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Football training intensity and learning concentration: Roles of fatigue and sleep quality

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Abstract

School-based football training may support students' cognitive functioning, but variations in training intensity and recovery conditions may be associated with their concentration during learning. This study examined the relationship between football training intensity and learning concentration, with physical fatigue and sleep quality tested as indirect pathways.A quantitative cross-sectional study was conducted among 89 eligible junior high school students participating in extracurricular football activities using a total sampling approach. Football training intensity and learning concentration were measured using researcher-developed scales, while physical fatigue and sleep quality were assessed using adapted versions of the Pediatric Quality of Life Inventory (PedsQL) Multidimensional Fatigue Scale and Pittsburgh Sleep Quality Index (PSQI), respectively. Data were analyzed using path analysis with bootstrapping. Training intensity showed a significant positive direct association with learning concentration ($\beta = 0.097$, $p = 0.002$). The indirect pathway through physical fatigue was significant ($\beta = 0.057$, $p = 0.015$), whereas the pathway through sleep quality was not significant ($\beta = 0.005$, $p = 0.716$). Physical fatigue was positively associated with learning concentration ($\beta = 0.506$, $p < 0.001$), while sleep quality was not significantly associated with learning concentration ($\beta = 0.045$, $p = 0.714$). The model explained 44.9% of the variance in learning concentration ($R^2 = 0.449$). These findings provide preliminary evidence that training intensity and physical fatigue are associated with learning concentration, while highlighting the importance of considering training and recovery conditions when managing school-based football activities.

Keywords: Football training intensity, learning concentration, physical fatigue, sleep quality.

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INTRODUCTION

Physical education and school-based sports activities play a significant role in supporting adolescents' physical, cognitive, and psychosocial

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development. School-based sports activities are also linked to students' academic performance, particularly their learning concentration. In educational settings, extracurricular sports programs are strategically implemented not only to enhance physical fitness but also to foster discipline, self-regulation, positive learning behavior, attention levels, readiness to learn, and overall cognitive performance. Recent evidence consistently shows that regular participation in structured physical activity improves executive function, attention control, and academic engagement among children and adolescents (Álvarez-Bueno et al., 2017; Donnelly et al., 2016; Singh et al., 2019). These findings suggest that appropriately regulated physical activity can support cognitive readiness for academic tasks. However, these benefits do not occur uniformly across all activity types or exercise intensities. The extent to which physical activity supports cognitive function is strongly influenced by training load, intensity, duration, and adequate recovery. While physical activity may support cognitive function, high training intensity can also cause fatigue that may reduce concentration, making it important to consider the balance between these effects.

Football (soccer) is one of the most widely implemented extracurricular sports at the junior high school level, commonly offered in school programs and actively participated in by students aged 13–15 (Suryadi et al., 2023). Extracurricular school-based sports are recognized as an effective medium for increasing students' physical activity and engagement in structured exercise, as participants tend to be more physically active than non-participants (Meester et al., 2014). Soccer is particularly relevant in educational contexts because it requires a combination of endurance, speed, agility, strength, and coordination that supports overall physical fitness development (Mihardita & Putri, 2025). However, beyond these benefits, soccer also places considerable physical demands on participants. The sport involves intermittent high-intensity activities such as sprinting, rapid acceleration, and frequent changes of direction, which impose substantial physiological demands on participants

(Sarmento et al., 2014). These activity patterns can increase both acute and cumulative physical fatigue, particularly among students who are simultaneously managing academic demands. Within school contexts, football training is expected to enhance students' physical development and overall readiness for learning, but these benefits largely depend on the balance between training load and recovery. In this study, training intensity is considered a source of physiological stress. At the same time, physical fatigue and sleep quality are conceptualized as recovery-related factors that may affect students' concentration in learning. Excessive training intensity without adequate recovery may increase physical fatigue and potentially impair cognitive functioning (Halson, 2014).

Learning concentration is a core cognitive ability that enables students to sustain attention, manage distractions, and effectively process academic information. It is closely related to students' readiness to engage in classroom learning, making it a relevant outcome for students participating in school-based sports activities. Concentration is also particularly sensitive to physiological conditions such as physical fatigue and sleep quality, which training demands are likely to influence. Empirical research indicates that physical fitness and regular physical activity are positively associated with attention performance in adolescents (Kornia et al., 2025; Schmidt et al., 2017). From a physiological perspective, concentration is influenced by the body's capacity to adapt to and recover from exercise demands.

Physical training requires substantial metabolic and neural resources, and when training demands exceed recovery capacity, temporary reductions in cognitive performance may occur. High physiological load can increase fatigue, alter neurotransmitter activity, and reduce attentional resources, making it more difficult for students to maintain focus during academic tasks. In contrast, when training intensity is balanced with adequate recovery, regular physical activity may enhance cognitive functioning by improving cerebral blood flow, neuroplasticity, and overall brain health. Consequently, the

relationship between training intensity and learning concentration is not necessarily linear. While moderate physical activity may enhance cognitive function, excessive physiological load may produce adverse effects when fatigue accumulates, and recovery processes are insufficient to maintain optimal cognitive functioning. In school extracurricular settings, excessive physiological load may arise when training intensity, frequency, and duration exceed students' recovery capacity.

For adolescent students, recovery opportunities may be constrained by academic commitments, including classroom activities, homework, and examination preparation. Consequently, the interaction between intensive football training and academic demands may increase fatigue accumulation, impair recovery processes, and potentially affect cognitive functioning and learning-related outcomes.

Physical fatigue represents a key mechanism linking training intensity and cognitive performance. It is a direct physiological consequence of increased exercise intensity, as higher training loads impose greater metabolic and neuromuscular demands on the body. Elevated levels of physical fatigue have been shown to reduce alertness, impair executive functioning, and decrease the ability to sustain mental effort (Cutsem et al., 2017; McMorriset al., 2016). This conceptual role makes physical fatigue an appropriate indirect pathway linking training intensity and learning concentration, rather than merely a covariate. In school-based extracurricular settings, students often balance regular training sessions with academic responsibilities. When recovery is insufficient, accumulated physical fatigue may interfere with students' concentration on learning, particularly during periods of high academic demand (Oberste et al., 2019). This is especially relevant for secondary school students who participate in extracurricular activities while simultaneously managing homework, examinations, and regular classroom tasks. Under these conditions, inadequate recovery may increase the risk of reduced concentration during learning.

In addition to physical fatigue, sleep quality is an important recovery-related factor influencing cognitive functioning in adolescents. It is conceptualized as another pathway through which training intensity may be indirectly associated with learning concentration. Sleep quality may be influenced by the physiological demands of physical activity, particularly when training intensity is high, and recovery processes are disrupted. Adequate sleep supports memory consolidation, attentional regulation, and emotional stability (Wang & Chen, 2025). In contrast, poor sleep quality has been associated with increased daytime sleepiness, reduced concentration, and lower academic performance (Lo et al., 2016). Although physical activity can influence sleep patterns, the indirect pathway through sleep quality linking training intensity and learning concentration in school-based football programs remains insufficiently understood. Accordingly, physical fatigue and sleep quality are examined as complementary indirect pathways through which training intensity may be associated with students' learning concentration.

Despite growing evidence regarding physical activity and cognitive outcomes, empirical findings on the relationship between sports training intensity and learning concentration remain inconsistent. These inconsistencies likely stem from differences in training intensity levels, sport type, age groups, and educational contexts, as well as limited consideration of recovery-related variables, including physical fatigue and sleep quality, which may condition the effects of training on cognitive performance. Some studies report cognitive enhancement following structured exercise interventions (Singh et al., 2019). In contrast, others suggest that excessive training load without adequate recovery may elevate fatigue and impair attention performance (Oberste et al., 2019). However, most previous studies have examined physical activity and cognitive function in general terms or have focused on a single recovery-related mechanism. Research specifically examining football training intensity within junior high school extracurricular settings while simultaneously accounting for both physical fatigue and sleep

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quality as recovery-related mechanisms remains limited. As a result, there is limited evidence from studies that simultaneously examine the indirect pathway through physical fatigue and the indirect pathway through sleep quality in the association between football training intensity and learning concentration, particularly among junior high school students participating in extracurricular sports programs.

Therefore, this study aims to examine the relationship between football training intensity and learning concentration among seventh- to ninth-grade students participating in extracurricular football activities at SMP Negeri 1 Siliragung. Specifically, this study investigates (1) the direct relationship between training intensity and learning concentration, (2) the indirect association between training intensity and learning concentration through physical fatigue, and (3) the indirect association between training intensity and learning concentration through sleep quality as a recovery-related factor. By integrating training intensity, training load, and recovery-related mechanisms within a single analytical framework, this study aims to expand understanding of the relationships among exercise intensity, physical fatigue, sleep quality, and learning concentration in school-based sports. The findings may also provide empirical evidence and preliminary practical considerations for educators and coaches managing school-based football training programs that support students' cognitive functioning while considering their academic demands and remaining consistent with the study's non-experimental nature.

METHOD

Research Design and Setting

This study employed a quantitative cross-sectional correlational design to examine the relationships among football training intensity, physical fatigue, sleep quality, and learning concentration. The analysis focused on estimating direct and indirect relationships within the proposed theoretical model. We examined physical fatigue and sleep quality as hypothesized indirect pathways

between football training intensity and learning concentration. Given the cross-sectional design, all relationships were interpreted as associative rather than causal. All variables were measured at a single point in time among students actively participating in extracurricular football activities, allowing the study to capture their concurrent physical and cognitive conditions (Creswell, 2018). Structural path analysis was used to examine the relationships among variables, including the hypothesized indirect pathways within the theoretical model (Kline, 2016). The study was conducted among students participating in the football extracurricular program at SMP Negeri 1 Siliragung, Banyuwangi, Indonesia, during the 2025/2026 academic year.

Population and Sample

The population comprised 98 students in Grades VII–IX who were registered in the football extracurricular program at SMP Negeri 1 Siliragung during the 2025/2026 academic year. Students were eligible for inclusion if they were officially registered in the football extracurricular program, had participated in training sessions for at least the previous three months, attended a minimum of 75% of scheduled training sessions during the data collection period, and agreed to participate voluntarily. Following screening, 89 students aged approximately 12–15 years completed the questionnaires and were included in the study using a total sampling approach. Nine students were excluded because of incomplete attendance records and/or questionnaire responses. The final sample consisted of 30 students from Grade VII, 23 students from Grade VIII, and 36 students from Grade IX. All participants were male because the football extracurricular program at SMP Negeri 1 Siliragung consisted exclusively of male students during the study period; therefore, no female students were eligible for inclusion. Written informed consent was obtained from the parents or legal guardians of all participants, and students provided assent before participation.

Variables and Instruments

The proposed model examined four variables: football training intensity as the predictor variable; physical fatigue and sleep quality as variables representing the hypothesized indirect pathways; and learning concentration as the outcome variable.

Football training intensity was measured using a nine-item researcher-developed questionnaire based on the training load principles of Bompa and Buzzichelli (2019). The instrument covered four dimensions: training frequency, training duration, perceived training load intensity, and training discipline. Participants rated responses on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Total scores ranged from 9 to 45, with higher scores indicating greater perceived football training intensity. Experts in sports science reviewed the instrument, and it demonstrated acceptable internal consistency in the present study (Cronbach's $\alpha = 0.761$).

Physical fatigue was measured using an adapted version of the PedsQL™ Multidimensional Fatigue Scale (Varni & Limbers, 2008), comprising the dimensions of General Fatigue, Sleep/Rest Fatigue, and Cognitive Fatigue. The original adapted instrument contained 18 items, and following validity testing, 17 items were retained for the final analysis. Item wording was adapted to the context of school football extracurricular activities while retaining the original conceptual dimensions. The Indonesian version was prepared using translation and cultural adaptation procedures, including forward–backward translation and expert review. Responses were rated on a five-point Likert scale, with negatively worded items reverse-scored prior to analysis. Total scores for the final 17-item instrument ranged from 17 to 85, with higher scores indicating greater levels of perceived fatigue. The instrument demonstrated excellent internal consistency in the present study (Cronbach's $\alpha = 0.891$).

Sleep quality was measured using an instrument adapted from the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989). The adapted instrument initially contained 11 items covering five dimensions: sleep efficiency, sleep disturbances, sleep duration, subjective sleep quality, and

sleep latency. After validity testing, the final instrument retained nine items. The instrument was linguistically adapted for junior high school students while retaining the original conceptual domains. Responses were rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), and negatively worded items were reverse-scored before the total score was calculated. After scoring, total scores ranged from 9 to 45, with higher scores indicating better sleep quality, characterized by adequate sleep duration, higher sleep efficiency, fewer sleep disturbances, shorter sleep latency, and a more positive subjective evaluation of sleep. The final instrument demonstrated good internal consistency in the present study (Cronbach's α = 0.789). Learning concentration was measured using a nine-item researcher-developed Learning Concentration Scale based on the indicators proposed by Slameto (2015). The instrument assessed four dimensions: attentional focus, information processing, self-control, and sustained concentration during classroom learning. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Total scores ranged from 9 to 45, with higher scores indicating better learning concentration. Before data collection, experts reviewed the instrument for content relevance, clarity, and representativeness. The scale demonstrated acceptable internal consistency in the present study (Cronbach's α = 0.804).

Validity and Reliability

Construct validity was evaluated using confirmatory factor analysis (CFA) in JASP version 0.18.3.0 to assess the measurement model's adequacy. Model fit was evaluated using χ^2, Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). CFI and TLI values ≥ 0.90 and RMSEA and SRMR values ≤ 0.08 were considered indicative of acceptable model fit (Kline, 2016; Hair et al., 2019). Convergent validity was assessed using Average Variance Extracted (AVE), with values ≥ 0.50 considered acceptable. Internal consistency reliability was evaluated using Cronbach's alpha

coefficients, with values ≥ 0.70 considered acceptable for behavioral research (DeVellis, 2017).

Data Collection Procedure

Data were collected from March 10 to March 13, 2026, during the second semester of the 2025/2026 academic year. Following formal permission from the school, the researcher coordinated with the extracurricular activity advisor and teachers to schedule data collection. Participants received standardized instructions regarding the study procedures and completed the questionnaires in a supervised classroom setting during school hours. The researcher remained available to answer questions and provide clarification when necessary. Questionnaire completion required approximately 10–15 minutes. Responses were checked for completeness before analysis, collected anonymously, and used solely for research purposes.

Data Analysis

Descriptive statistics were calculated using IBM SPSS Statistics version 27 and JASP version 0.18.3.0. The hypothesized direct and indirect relationships among football training intensity, physical fatigue, sleep quality, and learning concentration were examined using PROCESS Macro Model 4 (Hayes, 2018) with ordinary least squares regression. Normality was assessed using skewness and kurtosis, with values between −2 and +2 considered acceptable. Multicollinearity was evaluated using tolerance (> 0.10) and variance inflation factor (VIF < 10), while linearity was examined through scatterplot inspection (Hair et al., 2019).

Physical fatigue and sleep quality were examined as parallel indirect pathways between football training intensity and learning concentration. Indirect associations were evaluated using bootstrapping with 5,000 resamples to estimate bias-corrected 95% confidence intervals. Bootstrapping was used because it provides robust estimates of indirect associations without requiring the sampling distribution of the indirect effect to meet the assumption of

normality (Hayes, 2018). An indirect association was considered statistically significant when its 95% bootstrap confidence interval did not include zero. Statistical significance for direct associations was set at *p* < .05.

Ethical Considerations

This study was conducted in accordance with ethical principles for research involving human participants. Formal approval from an institutional research ethics committee was not obtained prior to data collection. The Principal of SMP Negeri 1 Siliragung granted administrative permission to conduct the study through an official research authorization letter dated 12 March 2026; the letter did not include an official reference number. As all participants were minors, written informed consent was obtained from their parents or legal guardians, and informed assent was obtained from all participating students prior to participation. Participation was voluntary, and students were informed of their right to decline or withdraw at any time without penalty. No personally identifiable information was collected, questionnaire responses were anonymized, and the data were securely stored and used solely for research purposes.

RESULTS

This study examined the relationship between football training intensity and learning concentration among junior high school students participating in extracurricular football activities. Table 1 presents the results of the structural model analysis, including the direct and total effects of football training intensity on learning concentration.

Table 1. Direct and Total Effects of Training Intensity on Learning Concentration

Effect Type	Estimate (β)	p-value
Direct Effect	0.097	0.002
Total Effect	0.159	< 0.001

Table 1 presents the direct and total effects of training intensity on learning concentration. The results indicate that training intensity has a positive

and statistically significant direct effect on learning concentration (β = 0.097, p = 0.002). Although the coefficient is relatively small, the relationship remains statistically significant. The total effect of training intensity on learning concentration was also positive and statistically significant (β = 0.159, p < 0.001), indicating an overall positive association between the two variables. Table 2 presents details on the indirect effects through the tested indirect pathways.

Table 2. Indirect Effects of Training Intensity on Learning Concentration

Mediation Variable	Estimate (β)	p-value
Sleep Quality	0.005	0.716
Physical Fatigue	0.057	0.015
Total Indirect Effect	0.062	0.006

Note. Higher physical fatigue scores indicate greater levels of perceived physical fatigue. Higher sleep quality scores indicate better sleep quality.

Table 2 presents the indirect associations between training intensity and learning concentration through sleep quality and physical fatigue. The indirect association through sleep quality was not statistically significant (β = 0.005, *p* = 0.716, 95% CI = −0.023 to 0.034). Because the 95% confidence interval included zero, the hypothesized indirect pathway through sleep quality was not supported. In contrast, the indirect association through physical fatigue was statistically significant (β = 0.057, *p* = 0.015, 95% CI = 0.011 to 0.103). Because the confidence interval did not include zero, the indirect pathway through physical fatigue was supported. Higher physical fatigue scores represented greater perceived fatigue; therefore, greater training intensity was associated with learning concentration through increased physical fatigue. The total indirect association was statistically significant (β = 0.062, *p* = 0.006, 95% CI = 0.018 to 0.107), indicating a significant overall indirect association between training intensity and learning concentration. Among the two hypothesized indirect pathways examined, only the pathway through physical fatigue reached statistical significance.

Table 3. Structural Path Estimates

Relationship	Estimate (β)	*p-value*
Training Intensity on Learning Concentration	0.097	0.002
Training Intensity on Sleep Quality	0.118	0.002
Training Intensity on Physical Fatigue	0.112	0.003
Sleep Quality on Learning Concentration	0.045	0.714
Physical Fatigue on Learning Concentration	0.506	< 0.001

Table 3 summarizes the structural path estimates among the study variables. Football training intensity had significant positive effects on learning concentration (β = 0.097, *p* = 0.002), sleep quality (β = 0.118, *p* = 0.002), and physical fatigue (β = 0.112, *p* = 0.003). Physical fatigue was positively associated with learning concentration (β = 0.506, *p* < 0.001), whereas sleep quality was not significantly associated with learning concentration (β = 0.045, *p* = 0.714).

Table 4. Coefficient of Determination (R2)

Endogenous Variable	R^2
Learning Concentration	0.449
Sleep Quality	0.100
Physical Fatigue	0.091

The coefficient of determination indicates that training intensity, sleep quality, and physical fatigue explain 44.9% of the variance in learning concentration (R^2 = 0.449). In addition, sleep quality and physical fatigue explain 10.0% (R^2 = 0.100) and 9.1% (R^2 = 0.091) of the variance, respectively.

DISCUSSION

The findings indicate a statistically significant positive direct association between football training intensity and students' learning concentration. This result is consistent with previous evidence suggesting that structured physical activity is positively associated with cognitive readiness, attentional control, and executive functioning among adolescents (Álvarez-Bueno et al., 2017; Donnelly et al., 2016). From a theoretical perspective, regular physical activity may support cognitive functioning through neurophysiological mechanisms such as increased cerebral blood flow, neuroplastic adaptations, and brain-derived neurotrophic factor (BDNF), which may facilitate information

processing and attention. However, these mechanisms were not directly assessed in the present study and should therefore be considered explanatory possibilities rather than demonstrated mechanisms.

The direct association between training intensity and learning concentration was statistically significant but relatively small (β = 0.097), indicating that training intensity represents only one factor associated with students' concentration. Previous research has similarly linked structured physical activity with attention regulation and classroom engagement among adolescents (Schmidt et al., 2017). The modest magnitude observed in the present study is also consistent with the broader view that cognitive performance in learning contexts is influenced by multiple interacting internal, psychological, and academic factors, including motivation, self-efficacy, and cognitive strategies within the framework of self-regulated learning (Panadero, 2017). Thus, participation in school-based football activities may contribute to conditions associated with learning concentration. Still, training intensity should not be regarded as a dominant or independent determinant of students' cognitive functioning.

The indirect association between training intensity and learning concentration through sleep quality was not statistically significant. This finding suggests that sleep quality, as operationalized in the present study, did not constitute a supported indirect pathway between the two variables. Although previous research suggests that physical activity and adequate sleep may support cognitive functioning in adolescents, this finding indicates that sleep quality did not make a statistically significant contribution to the tested indirect pathway in this sample. This discrepancy may reflect differences in exercise timing and duration, individual adaptation, or limited variability in sleep characteristics among participants (Hasan et al., 2022; Kredlow et al., 2015). The study also did not assess potentially relevant factors such as daily sleep habits and academic workload, which may influence the relationship between physical activity, recovery, and cognitive functioning. Moreover, aspects such

as total sleep duration, sleep consistency, and recovery patterns may capture dimensions of adolescent sleep that are relevant to concentration but were not fully represented in the present analysis. In addition, self-reported sleep measures and the cross-sectional design may have limited the ability to capture temporal changes in sleep and cognitive functioning. Therefore, the non-significant indirect association should not be interpreted as evidence that sleep is unimportant for learning concentration, but rather that the hypothesized pathway through the sleep quality measure used in this study was not supported.

In contrast, physical fatigue constituted a statistically significant indirect pathway between training intensity and learning concentration. Physical fatigue was positively associated with learning concentration ($\beta = 0.506$, $p < 0.001$). Higher scores on the physical fatigue measure represented greater perceived fatigue; therefore, the positive coefficient indicated that greater perceived fatigue was associated with higher learning concentration scores in the observed sample. This direction differs from theoretical expectations and previous sport science literature, which generally associates greater fatigue with poorer cognitive functioning. Fatigue theory suggests that accumulated physical load may temporarily reduce the cognitive resources required for sustained attention and information processing (Enoka & Duchateau, 2016), while acute and accumulated fatigue have been associated with reduced alertness, lower attentional capacity, and poorer executive functioning (Cutsem et al., 2017).

Several factors may explain this unexpected association, including differences in participant characteristics, measurement approaches, training structure, recovery practices, academic workload, individual fitness levels, training contexts, and the multidimensional nature of perceived fatigue. Students who regularly participate in extracurricular football may also differ in their adaptation to routine training demands. Nevertheless, these explanations remain tentative because the present study did not directly measure

physiological adaptation or the relevant contextual factors. Given the study's cross-sectional design and measurement characteristics, interpret the positive association between perceived physical fatigue and learning concentration cautiously. It should not be taken to indicate that increasing physical fatigue improves concentration. This unexpected finding requires further examination using longitudinal or experimental designs.

Taken together, the findings demonstrate a statistically significant direct association between training intensity and learning concentration and a significant indirect association through physical fatigue. In contrast, the indirect pathway through sleep quality was not supported. This pattern fits within the recovery–stress balance framework, which emphasizes the relationship between training demands and recovery processes for physical and cognitive functioning (Kellmann & Beckmann, 2021). Within this framework, insufficient recovery may be associated with increased fatigue and reduced physical and cognitive functioning. However, because all variables were measured at a single point in time, the observed direct and indirect pathways represent statistical associations within the proposed model rather than evidence of temporal or causal mechanisms.

Several limitations should be acknowledged. First, the model explained 44.9% of the variance in learning concentration, indicating that other relevant factors were not captured within the present framework. Second, the cross-sectional design limits causal and temporal interpretations because the relationships were assessed at a single point in time (Setia, 2016). Third, reliance on self-report measures may have introduced subjective response bias. The operationalization of physical fatigue may also involve ambiguity because fatigue was measured based on participants' self-perceived conditions rather than objective physiological indicators, which may affect the precision of construct measurement.

Furthermore, using single-source self-report data collected from the same participants at the same time increases the risk of common method variance.

It may potentially overestimate relationships among the variables (Kaltsonoudi et al., 2022). The unexpected positive association between physical fatigue and learning concentration further requires cautious interpretation because it differs from the direction commonly reported in previous literature. Future studies should use longitudinal designs, incorporate objective indicators of training load and recovery, such as heart-rate monitoring, and examine additional psychological and contextual variables, including motivation and stress regulation, that may contribute to learning concentration and strengthen the model's explanatory power (Impellizzeri et al., 2018).

The findings offer preliminary practical implications for managing school-based football extracurricular programs. Rather than focusing solely on training intensity, the observed relationships highlight the importance of considering training load and recovery together in relation to students' concentration in learning. Schools, coaches, and physical education teachers should therefore consider training frequency, training volume, training intensity, and adequate recovery periods when planning extracurricular football activities (Impellizzeri et al., 2018; Kellmann & Beckmann, 2021). Given the cross-sectional nature of the study, these implications should be regarded as preliminary considerations rather than prescriptive recommendations. Maintaining an appropriate balance between training demands and recovery may provide a relevant framework for supporting students' physical development and participation in football activities while preserving their readiness to concentrate during academic learning.

CONCLUSSION

This study examined the relationship between football training intensity and learning concentration among seventh- to ninth-grade students participating in school-based extracurricular football activities. The results showed a significant positive direct association between football training intensity and learning concentration and a significant indirect association

through physical fatigue. In contrast, the indirect pathway through sleep quality was not supported. These findings provide empirical evidence on the direct and indirect associations among training intensity, physical fatigue, sleep quality, and learning concentration in a school-based adolescent football context.

The findings should be interpreted cautiously given the cross-sectional design, reliance on self-report measures, and single-school sample. From a practical perspective, schools and coaches may consider balancing training load with adequate recovery when planning extracurricular football activities to support students' learning concentration. Future studies should employ longitudinal or experimental designs and incorporate objective measures of training load and recovery to strengthen the evidence regarding these relationships.

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