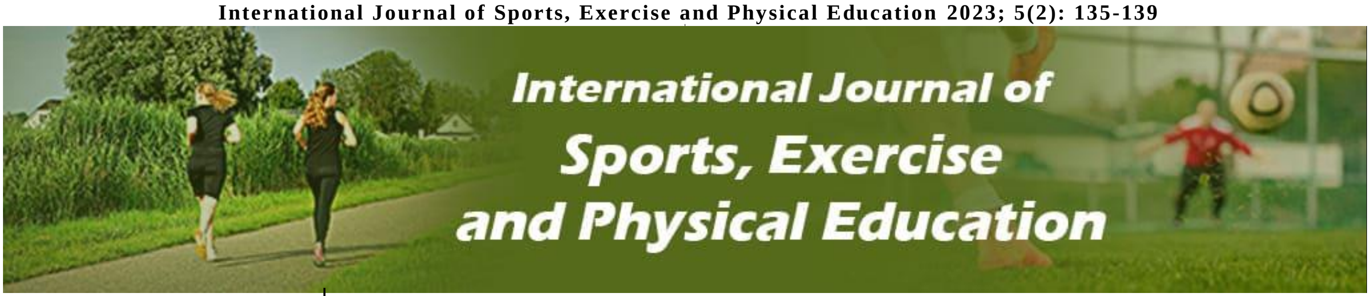

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Influence of circadian rhythm on body temperature and physical performance between male and female athletes in Kerala

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Abstract
Athletic performance is a multifaceted phenomenon influenced by various physiological, psychological, and environmental factors. Among these, circadian rhythm—a natural, internal process that regulates the sleep-wake cycle and repeats roughly every 24 hours—plays a critical role in modulating body functions, including body temperature and physical performance. Understanding how circadian rhythms impact these factors can provide valuable insights into optimizing training and performance strategies for athletes.
Body temperature, which fluctuates throughout the day in accordance with circadian rhythms, has been shown to correlate with athletic performance. Typically, body temperature peaks in the late afternoon and early evening, which often coincides with peak physical performance. These variations are particularly relevant for sprinters, whose performances are highly dependent on muscle function and metabolic efficiency, both of which are influenced by body temperature.
In Kerala, a state in southern India known for its tropical climate and a burgeoning athletic community, the interplay between circadian rhythms, body temperature, and physical performance among sprinters presents a unique field of study. This research aims to investigate the influence of circadian rhythms on body temperature and physical performance in male and female sprinters from Kerala, exploring potential gender differences in these physiological patterns.
By examining these relationships, we can enhance our understanding of how circadian rhythms impact athletic performance and potentially develop gender-specific training and competition schedules that align with athletes' biological peaks. This could lead to improved performance outcomes and more effective training regimens for sprinters in Kerala and beyond.

Keywords: Kerala, exercise, circadian rhythm & body temperature, physiological patterns

Introduction
Achieving excellence in elite sports is the primary goal of any athlete at the highest level of competition. The relentless pursuit of victory, the drive to surpass previous achievements, and the ambition to constantly push the boundaries of performance are intrinsic qualities that define elite athletes. To attain and maintain peak performance, athletes must continuously strive to improve their speed, anticipation, technical prowess, tactical acumen, and endurance, particularly in field sports where the demands are ever-evolving.
The pursuit of perfection in sports demands significant investments of time and resources from clubs, coaches, and athletes alike. The increasing competitiveness within sports means that the margin between success and failure continues to narrow, necessitating even greater dedication and financial commitments.
The success of an athlete in sports is gauged primarily by their competitive performance, which is influenced by a myriad of factors. These factors include both mental and physical components, somatotypes, motor skills, age, psychological attributes, training levels, genetic predispositions, and susceptibility to injuries. Among these variables, the biological phenomenon holds paramount importance as it cyclically fluctuates and significantly impacts the physical performance and movement-oriented behaviors of athletes.
In essence, the interplay between biological processes and sporting performance is complex and multifaceted, with the biological phenomena serving as a cornerstone that shapes athletes' abilities and achievements on the field.

Understanding and optimizing this relationship is crucial for athletes, coaches, and sports scientists alike as they seek to unlock the full potential of human performance in elite sports.

Methodology & Subjects

The study's sample comprised randomly selected participants from the pool of state-level athletes who took part in the 59th Kerala State Senior Athletic Championship. A total of 120 athletes, with an equal representation of 60 males and 60 females, were included in the study. These athletes participated in various track and field events, including sprinting, middle-distance running, long-distance running, vertical jumping, horizontal jumping, and throwing events. The athletes were drawn from all fourteen districts of Kerala, ensuring a geographically diverse representation. The age range of the participants was between 17 to 25 years, with a mean age of 22.59±0.9 years. Athletes with more than three years of competitive experience were specifically chosen to ensure a level of proficiency and familiarity with competitive athletics.

Tools

Morningness-Eveningness questionnaire (Horne JA and Ostberg O, 1976)

The circadian rhythm type among the athletes was assessed using the Morningness-Eveningness Questionnaire (MEQ). This questionnaire evaluates various aspects of an individual's circadian rhythm, including their preferred times for waking up and going to bed, as well as their subjective preferences for physical and mental activity. Additionally, the questionnaire assesses the athlete's subjective alertness.

The MEQ consists of a total of nineteen questions, each with Likert-type responses. Participants are provided with four choices of answers, which categorize them into one of the following: Definite Morning Type (DMT), Moderate Morning Type (MMT), Moderate Evening Type (MET), Definite Evening Type (DET), or Intermediate Type (IT).

The questions within the MEQ are carefully constructed to ensure clarity and avoid any leading or embarrassing inquiries that may influence responses. Questions are presented in a logical sequence, and the order of choices within each answer is balanced to prevent response bias.

Scoring of the MEQ involves assigning loading factors to each question based on their discriminatory power in determining morningness-eveningness. These loading factors are then rounded off to whole numbers for simplicity of scoring. Scores range from 16 to 86, with higher scores indicating a greater tendency towards morningness or eveningness.

Specific scoring instructions are provided for different questions within the MEQ to ensure accurate assessment. For example, scores for questions involving time scales are assigned based on the position of the participant's response on the scale. Additionally, scoring ranges are provided for questions where participants mark crosses or circles.

Overall, the scores obtained from the MEQ are summed, and the total is converted into a five-point scale, representing the athlete's circadian rhythm type. This tool provides valuable insights into the athletes' chronotype, which can inform training and competition schedules tailored to their individual circadian preferences.

Digital Thermometer (Model No MT-101)

Axillary temperature (AT) was measured using inexpensive temperature devices (model no MT-101 Stupendous Handheld DT), manufactured by DT Manufacturers based in India. These devices were utilized in accordance with the method instruction manuals. The devices were positioned high in the central axillary region (AR) with the subject's right arm adducted, following the removal of sweat with antiseptic lotion to ensure accuracy.

The DT Manufacturers' temperature devices boast high durability, a robust structure, and precise temperature measurement capabilities. The display range of the device is 32.0 to 42.0 °C (90 to 107.6°F), with an accuracy of ±0.1 °C (±0.2°F). The minimum scale for measurement is 0.1, and the measurement time is 60 ±10 seconds for oral use and 100 ±20 seconds for underarm use.

Additionally, the device features a beeper function and auto shut-off feature for convenience. It operates using a 1.5V button battery (LR/SR-41) and has memory capabilities to recall the last measuring reading. The LCD size is 15.5 x 6.5mm, and the overall dimensions of the device are 127 x 18 x 10mm, with a net weight of 10.5g. These features ensure efficient and reliable measurement of axillary temperature for the study.

Procedure

Before conducting the tests, a meeting was convened with all participants to provide them with a comprehensive explanation of the study's objectives, the testing procedure, and the level of effort expected from them. This meeting served to ensure that participants fully understood the purpose of the study and were adequately prepared for the tests.

Following the briefing session, the necessary data collection commenced by administering the tests for the selected variables. Participants were guided through each step of the testing process to ensure consistency and accuracy in data collection. Special attention was paid to maintaining standardized conditions across all participants to minimize potential sources of bias or variability.

Throughout the testing procedure, participants were encouraged to exert their best effort and cooperate with the instructions provided by the researchers. Any queries or concerns raised by the participants were addressed promptly to maintain their comfort and confidence throughout the testing process.

Overall, the procedure aimed to establish a conducive environment for data collection while ensuring that participants were fully informed and engaged in the study. This approach helped to optimize the reliability and validity of the data collected for subsequent analysis and interpretation.

Statistical analysis of data

All statistical analyses were performed using SPSS software (release 2.0, SPSS, Chicago, IL). Analysis of Variance (ANOVA) was employed to assess differences between the subjects included in the study. ANOVA is a robust statistical technique used to compare means across multiple groups and determine whether there are statistically significant differences between them.

The choice of ANOVA reflects its suitability for examining variations in the data across different groups, which is essential for understanding the impact of various factors on the variables under investigation. By applying ANOVA, we were able to evaluate the significance of any observed differences between subjects, providing valuable insights into the relationships between variables and groups.

The utilization of SPSS software facilitated efficient data analysis, allowing for the exploration of complex relationships and patterns within the dataset. This comprehensive statistical approach enabled us to draw meaningful conclusions from the collected data and evaluate the hypotheses formulated for the study.

Overall, the statistical analysis conducted using ANOVA in SPSS contributed to a rigorous and systematic examination of the data, enhancing the validity and reliability of the study's findings.

Results

The results of the study were collected and analyzed to investigate the circadian rhythm of athletes and its influence on daytime variation in temperature and performance components. All statistical analyses were conducted using SPSS (release 2.0, SPSS, Chicago, IL).

The results reveal a significant increase in body temperature (BT) between male (MM) and female (FF) genders (GN), with mean scores of 96.90°F (54.03%) and 97.10°F (54.14%), respectively, indicating an average increase of 0.11%. This rise in BT influenced an improvement in the subjects' physical fitness (PF), from a mean score of 572.40 (24.53%) to 641.28 (27.48%), with an average increase of 2.95%. In general, the results show a 2.84% increase in PF corresponding to the increase in BT between genders. This finding supports Gierse's (1842) [10] conclusion that women exhibit higher temperatures than men over a 24-hour period.

This conclusion is based on studies by Carandente F, Angeli A, Crosignani P, *et al*. (1987), which indicate that an elevated temperature difference is usually observed during the circa-mensal rhythm, ranging from 0.5-1.0°F around and several days after ovulation throughout the luteal phase, with an approximately 0.9°F increase in temperature prevailing during the follicular phase. This conclusion is similar to the study conducted by Coyne *et al*. (2000), which found that core body temperature is highest in the luteal phase (99.3°F) and lowest in the preovulatory (98.4°F) and follicular phases (98.7°F). The persistence of circadian rhythm of body temperature during the luteal phase enhances body temperature.

The use of oral contraceptives prior to the scheduled date of competition to abolish the circa-mensal rhythm also significantly increased body temperature by approximately 1.08°F. This conclusion is similar to the study conducted by Baker *et al*. (2001), which found an upward rise of approximately 1.08°F during circa mensal rhythm variations attributed to hormonal shifts during the menstrual cycle, indicating that progesterone increases body temperature while estrogen has a lowering effect, along with the influence of environmental temperature. These factors contribute to the difference in BT and PF between genders.

The results agree with Kenneth *et al*. (2002), which found a positive relationship between body temperature and performance while controlling for circadian phase and hours awake within the normal circadian range of body temperature. The results are also consistent with studies conducted by Holland *et al*. (1985), which showed that an increase in core temperature was associated with significant increases in the speed of performance on tests of reasoning, memory, and mood, by 11% and 10%, respectively. The findings of this study support the hypothesis that temperature significantly affects the physical performance of male and female athletes. This finding also has important implications, as it could be a useful tool for coaches and athletes to improve training and racing principles during competitions.

The graphical representation of the mean score of diurnal variation and the time peak of performance components presented below in Fig 1, 2, 3 and 4.

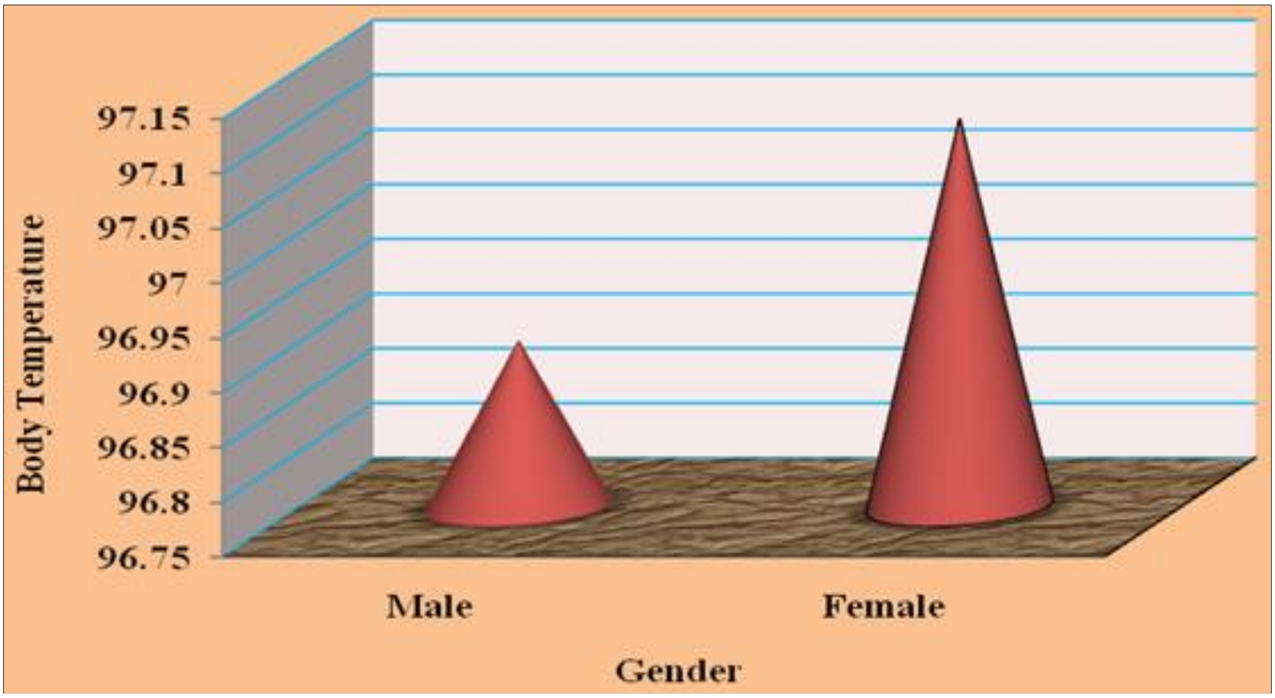

Fig 1: Estimated marginal means on mean score of temperature on gender

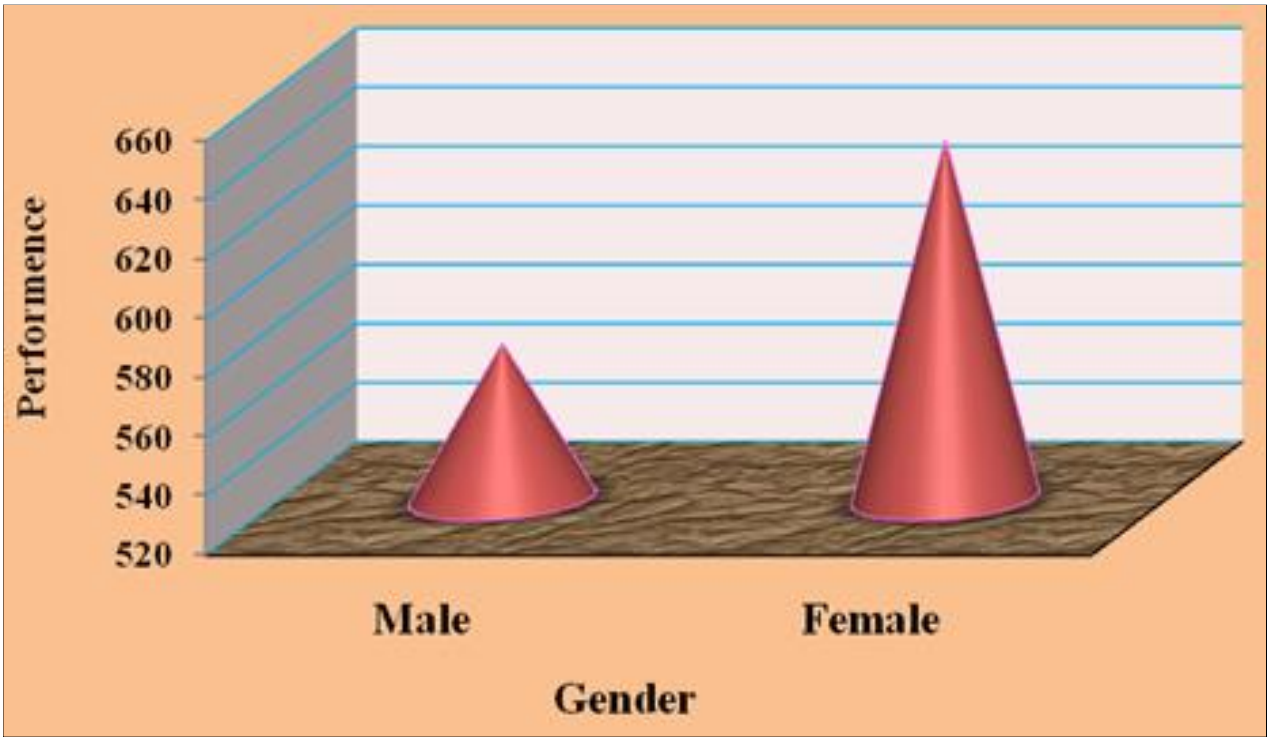

Fig 2: Estimated marginal means on mean score of performance on gender

Table 1: Descriptive statistics of dependent variable temperature on genders

Dependent variable	Gender	Mean	Std. Deviation	N
Temperature	Male and Female	96.90	.94169	60
		97.10	1.07214	60
		Total 97.00	1.00	120

Table 2: Descriptive statistics of dependent variable performance on genders

Dependent variable	Gender	Mean	Std. Deviation	N
Performance	Male and Female	572.40	123.965	60
		641.28	120.983	60
		Total 606.84	126.776	120

Table 3: ANOVA on circadian rhythm type with dependent variables Temperature and Performance

Dependent Variable	Type III Sum of Squares	DF	Mean Square	F	Sig (P-Value)
Temperature	6.729	3	2.243	4.046	.010
	37.700	68	.554		
Performance	16023.747	3	5341.249	.354	.787
	1026620.517	68	15097.361		

* Significant at. 05 level

Discussion

The results indicate that there is no significant difference in body temperature between genders, although females show a slightly higher body temperature than males. Therefore, the hypothesis suggesting a significant difference in body temperature based on gender is rejected. This finding is consistent with previous research by Campbell, Gillin, Kripke, Erikson, and Clopton (1989) [1], who also reported higher body temperatures in women compared to men.

The slightly higher temperature in females could be attributed to several factors. Charkoudian and Johnson (1997) [4] suggest that the use of oral contraceptives could elevate body temperature among female athletes. Additionally, variations in body temperature across the menstrual cycle are noted, with temperatures being higher during the luteal phase due to increased levels of progesterone and estrogen (Stephenson & Kolka, 1993) [5].

Another factor contributing to higher temperatures in women is reduced sweating compared to men, as highlighted by Stephenson and Kolka (1985). Women typically have lower body mass, shorter stature, less muscle mass, and more body fat than men, which can influence thermoregulation, resulting in higher body heat. Furthermore, differences in sweat evaporation rates could also result in higher body temperatures (Havenith, 2001) [7].

In contrast, the results concerning physical performance indicate a significant difference between male and female athletes, with females showing higher mean performance values. This finding contradicts much of the existing literature, which typically reports a 10-12% performance gap favoring elite male athletes due to better access to resources, training, and the effects of androgens.

This performance gap suggests that the highest performance levels in women often do not match those of men in track and field events (Thibault *et al*., 2010) [6]. However, the higher performance of women in this study might be due to their dominance in specific events (Thibault *et al*., 2010) [6]. A more plausible explanation could be the unique physical characteristics of the selected female subjects in this study.

Conclusion

Achieving excellence in elite sports requires athletes to consistently strive for peak performance by enhancing their speed, technical skills, tactical knowledge, and endurance. The complex interplay between biological processes and physical performance is crucial in shaping an athlete's success. This study's findings underscore the importance of understanding circadian rhythms and their impact on body temperature and performance. The observed differences between male and female athletes highlight the need for tailored training and competition schedules. As competitiveness in sports intensifies, greater dedication and resource allocation become essential for athletes, coaches, and clubs to bridge the ever-narrowing gap between victory and defeat.

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