Tun J Sport Sci Med 2025; 3(4):1-12
https://doi.org/10.61838/tjssm.2025.3.4.1

Tunisian Journal of
Sports Science
and Medicine
Original Article

Effect of time of day on learning time and attention at physical education sessions in high school students

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Received:	Reviewed:	Revised:	Accepted:	Published:
2025-10-06	2025-11-10	2025-11-26	2025-12-09	2025-12-22

Abstract

Background: Biological rhythms shape students' physical and cognitive abilities throughout the day, directly affecting their attention and academic performance. Chronobiology reveals the importance of scheduling learning activities during the periods when pupils are most attentive and motivated to learn.

Aim: The study investigates the impact of time-of-day variations on learning time, attention, and instructional efficacy in physical education (PE), emphasizing alignment with students' physiological and cognitive rhythms.

Methods: Two PE lessons were analysed using the Learning Time Analysis System and the barrage test. Descriptive analysis of learning time distribution between morning and afternoon sessions revealed significant differences in activity allocation.

Results: Teachers spent more time in the morning on preparatory tasks (54.31% vs 36.44%) and group management (5.76% vs 1.06%), resulting in better cognitive function after sleep. Teachers spent more time on motor development in the afternoon (47.96% vs. 34.52% in the morning) and only 1.5% on physical conditioning. These sessions capitalized on peak physical readiness associated with circadian rhythms, such as heightened body temperature and increased neuromuscular efficiency. The acquisition of theoretical knowledge remained consistent across both periods (13.21% in the morning vs 10.93% in the afternoon). This indicates that cognitive performance was independent of the time of day. The findings also demonstrate a significant effect in term of attention which being higher in the morning versus the afternoon.

Conclusion: These findings highlight the influence of biological rhythms on learning time, attention, and performance and suggest that optimizing PE schedules by reserving mornings for cognitively demanding tasks and afternoons for physically intensive activities (e.g. skill practice, conditioning) may improve educational outcomes. The study advocates that teachers plan sessions to match students' chronobiological profiles, thereby improving motor engagement, reducing disengagement, and promoting academic success in PE.

Keywords: Learning Time Analysis System, Circadian Rhythms, Academic Performance, Temporal Variability

How to cite this article:

Ezzeddine G, Bouzid MS, Megudiche A, Souissi N. Effect of time of day on learning time and attention at physical education sessions in high school students. Tun J Sport Sci Med. 2025;3(4):1-12.

1. INTRODUCTION

Recognizing that optimizing physical education (PE) schedules to align with students' chronobiological profiles can potentially enhance instructional outcomes. PE sessions are structured activities in which pupils improve motor skills and resourcefulness **[1]**, supported by teachers who create positive learning environments **[2]**. Effective classroom management is teachers taking supportive measures before, during, and after sessions to help students learn **[3,4]**. Effective classroom management helps students stay focused on their tasks, makes them aware of their ability to learn, and gives meaning to the learning process. It includes planning, organizing teaching, learning activities and actively engaging students in the process **[5,6]**. Acting with learning in mind also means arranging time efficiently within a given period. Furthermore, teachers should ensure effective time management **[7]**, which includes maintaining educational continuity, keeping students motivated **[8]**, minimizing disruptions, and avoiding time wasting in order to reserve optimal time for learning **[9]**.

Studies in the field of effective teaching research have consistently emphasized the significance of student engagement or time on task as a predictor of academic success **[10,11]**. Particularly in PE teaching, learning time stands out as one of the most critical variables, representing the amount of time that a student spends engaged in physical activity **[12]**. Lower rates of learning time are generally correlated with reduced learning outcomes, slower progress, and potentially diminished engagement or motivation among students **[13]**.

It is will know that PE sessions should ensure the regulatory school time is respected and that sufficient time is available for physical activity (i.e., 60 to 80% of scheduled sessions should take place). Discrepancies between institutional school time and students' temporal preferences can have an impact on cognitive performance, emphasizing the importance of investigating the influence of time of day **[14,15,16]**. In this context, students who find themselves in a conflictual temporal framework, i.e., in a situation of incompatibility between their "time slots" and the school time set by the institution, may present their cognitive capacities at their lowest when it comes to learning. In these conflictual settings, a gap develops between what the student should be at any particular time and what they are. This gap motivates us to consider how student engagement varies with time of day. This concept is interesting because previous research has shown that physical and cognitive performance can differ depending on the time of day **[17,18]**. This presents the essential topic of determining the best time for successful learning, especially in the context of PE. The concept of the optimal learning moment refers to the most appropriate time to learn. However, research into the effect of time of day on students' learning time during PE lessons is very scarce. Thus, the purpose of this study was to assess the effect of time of day on students' learning time during PE sessions, with the hypothesis that learning time would be greater in the morning than in the afternoon. Understanding the impact of temporal elements on student learning time might help guide judgments on the best timing of PE programs within school schedules. As a result, this understanding can improve student participation and learning outcomes in PE. To investigate the potential impact of time of day on learning time and attention, we employed a mixed-methods approach incorporating direct observation of PE sessions and the administration of a standardized attention test.

2. Materials and Methods

2.1. Participants

Twenty-five high school students (14 boys characterized by a (height: 1.60±0.08 M ; weight: 53.35±5.09 kg), 11 girls characterized by a (height: 1.50±0.07 m; weight: 48.35±4.02 kg), mean age 15 ± 3.6 years) in their first year of the Tunisian secondary education system voluntarily participated in this study. The sample size was determined in advance using G*power software (version 3.1.9.2; Heinrich Heine University Düsseldorf, North Rhine-Westphalia, Germany) **[25]**. Parameters such as effect size, alfa error probability and power were set at 0.52, 0.05, 0.8 respectively. Participants were randomly selected, and students who practiced sports in civil, competitive, or amateur clubs, or within the high school sports association, were excluded. Approval for the study was obtained from the University Research Ethics Board (CPPSUD: 0295/2021) prior to recruitment. All participants, along with their teachers, school director, and parents/guardians, provided informed consent after being informed about the nature, objectives, methodology, and constraints of the study.

2.2. Design

Two data collection techniques were employed: observation and barrier testing. First, two physical education (PE) sessions were observed and coded: one in the morning and one in the afternoon. Secondly, students' attention capacities were measured using a barrage test, a perceptual-motor task that assesses attentional performance profiles throughout the day.

2.3. Data Collection

Students were filmed during two PE sessions held at different times of the day: morning (8:00 am) and afternoon (3:00 pm). These sessions were part of a sprinting training program. Data were collected through video and audio recordings of all student actions using two Sony camcorders (Handcam 4K model) equipped with an integrated projector and a wireless microphone paired with a Boom Tone DJ transmitter receiver (VHF 10HL F4 Micro H.F): one fixed at a corner of the field to capture a wide-angle view of the entire class, and another that followed the target students to capture all their movements. Concurrently, notes were taken to facilitate post-session analysis.

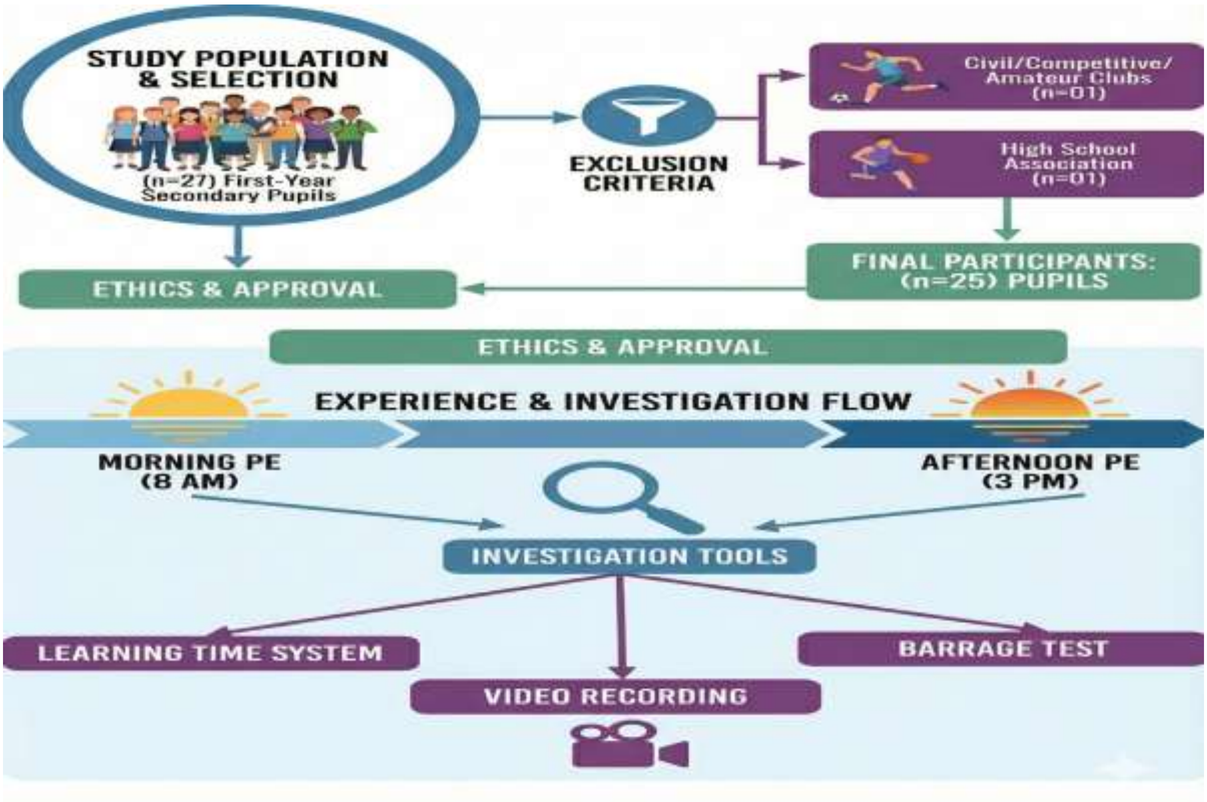

Figure 1. Flow diagram of the study

2.4. Measures

2.4.1. The learning time analysis system

The French version of the learning time analysis system was used to assess students' learning time in PE classes **[19]**. To improve observation, delayed videoscopic analysis was performed, which entailed revisiting the instruction sessions numerous times to ensure proper coding. Brunelle et al **[19]** used the short-interval approach, which consisted of six-second observation intervals followed by six-second coding intervals. The learning time analysis system is founded on the systematic collection of the durations learners dedicate to various educational activities, either automatically through digital platforms or via direct observation. Learning sessions are segmented into discrete time intervals, during which learner behaviors are coded according to well-defined categories. The collected data is then analyzed to determine the total and average time spent on each activity, as well as patterns that indicate the task's difficulty or simplicity. This analysis can also be used to assess learners' engagement levels and identify potential bottlenecks or obstacles. The validity of these measures is ensured by rigorous category definitions, standardized coding procedures, and the traceability of interactions in automated systems. Consequently, this tool provides reliable indicators for evaluating and improving the learning experience **[20,21]**.

2.4.2. The barrage test

The barrage test assesses students' attention and is a commonly used tool in chronopsychology **[22]**. It requires minimal equipment: a stopwatch, a pen, and A4 recording sheets. The test consists of crossing out all the signs with a specific shape in one minute, just before the PE session. The barrage test assesses attention by measuring the subject's ability to quickly locate and mark specific targets (letters, numbers, or signs) among distractors within a limited time. This task mainly calls on selective attention, i.e., the ability to focus attention on relevant stimuli while ignoring irrelevant elements, as well as sustained attention, which corresponds to the ability to maintain this level of attention over a prolonged period. When performing this task, the participant must visually scan a series of elements, inhibit automatic responses to distractors, and maintain a constant effort, which makes it possible to detect attentional deficits, in particular unilateral spatial neglect in cerebral palsy patients. Substitution errors (marking out an incorrect item) may suggest impulsivity, while omission errors (not crossing out a target) suggest a lack of attention. Administered fast, less than five minutes, this test shows strong sensitivity and dependability for spotting attentional problems. The barrage test is a reliable tool for assessing attentional processes, particularly selective and sustained attention. The test also provides quantitative and qualitative indicators of the subject's level of attentional engagement and any difficulties in maintaining or directing attention effectively.

2.5. Analysis

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) for Windows version 26.0 (SPSS, Inc., Chicago, IL, USA). Means, standard deviations, and standard errors (SE) were calculated for the selected variables. Parametric tests were preferentially used when the morning-afternoon difference distributions met normality assumptions (verified by Shapiro-Wilk test, $p > 0.05$), which applied to all parameters showing significant differences. For the few cases violating the normality assumption, equivalent non-parametric tests (Wilcoxon signed-rank test) were applied, though no significant differences were detected. The paired Student t-test was used to compare differences before and during the research intervention. A probability level of 0.05 was set as the criterion for statistical significance. Data processing involved listing all learning time analysis system behavior categories in Excel and calculating the time allocated to each category. The percentage of intervals for each category was calculated relative to the total number of intervals. Key categories for estimating the quality of participation included "motor engagement", "cognitive engagement", and "appropriate engagement" **[19]**.

3. Results

The following table presents the distribution of the time devoted to the PE session at the two times of the day.

Table 1. Comparative analysis of learning time between morning and afternoon sessions (Means, Parametric/Non-Parametric Tests, Effect Sizes, and Normality Tests).

Parameters	Morning Means	Afternoon Means	T test / T Wilcoxon*	P value	Cohen's d / r de Wilcoxon*	Normality W	Normality P value
Preparatory situations	54.31	36.94	2.356	0.027	0.47	0.949	0.207
Knowledge development situations	10.93	13.21	0.517	0.61	0.10	0.958	0.316
Motor development situations	34.52	47.96	2.137	0.043	0.43	0.941	0.147

Note: * ($p < 0.05$). Parameters marked with an asterisk (*) were analyzed using non-parametric tests: the Wilcoxon signed-rank test for paired comparisons, with Wilcoxon r effect size as the magnitude measure.

Table 1 indicates that Time spent on preparatory situations was significantly higher in the morning session ($p=0.027$). The table shows that 54.31% of time was devoted to preparatory situations. Time devoted to motor development was significantly higher ($p = 0.043$) in the afternoon session compared to the morning. And 47.96% of time was devoted to motor development. However, no significant differences were found in knowledge development situations between the morning and afternoon sessions.

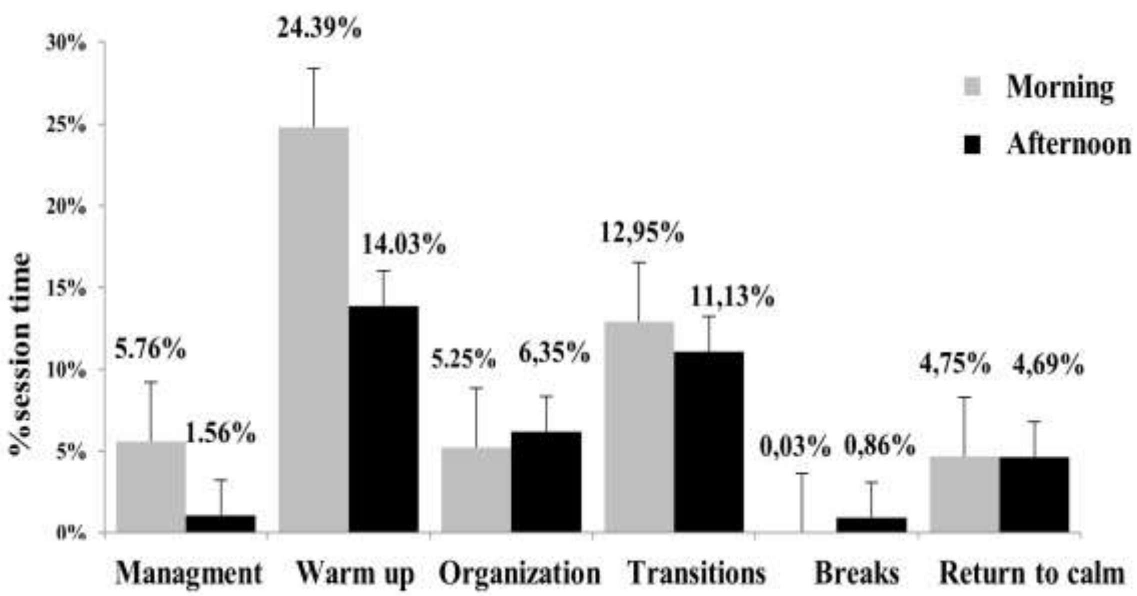

Figure 2. Comparative analysis of the components of preparatory situations between morning and afternoon sessions. * ($p < 0.05$)

The comparative analysis between morning and afternoon sessions revealed significant differences for specific parameters (figure 2). Dependent samples t-test demonstrated that Management time was significantly higher in morning sessions (5.76%) compared to afternoon sessions (1.56%); (t = 2.683, p = 0.013, d = 0.54). Similarly, Warm-up duration was substantially longer in the morning (24.39%) vs (14.03%) in the afternoon; (t = 5.479, p < 0.001, d = 1.10). No significant difference was found for Transitions (p = 0.324, d = 0.20). For non-normally distributed parameters, Wilcoxon signed-rank tests showed no significant differences: Organization (T = 129, p = 0.782, r = 0.05), Breaks (T = 132, p = 0.862, r = 0.04), and Return to calm (T = 98, p = 0.912, r = 0.02). Shapiro-Wilk tests confirmed normality assumptions for parametric analyses (W = 0.930-0.966, p > 0.05), except for Organization (W = 0.882, p = 0.008), Breaks (W = 0.855, p = 0.002), and Return to calm (W = 0.908, p = 0.029), which required non-parametric testing.

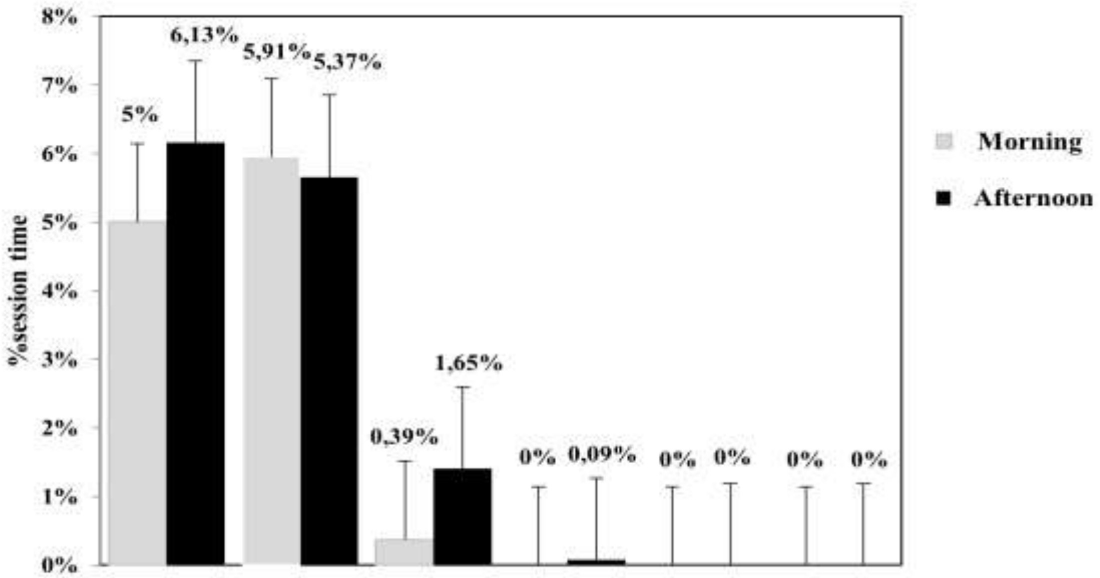

Figure 3. Comparative analysis between morning and afternoon of the Knowledge development situations. * (p <0.05)

Statistical comparisons of morning and afternoon sessions revealed no significant differences in all evaluated parameters (figure 3). Dependent samples t-tests for normally distributed variables revealed non-significant effects for Strategy (morning: 5.00% vs afternoon: 6.13%; t = 0.271, p = 0.789, d = 0.05), Technical aspects (5.91% vs 5.37%; t = 0.239, p = 0.814, d = 0.05), and Regulation (0.39% vs 1.65%; t = 0.399, p = 0.693, d = 0.08). Non-parametric Wilcoxon tests for skewed distributions revealed no significant differences in Ethics (0.00% vs 0.09%; T = 109.5, p = 0.874, r = 0.03), Additional information (0.00% vs 0.00%; T = 86.5, p = 0.967, r = 0.01), or Health (0.00% vs 0.00%; T = 52.5, p = 0.986, r = 0.00). The normality criteria were met for Strategy (W = 0.943, p = 0.158), Technical (W = 0.927, p = 0.074), and Regulation (W = 0.948, p = 0.197). However, Ethics (W = 0.879, p = 0.007), Additional information (W = 0.790, p < 0.001), and Health (W = 0.743, p < 0.001) needed non-parametric treatment.

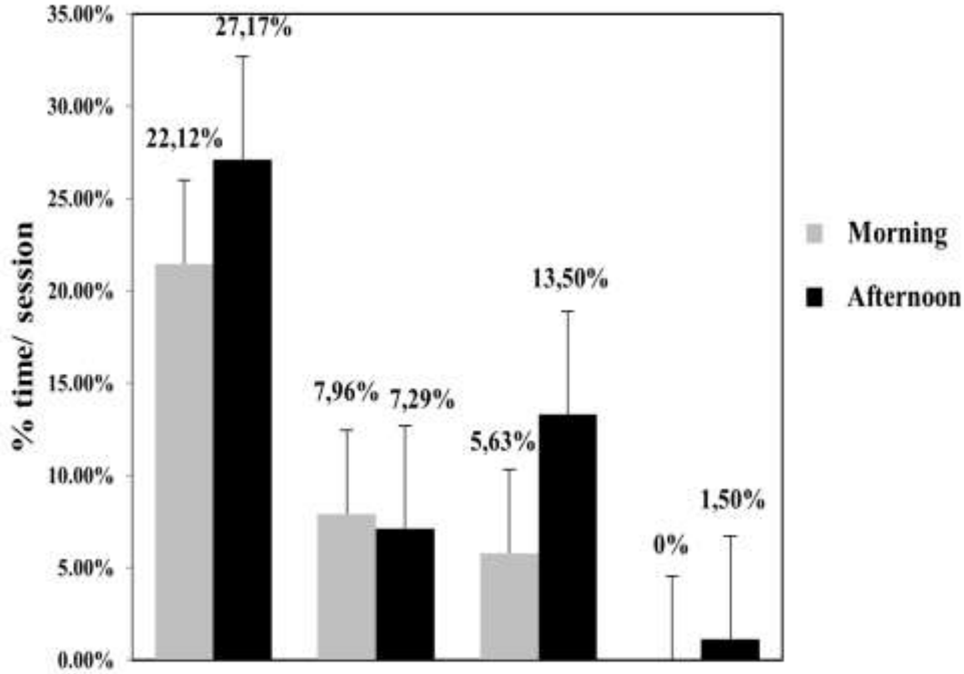

Figure 4. Comparative analysis between morning and afternoon of the Motor development situations. * (p <0.05)

Dependent samples t-tests for normally distributed parameters revealed that physical conditioning provided a statistically significant difference (morning: 0.00% vs afternoon: 1.50%; $t = 2.074$, $p = 0.049$, $d = 0.35$) (figure 4). The competitive situation approached but did not achieve significance (5.63% vs 13.50%; $t = 1.727$, $p = 0.097$, $d = 0.35$), whereas strategic competence revealed no significant difference (22.12% vs 27.17%; $t = 1.461$, $p = 0.157$, $d = 0.29$). The Wilcoxon signed-rank test found no significant difference in the non-normally distributed Technical ability (7.96% vs 7.29%; $T = 97$, $p = 0.624$, $r = 0.10$). Normality assumptions were confirmed for Strategic ability ($W = 0.967$, $p = 0.485$), Competitive situation ($W = 0.942$, $p = 0.149$), and Physical conditioning ($W = 0.923$, $p = 0.062$), while Technical ability necessitated non-parametric analysis (figure 4).

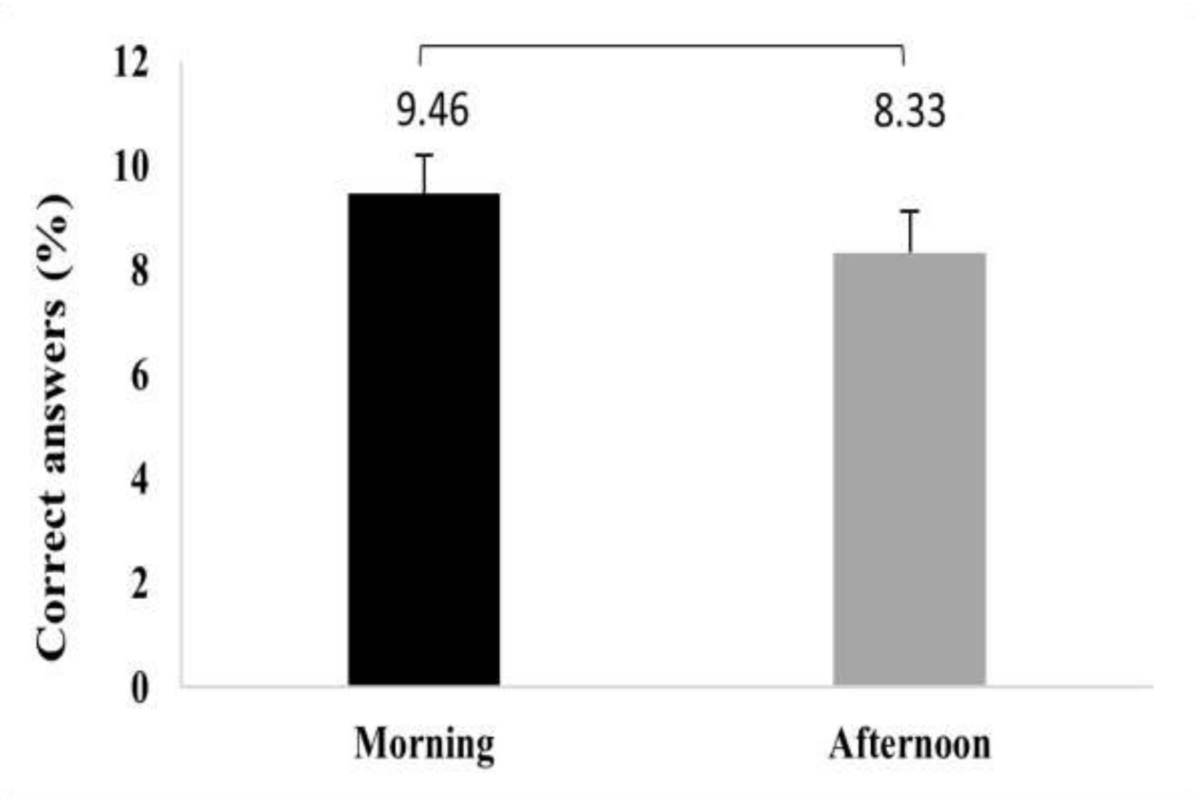

Figure 5. Average barrage test score. * ($p < 0.05$)

The analysis revealed a statistically significant difference in correct response rates between test sessions ($t = 2.209$, $p = 0.037$, $d = 0.44$) (Figure 5). Participants were more accurate in the morning sessions (9.46%) than in the afternoon sessions (8.33%). The Shapiro-Wilk test confirmed the normality hypothesis for this parameter ($W = 0.952$, $p = 0.245$), justifying the use of parametric tests.

4. Discussion

This study investigated the impact of time of day on the management of learning time, and attention of students in physical education (PE) sessions. Pupils' motor behavior, motor engagement and interest in the activities offered, are influencing elements that affect learning and predict students' achievement in PE. The descriptive study of learning time during a PE session indicated some differences in the distribution of time spent learning between the morning and afternoon. These temporal changes are consistent with well-established chronobiological patterns that highlight the importance of circadian rhythms in human performance. These results highlight how the time of day influences time management in PE and underscore its implications for instructional effectiveness.

In fact, the results show a significant effect in terms of preparatory situations in the afternoon than in the morning. This observation is consistent with previous research on cognitive performance peaks during late morning hours. In terms of time spent developing knowledge, the results show that there is no significant difference between the afternoon and the morning. This suggests that activities related to the acquisition of theoretical knowledge or to the reflection on motor practice are consistently integrated into all sessions, regardless of time, because they do not require the same level of temporal adaptation as physical activities **[23,24]**. Previous research (Munnilari et al **[23]**; Wiłkość-Dębczyńska et al **[24]**) suggests that cognitive learning is less sensitive to diurnal variations in PE. This finding underscores the distinction between fluid cognitive tasks (time-sensitive) and crystallized knowledge (time-resistant). This could be due to program constraints or the nature of these activities, which are less dependent on physiological fluctuations.

These findings support previous research emphasizing the necessity of aligning PE programs with children's circadian rhythms to improve both learning outcomes and participation rates. Specifically, the results show that motor development performance is significantly higher in the morning than in the afternoon. This pattern may reflect the interaction between circadian arousal and task complexity. The results presented suggest that the teacher could change the complexity or intensity of the activities depending on the time of day. These findings are consistent with those of Chtourou & Souissi **[25]** and Connolly **[26]**, who found that people's physical performance fluctuates during the day due to biological rhythms, especially the circadian. Preparatory situations appear to be better suited to the morning due to the higher cognitive demand, particularly in terms of following instructions and preparing for the session. This is consistent with neurocognitive research demonstrating optimal executive function in the late morning hours.

The findings are consistent with previous studies (Sato et al. **[27]** et Waterhouse et al. **[28]**). These researches demonstrate that circadian rhythms influence physical and cognitive function throughout the day. Sato et al. **[27]** and Waterhouse et al. **[28]** discovered that physical performance is higher in the afternoon, whereas cognitive performance is higher in the morning.

Furthermore, the results of this study highlight interesting variances in how teachers manage learning time depending on the time of day. These variations may reflect an implicit awareness of students' biological rhythms, even if not formally recognized. The teacher devotes more time in the morning to group management and warm-up than in the afternoon, when these amounts are significantly lower. These differences could be explained by organizational and physiological factors. Indeed, in the morning, students require more attention for group organization because they are still in a cognitive and physical adjustment phase following sleep **[29]**. The lack of distinction could also be explained by the fact that cognitive learning circumstances in PE, such as technique, strategy, and rule comprehension, are typically regarded as secondary to physical activities.

Furthermore, for motor development the results showed no significant differences between the morning and afternoon sessions. Teachers allocate consistent instructional time for strategic abilities, technical skills, competitive situations, and physical fitness throughout the day. These results reveal a complex relationship between circadian rhythms and the specific skills being developed. This stability is probable due to the fact that these activities are independent of variations in pupils' biological or cognitive rhythms **[28]**. However, certain differences from previous literature should be acknowledged. While many studies claim improved motor performance in the afternoon across multiple domains, our findings indicate that certain motor skills, such as strategic and technical ability, are unaffected by time of day. This could be explained by the fact that these skills rely more on learned behaviors and cognitive processing than on immediate physiological readiness, a distinction that has received less attention in previous research.

Nevertheless, one category stands out: "physical conditioning." Teachers spend 1.5% of their time on it in the afternoon and 0% in the morning. This difference is most probable due to biological cycles. Afternoons are ideal for maintaining body temperature and neuromuscular function **[23]**. This finding reinforces the importance of aligning physical demands with physiological readiness. In fact, Batejat et al. **[30]** found that children's attention spans were inconsistent throughout the day. These variations also affect attention, which also varies according to the time of day. This is consistent with the findings that attention fluctuates depending on task complexity and duration **[31]**. Dumas **[32]** and Kraemer et al. **[33]** discovered that students are more attentive in the morning and less attentive in the early afternoon.

Our results are consistent with previous studies (Cavet **[34]** and Escribano, C., & Díaz-Morales **[35]**) on attention revealing higher levels of attention during morning sessions. This morning advantage in attention has important implications for scheduling cognitively demanding tasks. Researches demonstrates that school schedules affect memory and attention variably depending on the time of day [34, 35]. It emphasizes the need to consider attentional variation in designing school activities, such as PE, to raise student involvement and learning results. Furthermore, propose that in PE, student involvement and learning results depend much on elements apart from time of day, including classroom management, instructional strategies, and the type of exercise. It is important to acknowledge that individual differences, such as chronotype, age, and prior experience, may modulate the influence of time of day on performance. Future research should explore these factors to provide more personalized recommendations. The planning of PE sessions could therefore benefit from taking greater account of these biological rhythms.

4.1. Practical implications

The teachers could choose to direct their concentration towards activities that are less physically strenuous yet more cognitively challenging when pupils show mental alertness in the morning **[36]**. In this context, Sato et al. **[27]** suggest that learning more rigorous and complex exercises is often more effective in the afternoon, when the body is more prepared for physical effort. Teachers should organize cognitively demanding tasks in the morning in order to take advantage of students' maximum attention span. They should also take into account the need to time PE exercises to correspond to students' biological rhythms. This optimizes learning and engagement. An educational culture that prioritizes physical activity over academic knowledge may exacerbate the problem **[37]**. The results indicate that teachers should adapt learning time to their students' physiological and cognitive needs. Motor skill activities should be scheduled for the afternoon, when students perform better physically **[38]**. At this stage, concrete and achievable solutions can be proposed, such as adopting flexible timetabling with teachers of other subjects, optimizing existing infrastructures (for example, by using outdoor spaces or establishing partnerships with local sports clubs), and integrating shorter but more frequent PE and sports sessions, such as active breaks in class, for example.

4.2. Limits

There are several limitations to this study. First, the small sample size (n = 25) limited the statistical power and generalizability of the findings. The Tunisian cultural context, as well as the unique characteristics of the education system, limits the applicability of the findings to other countries. Second, the exclusion of pupils who participate in extracurricular sports limits the applicability of the findings to more active populations. Third, implementing schedule adjustments based on circadian rhythms presents practical challenges for schools. Constraints include fixed timetables, limited facilities, and the need to coordinate with other subjects. The study did not look at pupils' chronotypes or other personal factors such as sleep quality and duration, nutritional status, and stress levels that could influence students' performance and engagement. Fourthly, Observer bias can modify results, but we have invited the observers to code the data consistently using Sieber's observation grid (2001) to minimize the effect of the observer. They coded the same randomly chosen session from the 20 filmed sessions. Their results showed an average of 85% agreement. To detect learning behavior specifically, they agreed 88% of the time. Fortin **[39]** considers these agreement levels satisfactory.

5. Conclusion

This study examined how time of day affects student learning and attentiveness in high school physical education (PE) classrooms. The data show significant temporal differences in learning activities, with preparatory situations and group management more important in the morning and motor development activities being preferred in the afternoon. The differences can be ascribed to changes in cognitive and physiological functioning caused by circadian rhythms, emphasizing the dynamic character of student participation throughout the school day. The results suggest that cognitive tasks requiring higher attention and mental processing may be more effectively scheduled in the morning when students' cognitive alertness is heightened. In contrast, tasks requiring greater physical activity seem to be better performed in the afternoon, coinciding with greater neuromuscular efficiency and better physical preparation. Notably, attention levels, as assessed, vary considerably according to the time of day; they are higher in the morning, confirming the link between temporal aspects and learning efficiency. The finding indicate that educators can improve student engagement, maximize learning outcomes, and promote more efficient time management by matching lesson planning with times of peak cognitive and physical performance during PE sessions. Future research should investigate the interaction between individual chronotypes, pedagogical techniques, and environmental variables in order to improve the timing of PE programs for diverse student populations. It will be necessary to work on larger samples and to broaden the cultural contexts and activities evaluated.

Ethical Approval and Consent to Participate

The study protocol received approval from the local institutional ethics committee in accordance with the Declaration of Helsinki principles. All participants provided written informed consent after receiving comprehensive information regarding study objectives, procedures, potential risks, and the voluntary nature of participation.

Consent for Publication

Not applicable.

Competing Interests

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Funding

The authors report no involvement in the research by the sponsor that could have influenced the outcome of this work.

Authors' Contributions

All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

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