and students' video reflections revealed four main dimensions: Gamification, Values, Academic Learning, and Workload. The findings are presented below according to these thematic categories.

Gamification (54 meaningful excerpts: seven from the students and 47 from the teacher). As expected, the program was the most widely discussed topic among participants. Students highlighted some of the elements of this new teaching and learning approach, such as the narrative used or the challenges proposed: "We [students in a group] felt that in the final battle we could only win" (student D). The professor tried to use this pedagogical approach to motivate the students and provide guidelines for solving the challenges using an attractive story. Among other things, the professor reflected on how important was for students the use of ICTs in gamification and included new updates. (15/09/2018).

Values (37 meaningful excerpts: nine from the students and 28 from the professor). The students mentioned issues such as effort and perseverance: "I worked hard and I was ready for the challenges" (student C), as well as respect for rules, helping others and appropriate behavior. The professor referred to values such as responsibility and autonomy in students and to his own worries regarding both: "I must trust my students and share more responsibilities with them because it [gamification] is working" (04/10/2018).

Academic learning (22 meaningful excerpts: five from the students and 17 from the professor). Students reflected on their academic learning, highlighting that it was positive: "I learned to observe, assess a task globally, and select the right solution to do it correctly. I have experienced Athletics from the inside [athlete] and from the outside [coach]" (student B), also for their training as future teachers/coaches: "We learned a valuable [pedagogical] tool for teaching Athletics using games" (student I). The professor reflected on the students' learning from the beginning of the experience: "I am very pleased with the tasks that the students have designed; they are so good that I will incorporate some of them in my classes next year" (30/09/2018).

Workload (eight meaningful excerpts from the professor). This theme emerged only from the professor's comments. He highlighted the extra workload and effort that this methodological approach required: "It [gamification] demands a high degree of weekly involvement" (15/10/2018). By the end of the semester, the professor considered the time invested in this pedagogical approach worthwhile after receiving the positive feedback from the students: "There is only one week left, and I believe that it has been a success, at least for me. It was worth getting here. There have been quite a few obstacles to overcome, but the feedback from the students has been very positive and motivating, which helps me continue in this new endeavor" (16/12/2018).

Discussion

Regarding the first objective, the results showed that the gamification instructional framework did not negatively affect students' satisfaction. They even believed that "the selected activities promoted learning" significantly more than the traditional approach. The Integrative Model for Teacher Change (Kern et al., 2020) highlights the need to modify teachers' pedagogical practices through frameworks that empower them and are linked to program satisfaction. This model reinforces the idea that this necessary change should begin in college, experiencing novel frameworks that may motivate teacher education students become better teachers (Richards et al., 2019) and gamification is one of them. The pedagogical structure used is a key element in Physical Education Teacher Education, because it may or may not connect with students, and in the present study, it did so more than before. Authors such as Daumiller et al. (2019) believe that it is important for university professors to use methodological frameworks that may help them improve the quality of the global teaching-learning process, and results from the present study showed that the gamification framework achieved this. Physical Education Teacher Education has the duty to empirically test them and teach them when they are positive (Mora-González et al., 2020; Pérez-López et al., 2017). The scarce previous research on Physical Education Teacher Education has found that gamification is perceived as a positive pedagogical approach for motivating students (Sierra & Fernández, 2019), which is in line with the results obtained in the present study.

The second objective was to examine the views of the participating students and professor after experiencing gamification for the first time. Regarding academic learning, students acknowledged that they had experienced a pedagogical approach that they could use in their professional future. This is particularly important, because the Integrative Model for Teacher Change highlights program satisfaction as a key element to promote change (Kern & Graber, 2017), and participants indicated that learning was important under the gamified framework.

Within this model, confidence in attempting change and willingness to adopt different teaching approaches (such as gamification) are two personal dispositions that may influence teachers' predisposition toward pedagogical change (Bechtel & O'Sullivan, 2007), and the results of the present study indicate that the gamified framework was positive for these future teachers.

In this regard, Navarro et al. (2024), implemented a gamification proposal based on the "MasterChef contest" with students enrolled in a teacher master's degree, highlighting the teacher's role as a differentiating element, and fostering higher levels of student engagement and satisfaction with the proposal. Only if this intended change begins in PETE, will novice teachers be able to endure physical education cultures at schools that do not support innovation (Curtner-Smith, 2017). Previous studies found similar outcomes in different university contexts (Jurgelaitis et al., 2019; Pérez-López et al., 2017), supporting the inclusion of gamification in university teaching, including physical education. Specifically, recent studies on gamified interventions based on popular culture, such as "PE Money Heist" or "Star Wars", have demonstrated significant improvements in students' motivational regulations, academic qualifications (Flores-Aguilar et al., 2023) and physical fitness (Mora-González et al., 2022).

Moreover, gamification has been identified as a pedagogical approach that improves students' participation (Huang et al., 2019; Pérez-López et al., 2025), while promoting values such as effort, resilience and responsibility, which are essential in student-centered educational contexts at all levels. In this line, research studies highlight the potential of hybridizing gamification with other pedagogical approaches, such as the Teaching Personal and Social Responsibility model, to further strengthen ethical and social dimensions in PE (Valero-Valenzuela et al., 2020), Cooperative Learning to support students' basic psychological needs, increase satisfaction with PE classes, and improve classroom climate (Flores-Aguilar et al., 2025; Jiménez-Parra et al., 2023), or Service-Learning to enhance motivation, learning, and social commitment (Navarro-Mateos & Pérez-López, 2026). Previous research has found that gamification can involve students in their learning, increasing class attendance (Pinter et al., 2020), which demands responsibility, commitment and effort. Both, the students and the professor's comments highlighted that the framework used to conduct the subject promoted these values. Jurgelaitis et al. (2019) argued that teacher educators must strive to educate future teachers using stimulating frameworks based on the students' interests in order to motivate them. The results of the present study showed that gamification placed students at the "center stage" by using an inspiring structure to encourage them to work hard, positively affecting their academic learning and, at the same time, fostering positive values.

Unfortunately, the professor's comments also uncovered a negative issue: workload. The framework required additional time and effort. Innovative pedagogical approaches require strong commitment and additional work from the teachers, which sometimes ends abruptly, when the "honeymoon period" is over (Goodyear & Casey, 2015). Previous research on gamification in primary and secondary physical education identified the same problem (Fernández-Río et al., 2020). Therefore, professors need support to implement these pedagogical approaches, and gamification is no exception. To enhance sustainability, future implementations could reduce workload by reusing materials, automating feedback through digital tools, adopting gradual or hybrid gamification models, and promoting collaboration and institutional support for instructors.

The present study also has some limitations. First, it included only one subject of the Physical Activity and Sport Sciences undergraduate program, with a small number of students. Future studies should include a larger number of subjects and participants. Second, quasi-experimental designs should be conducted to obtain causal information, and qualitative interviews should be included to extract more relevant information. Third, the questionnaire used in this study was specifically developed to address the research objectives and provided relevant data; however, it has not undergone formal psychometric validation. As such, the findings should be considered preliminary and interpreted with caution. Fourth, participants were recruited through convenience sampling from intact class groups, which limits the representativeness and generalizability of the findings. Consequently, results should be interpreted as context-bound and exploratory. Future studies including probably sampling or participants from multiple institutions would help confirm and extend these findings.

Conclusions

Gamification has been identified as a pedagogical framework suitable for Physical Education Teacher Education, with positive outcomes for future teachers. Students achieved higher grades, suggesting that they strived for the best result, and both their comments and those of their professors indicated that the framework promoted positive values such as effort, commitment, and responsibility, which are necessary for achieving high academic performance. Moreover, both participants in this study acknowledged that gamification helped improve students' academic learning. It was also perceived as a pedagogical approach that could be useful in their future professional practice in secondary physical education.

Therefore, the necessary change in physical education could begin during these teachers' initial training. However, there was one drawback: the implementation of this student-centered teaching approach increased the teacher's workload.

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Artistic swimmers performing a synchronized figure with technical precision and postural control.
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The book *Bases pedagógicas para una Educación Física de calidad. ESO*, coordinated by Cati Lecumberri, is clearly situated within the academic tradition that seeks to provide Physical Education with a solid pedagogical foundation, moving beyond reductionist perspectives focused exclusively on motor practice or performance. From its opening pages, the work raises a fundamental question: it is not enough to assume that physical activity is inherently educational; rather, it is necessary to understand under what conditions, with what intentionality, and through which pedagogical mediations it can truly contribute to the holistic development of students.

One of the main strengths of the text is its systemic approach. The quality of Physical Education is not attributed to a single factor but is understood as the result of the interaction among multiple elements: public policies, the sociocultural context, the school, the class group, and, ultimately, the individual characteristics of students. This ecological perspective makes it possible to situate teaching practice within a complex framework that both constrains—and at the same time enables—learning.

The work also stands out for its strong theoretical foundation. Throughout its chapters, it integrates contributions from pedagogy, psychology, sociology, philosophy, and neuroeducation, thus shaping an interdisciplinary view of learning. It emphasizes the idea that teaching does not guarantee learning, highlighting the complex, multidimensional, and non-linear nature of education processes. This standpoint is particularly relevant in Physical Education, where bodily experience does not automatically translate into meaningful learning.

Another noteworthy aspect is the attention given to the role of teachers. The teacher is presented as a key agent in the construction of high-quality learning environments, not only through methodological decisions but also through relational and ethical dimensions that directly influence student participation and engagement. In this regard, the book addresses issues such as planning through learning situations, formative assessment, inclusion based on Universal Design for Learning, and the integration of innovative pedagogical models.

From an applied perspective, the work combines theoretical reflection with practical proposals, facilitating its transfer to the school context. The suggested activities and teaching examples strengthen the connection between academic knowledge and educational practice.

In short, this is a rigorous, up-to-date, and necessary text. Its main contribution lies in offering a comprehensive framework that helps teachers ground their decisions and guide their practice towards a Physical Educations that is truly educational, inclusive, and aligned with contemporary challenges.