Effect of diurnal variations on cognitive and physical performance among female athletes

Efecto de las variaciones diurnas en el rendimiento cognitivo y físico de las atletas femeninas

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Abstract

Objective: humans' circadian rhythm is an important parameter in understanding current biological, physiological, and psychological status, which broadly affects physical fitness. The physiological mechanisms underlying circadian rhythms remain underexplored despite their potential impact on physical and mental health. The study aims to examine the effect of diurnal variations on cognitive and physical performance in female athletes.
Methodology: a counterbalanced within-subjects repeated measures design was employed, involving 15 healthy female university students aged 18 to 25. Each participant underwent cognitive and physical performance tests at three distinct times—6 AM, 12 PM, and 6 PM—on separate days.
Results: the study demonstrated a significant effect of diurnal variations on cognitive and physical performance indices.
Discussion: cognitive performance showed varied patterns across time points. Perceptual reasoning, measured by the Müller-Lyer test, peaked in the morning and was lowest in the evening. Working memory, assessed via the span digit test, showed moderate values at noon and evening. Strength, measured by the vertical jump, was highest in the evening and lowest in the morning. As assessed by the Illinois Agility Test, agility peaked at noon, with the lowest values recorded in the morning.
Conclusions: time of day significantly affects both cognitive and physical performance in female athletes. Strength peaks in the evening, agility at noon, and perceptual reasoning in the morning, while working memory shows moderate performance at noon and evening. These results suggest that athletes and coaches can optimize training and competition schedules based on diurnal cognitive and physical performance variations.

Keywords

Chronobiology; cognitive performance; diurnal variations; female athletes; physical performance.

Resumen

Objetivo**:** El ritmo circadiano humano es un parámetro fundamental para comprender su estado biológico, fisiológico y psicológico actual, lo que influye ampliamente en la condición física. Los mecanismos fisiológicos subyacentes a los ritmos circadianos siguen estando poco explorados, a pesar de su posible impacto en la salud física y mental. Este estudio tiene como objetivo examinar el efecto de diferentes momentos del día en el rendimiento cognitivo y físico de atletas femeninas. Metodología**:** Se empleó un diseño de medidas repetidas contrabalanceado dentro de los sujetos, involucrando a 15 estudiantes universitarias sanas de entre 18 y 25 años. Cada participante realizó pruebas de rendimiento cognitivo y físico en tres momentos distintos del día—6 AM, 12 PM y 6 PM—en días separados.
Resultados**:** El estudio mostró un efecto significativo de las variaciones diurnas en los índices de rendimiento cognitivo y físico.
Discusión**:** El rendimiento cognitivo presentó patrones variables a lo largo del día. El razonamiento perceptivo, medido por la prueba de Müller-Lyer, alcanzó su punto máximo en la mañana y fue más bajo en la noche. La memoria de trabajo, evaluada mediante la prueba de amplitud de dígitos, mostró valores moderados al mediodía y en la noche. La fuerza, medida por el salto vertical, fue mayor en la noche y menor en la mañana. La agilidad, evaluada con la prueba de agilidad de Illinois, alcanzó su punto máximo al mediodía y registró los valores más bajos en la mañana.
Conclusiones**:** La hora del día afecta significativamente el rendimiento cognitivo y físico en atletas femeninas. La fuerza alcanza su punto máximo en la noche, la agilidad al mediodía y el razonamiento perceptivo en la mañana, mientras que la memoria de trabajo muestra un rendimiento moderado al mediodía y en la noche. Estos resultados sugieren que los atletas y entrenadores pueden optimizar los horarios de entrenamiento y competición en función de las variaciones diurnas del rendimiento cognitivo y físico.

Palabras clave

Cronobiología; rendimiento cognitivo; variaciones diurnas; atletas femeninas; rendimiento físico.

Introduction

Performance research aims to enhance physical and mental performance by uncovering strategies that yield incremental improvements. In elite competition, success is often determined by the smallest of margins, making pursuing new methods to gain an edge highly appealing. One biological factor that may impact performance is the time of day (Mirizio et al., 2020; Hesketh & Esser, 2024) and individual variations in circadian rhythms (Lack et al., 2009). Human biological rhythms are responsible for the control of the body's normal functions, including sleep, mood, performance and behaviour. (Montaruli et al., 2021; Shakor, 2021). Many biological functions fluctuate cyclically within 24 hours, influenced primarily by light exposure and temperature changes. These cycles are circadian rhythms (Kim & Lazar, 2020; Koronowski & Sassone-Corsi, 2021; Neves et al., 2022). These endogenously driven near 24-hour circadian rhythms are controlled by the suprachiasmatic nucleus (SCN), which is situated in the anterior hypothalamus (Harvey et al., 2020; Hastings et al., 2020; Goltsev et al., 2022). Neural and hormonal outputs from the SCN drive a multitude of behavioural and physiological rhythms, with notable factors being temperature regulation, hormonal release and gene expression (Zhang et al., 2020; Jones et al., 2021; Mazuski et al., 2020; Bafna et al., 2023). Circadian rhythms are also synchronized/entrained by exogenous factors such as light and social signals (Grosjean et al., 2023; Kim & Lazar, 2020; Kaneko et al., 2020). The physiological and psychological features associated with superior athletic performance in team and individual sports vary according to the time of day (Lok et al., 2020; Martin-Lopez et al., 2025; Kons et al., 2025; Nobari et al., 2023). These features show ups or downs at maximum or minimum levels at particular times of the day.

Individuals must perform physically and mentally effectively in competitive environments, whether in high-pressure workplaces or elite sports. Many athletic endeavours require a blend of motor skills alongside perceptual and cognitive abilities (Schumacher et al., 2024; Zhang et al., 2024; Trecroci et al., 2021; Vitosevic, 2017). Numerous studies indicate that athletes with high cognitive performance exhibit better skill and sport-specific performance than those with lower cognitive abilities (Kalén et al., 2021; Müller et al., 2006; Williams et al., 2002). Traditionally, functional task evaluations have served as proxies for assessing cognitive performance, measuring aspects such as reaction time, spatial memory, and sensorimotor tasks (Harvey et al., 2020; Czaja et al., 2020; Teodoro et al., 2022; Edwards et al., 2007). Furthermore, circadian variations may affect neural factors like nerve conduction velocity, cerebral blood flow, and the release of brain-derived neurotrophic factor (BDNF) (Blatter, 2007; Etnier, 1997; Ehrhardt et al., 2024; Sochal et al., 2024); underscoring the potential relationship between circadian fluctuations in physiological functions and changes in cognitive and neuromuscular performance (Salehinejad et al., 2021; Xu et al., 2021).

The theoretical basis for anticipating such a rhythm is partly derived from recognizing that various biological and behavioural functions, which may impact athletic performance, display circadian rhythms. These include pulmonary function, core body temperature, mood, reaction time, memory and alertness, and cognitive performance (Shang et al., 2021; Joyce et al., 2022; Ksinan et al., 2024; Lai et al., 2022). Additionally, anecdotal evidence supports the notion of a performance rhythm, as athletic performance is often adversely affected following transmeridian travel (Reilly et al., 2005). If circadian rhythms regulate athletic performance, aligning performance analysis with biological markers like peak body temperature can improve accuracy, considering the significant variability in individual circadian phases (Pradhan et al., 2024; Ayala et al., 2021; Kons et al., 2025; Rad et al., 2020).

Knowledge about circadian rhythms in the realm of physical education remains quite limited. It is widely understood that human motor performance primarily relies on the efficiency of neuro-physiological coordination and psychological readiness. Numerous studies have examined the connection between circadian rhythms and various physiological parameters, finding that specific circadian time intervals influence most physiological metrics (such as heart rate, blood pressure, and body temperature). Consequently, motor performance could also be affected by circadian rhythms. While health and skill-related fitness are critical for motor performance, the specific components that play a dominant role are yet to be identified. Therefore, comprehensive research on circadian rhythms could help determine the optimal time frames for athletes to achieve peak performance levels, enhance training effectiveness, and better prepare for competitions.

Understanding the impact of seasonal changes on the circadian rhythms of physical fitness is essential, as these rhythms may either remain consistent throughout the year or fluctuate. The study aims to contribute to physical education by expanding knowledge on circadian rhythms, which could assist in planning training and competition strategies for improved motor performance. The researchers chose this topic after reviewing relevant literature and consulting with experts, recognizing the importance of investigating the effect of diurnal variations on cognitive and physical performance in female athletes. This area has seen limited research. This study specifically explores how diurnal variations affect cognitive abilities (such as perceptual reasoning and working memory) and physical performance (including strength and agility) in female athletes to identify peak performance times and understand how circadian rhythms affect these skills to optimize training and competition schedules.

Method

Study participants

In this within-subjects repeated measures design study, fifteen female university athletes out of fifty, aged 18-25 years (n=15 aged 21.41 ± 1.61) were randomly recruited from the Department of Physical Education and Sport Science, Visva-Bharati, Santiniketan, West Bengal, India. Participants were selected based on their active engagement in sports activities. A counterbalanced design was used to minimize order effects, randomly assigning participants to different diurnal variation conditions to control for fatigue or learning effects. To determine the appropriate sample size, the researchers conducted an a priori power analysis using G*Power 3.1.9.7 software, assuming an alpha level of 0.05 and an effect size of 0.40 for a repeated measure ANOVA. The analysis suggested that 12 participants were required to achieve 80% statistical power. To account for potential dropouts, 15 participants were recruited from the Department of Physical Education and Sport Science, Visva-Bharati, Santiniketan, West Bengal, India.

Procedure

An orientation program was conducted in collaboration with university administrators to explain the study's objectives. Subjects who met the study's criteria and were willing to participate were invited to join. Each participant completed tests at three different times on separate days: 6 AM, 12 PM and 6 PM. Adequate rest was provided to the subjects between test days to prevent fatigue or training effects. The cognitive performance, i.e. perceptual reasoning and working memory, and physical performance, i.e. strength and agility tests, were administered in a fixed order. Identical locations and standardized instructions were given to ensure consistency across trials. All research procedures adhered to relevant guidelines and regulations, including the latest version of the Helsinki Declaration. Participants completed a questionnaire covering their injury history, medication use, known diseases, and daily diet patterns. Written informed consent was obtained from all participants after providing a detailed explanation of the study objectives and procedures. Participation was entirely voluntary, and participants were assured of the confidentiality and anonymity of their responses.

Location of the study

The study was conducted at the Department of Physical Education and Sport Science sports ground in Visva-Bharati, Santiniketan, West Bengal, India.

Inclusion and Exclusion Criteria

As part of the inclusion criteria, the study included active female athletes to ensure that variations in performance were primarily due to circadian effects rather than differences in baseline fitness levels. All participants were hostel residents and regular department students, ensuring a similar lifestyle regarding biological clock and dietary habits. As exclusion criteria, we predefined the presence of chronic diseases (e.g., diabetes, obesity, metabolic syndrome) and the use of medications affecting fitness attributes. Additionally, individuals with airway hyper-responsiveness were excluded.

Test/Tools

The study assessed the following dependent variables:

Cognitive Performance

1. Perceptual Reasoning: Assessed using the Müller-Lyer Illusion Test, where participants are asked to compare the lengths of lines altered by visual cues. The measure is recorded in centimetres. In this test, higher values indicate better perceptual reasoning, as more accurate judgments of line length suggest stronger visual-spatial processing.

2. Working Memory: Measured through the Digit Span Test, part of the Wechsler Adult Intelligence Scale. Both tests used are internationally validated cognitive assessment tools. It assesses short-term memory capacity by having subjects repeat sequences of numbers, evaluated by their score. In the Digit Span Test, higher scores reflect greater working memory capacity, whereas lower scores may indicate limitations in attention or mental retention span.

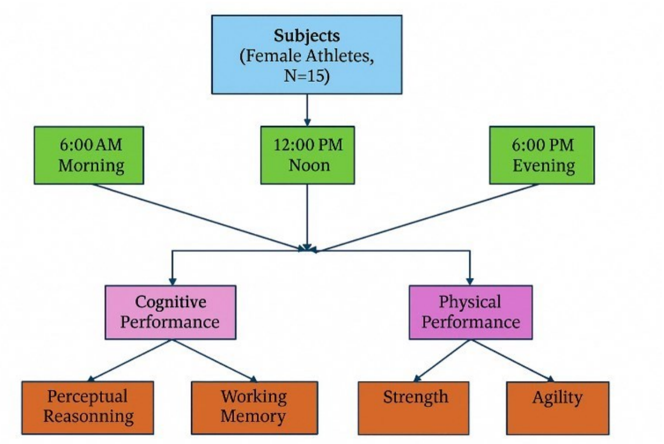
The Müller-Lyer Illusion Test (Müller-Lyer, 1889; Pérez-Fabello & Campos, 2023) and the Digit Span Test (Miller, 1956; Geva et al., 2021) were employed to assess perceptual reasoning and working memory, respectively. These tools are both theoretically foundational and empirically validated in contemporary cognitive research.

Physical Performance

1. Strength: Evaluated using the Vertical Jump Test, which measures the explosive strength of the lower limbs. Results are measured in centimetres.

2. Agility: Tested using the Illinois Agility Test, a well-known measure of speed and coordination through a course. The results are recorded in meters.

Figure 1. Flow diagram outlining the Study Design



Statistical Analysis

All data was analyzed using JAMOVI Version 2.4 software. The level of significance was set at $P<0.05$. Before parametric tests like repeated measures ANOVA, the normality assumption was evaluated for each dependent variable (perceptual reasoning, working memory, strength, and agility) at each time point (morning, noon, and evening). The Shapiro-Wilk test was used to assess whether the data were normally distributed. Parametric statistics were used on normally distributed data. The assumption of homogeneity of variances was assessed using Levene's test. This test ensures that the variance of the dependent variables is equal across the different time points (morning, noon, and evening).

Parametric data are expressed as mean and standard deviations (Mean ± SD). Repeated-measures parametric data was checked for sphericity using Mauchly's test, and if violated, the Greenhouse-Geisser correction was used.

A paired samples t-test was used to determine whether there were differences between the participants in cognitive and physical performance at different time frames. A one-way repeated measure analysis of variance (ANOVA) with Bonferroni adjustment was used to determine whether there were differences in Cognitive and Physical performance over the course of the different time frames. When a significant effect was found, pairwise comparisons were performed with a Bonferroni correction for multiple comparisons.

Where possible, effect sizes were calculated using partial eta squared (η^2_p) to analyze variances or Cohen's dz for paired comparisons. Partial eta squared (η^2_p) was interpreted as follows: small (0.01), medium (0.06) and large (0.15) (Cohen, 1988). Cohen's dz was interpreted as follows: small (<0.50), moderate (0.50–0.80) and large >0.80 (Cohen, 1988).

Ethics

The study was approved by the Ethics Committee for Research of the Department of Physical Education and Sport Science, Visva-Bharati University, West Bengal, India (Registration No: VB-1776 of 2017-18), in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments.

Results

The study's results revealed a significant effect of diurnal variations on female athletes' cognitive and physical performance. Perceptual reasoning, measured by the Müller-Lyer test, peaked in the morning (6 AM) and was lowest in the evening (6 PM), while working memory, assessed through the span digit test, was moderate at noon and evening, with the lowest performance in the morning. Physical performance showed a clear circadian pattern, with strength evaluated through the vertical jump, highest in the evening (6 PM) and lowest in the morning. At the same time, agility, measured using the Illinois Agility Test, peaked at noon and was lowest in the morning. Statistical analysis using repeated measures ANOVA confirmed significant effects of diurnal variations on cognitive and physical performance (η^2_p values: perceptual reasoning = 0.391, working memory = 0.236, strength = 0.649, agility = 0.555). These findings suggest optimizing training schedules based on these fluctuations may enhance performance.

Table 1. Descriptive Statistics for Perceptual Reasoning in Female Athletes across Time Points

Statistics	Morning	Noon	Evening
Mean	25.637	24.428	23.619
Standard Deviation	1.900	1.752	1.481
Std. Error	0.491	0.452	0.382
Skewness	-0.030	0.929	-0.793
Kurtosis	-0.742	-0.808	-0.440
Maximum Score	28.560	27.610	25.560
Minimum Score	22.060	22.550	20.540
Coefficient of variation	0.074	0.072	0.063

Table 1 shows the descriptive statistics for perceptual reasoning scores across three-time points (morning, noon, and evening). For both perceptual reasoning and working memory tasks, higher scores are indicative of better performance. Although clinical thresholds were not applied in this study, values significantly below the sample average may reflect comparatively weaker cognitive functioning. The mean scores show a decreasing trend from morning (25.637) to evening (23.619), indicating a decline in perceptual reasoning performance throughout the day. The standard deviation and coefficient of variation suggest greater consistency in scores during the evening.

Table 2. Repeated Measure ANOVA for Perceptual Reasoning in Female Athletes across time points

Within Subjects Effects							
Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2p
Time	None	30.944	2.000	15.472	8.999	< .001	0.391
Residuals	None	48.138	28.000	1.719			

Note: Type III Sum of Squares

Table 2 shows the repeated measures ANOVA results, showing a significant time effect ($F = 8.999$, $p < .001$, $\eta^2p = 0.391$), indicating that perceptual reasoning varies significantly across time points.

Table 3. Pairwise Comparisons of Perceptual Reasoning in Female Athletes across Time Points

			95% CI for Mean Difference				
		Mean Difference	Lower	Upper	SE	t	pbonf
Morning	Noon	1.209	-0.010	2.429	0.479	2.526	0.052
	Evening	2.018	0.799	3.237	0.479	4.215	< .001
Noon	Evening	0.809	-0.411	2.028	0.479	1.689	0.307

Note: P-value and confidence intervals were adjusted to compare a family of 3 estimates (confidence intervals were corrected using the Bonferroni method).

Table 3 shows pairwise comparisons. A significant difference is observed between morning and evening (pbonf < .001), while the morning-noon and noon-evening differences are not statistically significant.

Figure 2 graphically illustrates the trend of perceptual reasoning scores across the time points, visually confirming the decreasing trend observed in the tables.

Figure 2. Graphical Representation of Perceptual Reasoning in Female Athletes Across Time Points

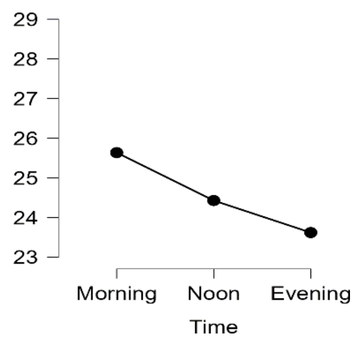


Table 4. Descriptive Statistics for Working Memory in Female Athletes across Time Points

Statistics	Morning	Noon	Evening
Mean	6.393	6.940	6.940
Standard Deviation	0.773	1.119	1.200
Std. Error	0.200	0.200	0.200
Skewness	0.130	-0.493	0.021
Kurtosis	0.307	-0.118	-0.323
Maximum Score	8.000	8.600	9.000
Minimum Score	5.000	4.600	4.600
Coefficient of variation	0.121	0.121	0.121

Table 4 presents the descriptive statistics for working memory across three-time points (morning, noon, and evening). The mean scores indicate an improvement from morning (6.393) to noon (6.940), which remains constant in the evening. The coefficient of variation remains stable across all time points, suggesting similar variability in scores.

Table 5. Repeated Measure ANOVA for Working Memory in Female Athletes across time points

Within Subjects Effects							
Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2p
Time	None	2.988	2.000	1.494	4.332	0.023	0.236
Residuals	None	9.658	28.000	0.345			

Note: Type III Sum of Squares

Table 5 shows the repeated measures ANOVA results, showing a significant time effect ($F = 4.332$, $p = 0.023$, $\eta^2p = 0.236$), indicating that working memory performance varies across the day.

Table 6. Pairwise Comparisons of Working Memory in Female Athletes across Time Points

			95% CI for Mean Difference				
		Mean Difference	Lower	Upper	SE	t	pbonf
Morning	Noon	-0.547	-1.093	-5.610×10-4	0.214	-2.549	0.050
	Evening	-0.547	-1.093	-5.610×10-4	0.214	-2.549	0.050
Noon	Evening	0.000	-0.546	0.546	0.214	0.000	1.000

Note. P-value and confidence intervals we re adjusted to compare a fam ily of 3 estimates (co nfidence inter vals were corr ected using the Bonferroni method).

Table 6 shows pairwise comparisons. A significant improvement is observed from morning to noon (pbonf = 0.050) and morning to evening (pbonf = 0.050), but no significant difference exists between noon and evening (pbonf = 1.000).

Figure 3 visually represents the trend of working memory performance, showing an increase from morning to noon and stabilization in the evening.

Figure 3. Graphical Representation of Working Memory in Female Athletes Across Time Points

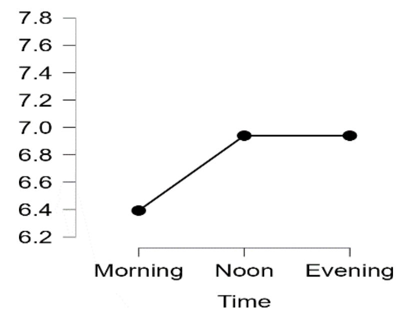


Table 7. Descriptive Statistics for Strength Measurements in Female Athletes across Time Points

Statistics	Morning	Noon	Evening
Mean	35.400	36.667	39.400
Standard Deviation	4.388	4.047	4.239
Std. Error	1.133	1.045	1.095
Skewness	0.298	0.041	-0.302
Kurtosis	-0.845	-0.790	-0.931
Maximum Score	43.000	43.000	45.000
Minimum Score	29.000	30.000	32.000
Coefficient of variation	0.124	0.110	0.108

Table 7 presents the descriptive statistics for strength measurements across three-time points (morning, noon, and evening). The mean values indicate an increasing trend, with strength improving from morning (35.400) to noon (36.667) and peaking in the evening (39.400). The coefficient of variation decreases slightly, suggesting more consistency in scores as the day progresses.

Table 8. Repeated Measure ANOVA for Strength Measurements in Female Athletes across time points

Within Subjects Effects							
Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2p
Time	None	125.378	2.000	62.689	25.830	< .001	0.649
Residuals	None	67.956	28.000	2.427			

Note: Type III Sum of Squares

Table 8 shows the repeated measures ANOVA results, showing a significant time effect ($F = 25.830$, $p < .001$, $\eta^2p = 0.649$), indicating that strength performance significantly varies across the time points.

Table 9. Pairwise Comparisons of Strength Measurements in Female Athletes across Time Points

			95% CI for Mean Difference				
		Mean Difference	Lower	Upper	SE	t	pbonf
Morning	Noon	-1.267	-2.715	0.182	0.569	-2.227	0.103
	Evening	-4.000	-5.449	-2.551	0.569	-7.032	< .001
Noon	Evening	-2.733	-4.182	-1.285	0.569	-4.805	< .001

Note: P-value and confidence intervals were adjusted to compare a family of 3 estimates (confidence intervals were corrected using the Bonferroni method).

Table 9 shows pairwise comparisons. A significant difference is observed between morning and evening (pbonf < .001) and noon and evening (pbonf < .001), while the difference between morning and noon is not statistically significant (pbonf = 0.103).

Figure 4 visually illustrates the increasing trend in strength measurements, highlighting peak performance in the evening.

Figure 4. Graphical Representation of Strength Measurements in Female Athletes Across Time Points

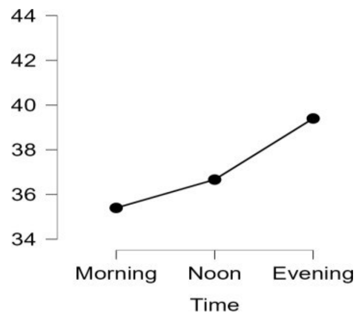


Table 10. Descriptive Statistics for Agility Measurements in Female Athletes across Time Points

Statistics	Morning	Noon	Evening
Mean	14.010	13.335	13.412
Standard Deviation	0.586	0.548	0.373
Std. Error	0.151	0.142	0.096
Skewness	0.383	0.853	0.177
Kurtosis	0.478	0.369	-0.416
Maximum Score	15.310	14.500	14.130
Minimum Score	13.000	12.590	12.810
Coefficient of variation	0.042	0.041	0.028

Table 10 presents the descriptive statistics for agility measurements across three-time points (morning, noon, and evening). The mean agility time decreases from morning (14.010 sec) to noon (13.335 sec) and remains almost the same in the evening (13.412 sec), indicating improved agility in the afternoon. The coefficient of variation is lowest in the evening, suggesting more consistent performance.

Table 11. Repeated Measure ANOVA for Agility Measurements in Female Athletes across Time Points

Within Subjects Effects							
Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	$\eta^2 p$
Time	None	4.098a	2.000^a	2.049^a	17.427^a	< .001a	0.555a
Residuals	None	3.292	28.000	0.118			

Note. Type III Sum of Squares
[a]Mauchly's test of sphericity indicates that the assumption of sphericity was violated (p < .05).

Table 11 shows the repeated measures ANOVA results, showing a significant time effect (F = 17.427, p < .001, $\eta^2 p$ = 0.555), indicating that agility performance significantly varies across the time points. However, Mauchly's test suggests a violation of sphericity, meaning adjustments were needed for analysis.

Table 12. Pairwise Comparisons of Agility Measurements in Female Athletes across Time Points

			95% CI for Mean Difference				
		Mean Difference	Lower	Upper	SE	t	pbonf
Morning	Noon	0.675	0.356	0.994	0.125	5.393	< .001
	Evening	0.598	0.279	0.917	0.125	4.776	< .001
Noon	Evening	-0.077	-0.396	0.242	0.125	-0.618	1.000

Note: P-value and confidence intervals were adjusted to compare a family of 3 estimates (confidence intervals were corrected using the Bonferroni method).

Table 12 provides pairwise comparisons. Significant differences are observed between morning and noon (pbonf < .001) and morning and evening (pbonf < .001), but no significant difference exists between noon and evening (pbonf = 1.000).

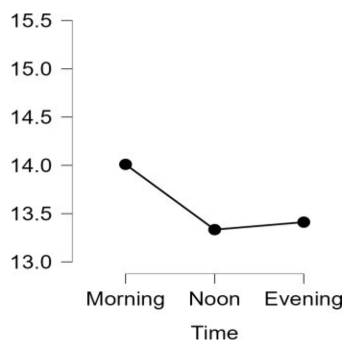
A task schedule was assigned to participants using a counterbalanced order. This minimized the impact of order effects, and Table 13 shows the distribution of task timings across participants.

Table 13. Counterbalanced Task Assignment Schedule per Participant Across Time Points

Participant	Task at 6:00 AM	Task at 12:00 PM	Task at 6:00 PM
P1	Perceptual Reasoning	Working Memory	Strength
P2	Working Memory	Strength	Agility
P3	Strength	Agility	Perceptual Reasoning
P4	Agility	Perceptual Reasoning	Working Memory
P5	Perceptual Reasoning	Working Memory	Strength
P6	Working Memory	Strength	Agility
P7	Strength	Agility	Perceptual Reasoning
P8	Agility	Perceptual Reasoning	Working Memory
P9	Perceptual Reasoning	Working Memory	Strength
P10	Working Memory	Strength	Agility
P11	Strength	Agility	Perceptual Reasoning
P12	Agility	Perceptual Reasoning	Working Memory
P13	Perceptual Reasoning	Working Memory	Strength
P14	Working Memory	Strength	Agility
P15	Strength	Agility	Perceptual Reasoning

Figure 5 visually represents the trend in agility performance, showing significant improvement from morning to noon, with stability in the evening.

Figure 5. Graphical Representation of Agility Measurements in Female Athletes Across Time Points



Discussion

Competitive athletes face significant pressure to excel, driven by advancements in sports science, technology, and the rewards associated with winning medals in competitions (Huang, 2022; Klingner et al., 2023; Ong & Chua, 2021; Low et al., 2022). Consequently, it is essential to thoroughly investigate any potential performance enhancements that could offer a competitive advantage. The study investigated the effect of diurnal variations on cognitive and physical performance in female athletes. The findings indicated that cognitive performance, particularly in perceptual reasoning and working memory, was significantly enhanced in the evening compared to other times of the day. Additionally, the physical performance showed notable improvement in strength during the evening, while agility was superior at noon compared to other times of the day.

The findings indicate that increased core temperature observed in the afternoon enhances peripheral mechanisms involved in muscle contraction, improving short-term maximal performance (Belkhir et al., 2019; Racinais & Oksa, 2010). This rise in body temperature may also increase the extensibility of connective tissues and enhance their viscosity and conduction velocity (Brandl et al., 2023; Bianchi et al., 2022). Research has shown that the body's core temperature reaches its lowest point at 4:30 AM, gradually rising throughout the day and peaking at 6:00 PM (Vitosevic, 2017). This internal core temperature is controlled by nerve cells in the hypothalamus. The circadian rhythm of core temperature primarily arises from daily variations in heat loss through the extremities, facilitated by the vasodilation of the skin's blood vessels (Coiffard et al., 2021; Refinetti, 2020).

There is a positive correlation between body temperature and athletic performance. Elevated body temperature can enhance metabolic reactions, improve the extensibility of connective tissues, reduce muscle viscosity, and increase the speed of action potential transmission (Castelli et al., 2025; Nicolaisen et al., 2020). In their review of 113 articles, Thun et al. (2015) found that athletic performance peaked when core body temperature was generally at its highest. The effect of diurnal variations observed may be consistent with a review article that acknowledges circadian variation impacts performance, with the evening hours producing improved athletic performance (Chtourou & Souissi, 2012; Thun et al., 2015; Lok et al., 2020; Martin-Lopez et al., 2025). The impact of diurnal variations on cognitive performance, particularly perceptual reasoning and working memory, aligns with circadian rhythms that regulate alertness and mental capacity throughout the day (Holleman et al., 2022; Lai et al., 2022; Farahani et al., 2021). Healthy individuals typically demonstrate satisfactory levels of cognitive performance between 10:00 AM and 2:00 PM and again from 4:00 PM to 10:00 PM. These time frames align with standard office hours when conducting neuropsychological assessments.

Research generally suggests that cognitive performance can peak at particular times, influenced by both the nature of the task and individual characteristics. Perceptual reasoning, which involves analyzing and interpreting visual information to solve problems, often shows improvement in the evening for many people. Studies indicate that evening hours are linked with heightened mental flexibility and problem-solving capacity, likely due to increased alertness and arousal at circadian peaks. As the day advances, especially toward late afternoon and early evening, the circadian rhythm enhances brain activation and alertness, which supports stronger performance on tasks involving complex visual and spatial reasoning. Working memory, the capacity to temporarily hold and work with information, also often improves in the evening, following a pattern similar to perceptual reasoning. This enhancement is likely because late afternoon and early evening align with peak cognitive performance times when alertness, attention, and concentration are at their highest.

Working memory depends on sustained attention and executive functions, which benefit from the circadian-driven boost in alertness and energy later in the day. This makes evening hours especially favourable for tasks requiring working memory. Components of attention exhibit homeostatic and circadian variations, impacting alertness and selective and sustained attention, which tend to improve throughout the day and reach higher levels in the afternoon and evening (Taillard et al., 2021). Working memory tasks improved markedly during the evening hours, correlating with the effect of diurnal variations on alertness and mental activation in the late afternoon and evening. These findings suggest that training sessions or skill-based learning activities requiring cognitive engagement could be more effective if scheduled later in the day (Farahani et al., 2021; Orban et al., 2020; Cox et al., 2024). May et al. (1993) found that perceptual reasoning and problem-solving tasks were performed with greater accuracy and efficiency later in the day, which was linked to circadian rhythm effects on alertness and cognitive flexibility.

Ample evidence suggests that acute fatiguing exercise generally boosts cognitive function, especially for tasks engaging the prefrontal cortex. Research shows that high-intensity aerobic exercise influences excitability and inhibition in the motor cortex of the upper limbs (Hendy et al., 2022). Neuroplastic changes from aerobic exercise, even after a single session, can significantly alter cortical excitability and affect neural circuits (Kuo et al., 2023). As a result, resistance exercises may enhance cognitive performance through mechanisms like improved nerve conduction velocity, increased cerebral blood flow, and the release of brain-derived neurotrophic factor (BDNF) (Huang et al., 2014; Helm et al., 2017).

Conclusions

This study highlights the significant effect of diurnal variations on both cognitive and physical performance in female athletes. Strength and agility exhibit distinct peak performance times, suggesting the need for personalized training schedules that account for these variations. The findings reinforce the concept that circadian rhythms and physiological factors play a crucial role in athletic performance, advocating for an integrated approach to training that considers the timing of physical and cognitive demands.

Future research should explore how diurnal variations affect different populations, including male athletes and those from various sports disciplines. Additionally, future studies should account for individual chronotypes, sleep quality, and lifestyle factors, which may influence cognitive and physical performance. Coaches and sports scientists can leverage these findings to design training programs aligning with athletes' natural performance peaks, potentially enhancing training effectiveness and competition readiness. Additionally, investigating the role of sleep quality, nutrition, and recovery strategies in performance variations could provide deeper insights into optimizing athletic potential. Ultimately, by harnessing the knowledge of diurnal performance patterns, athletes and coaches can better prepare for competitions, enhancing overall performance and success in their sporting endeavours.

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