Volume 3, Issue 2, 2026

Intuitions & Insights

An Interdisciplinary Peer Reviewed Research Journal

ISSN: 3048-6793

Sex-based variations in physical characteristics and their association with morningness–eveningness patterns

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Abstract: **The study aimed to examine sex differences in anthropometric variables and their relation with chronotype among twenty-one students of Zoology of Raghunathpur College using the Morningness–Eveningness Questionnaire (MEQ). The majority of participants (10) were classified as moderately morning type, while nine were neither type and only one participant each belonged to definitely morning and moderately evening types. Two-tailed Welch's t-tests indicated significant sex-based differences in height, weight and body mass index (BMI), with males showed higher mean values than females (p < 0.05). There was no significant difference between MEQ scores of males and females (p = 0.9479), suggesting that chronotype distributions were alike. Tukey post-hoc analyses confirm these results. The analysis of covariance (ANCOVA) analysis showed that BMI and age are not predictor of MEQ score in both sexes. Principal Component Analysis (PCA) indicated that the first principal component was associated predominantly with body size variables (weight, BMI and height), whereas the second principal component reflected an inverse association between age and chronotype. The results point out evident sex differences in physical characteristics, but indicate that chronotype does not depend on anthropometric variables.**

Key-words: Body mass index (BMI), Chronotype, Morningness–Eveningness Questionnaire (MEQ), Principal Component Analysis

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Received: 01.03.2026; **Accepted**: 15.07.2026; **August 2026**

1. Introduction

Circadian rhythm is a natural cycle of 24 hours at the level of cell, organ, or organism that governs many normal physiology, behavior and psychology in humans. It regulates sleep–wake cycles, hormone release, enzymatic activity, body temperature and cellular activity. Although these rhythms are endogenously generated, they can be entrained by environmental cues such as light–dark cycles and ambient temperature (Dijk et al., 2012; Shanahan et al., 1997). The suprachiasmatic nucleus (SCN) in the hypothalamus acts as a central pacemaker to regulate internal biological clocks by entraining to peripheral cues from external environments (Patton & Hastings, 2018; Hastings et al., 2014). The Chronotype describes individual differences in circadian preference that can then define time of sleep and peak activity periods across the day. These preferences allow to classify individuals as morning types, evening types and intermediate types (Horne & Östberg, 1976). Individuals who wake up early typically show peak alertness during morning hours and tend to be healthier overall, both mentally and physically (Giampietro & Cavallera, 2007). Conversely, evening-type individuals, more enjoy late-night activities, show poor wake-up in the morning and are characterized with lower cognitive performance, higher stress levels and poorer social adjustment (Giampietro & Cavallera, 2007; Achilles, 2003). Eveningness is related with decreased efficiency in cognitive tasks (Giannotti et al., 2002; Kirby & Kirby, 2006; Randler, & Frech, 2006). Research indicates that morning types do better on tasks requiring short-term memory and fine motor skills (Vidueira et al., 2023; Vollmer et al., 2013). In general, alertness levels are high in the morning and decrease in the evening, followed by a rise in sleepiness. Sensory processing (Lotze et al., 1999), motor coordination (Edwards et al., 2007), reaction time (Wright et al., 2002), time perception (Campbell et al., 2001), memory (Folkard & Monk, 1980), verbal ability (Monk TH, Carrier, 1997), mathematical performance (Blake, 1967), and complex activities like simulated driving (Lenné et al, 1997) are all impacted by these variations. In general, performance tends to decrease at night (Edwards et al., 2007). Furthermore, the homeostatic sleep-wake process interacts with circadian rhythms in such a way that adequate sleep restores cognitive efficiency while prolonged wakefulness reduces task performance (Deboer, 2018). Beyond cognitive aspects, chronotype significantly affects metabolic health and disease risk. Several evidence links circadian preference with conditions like metabolic syndrome, type 2 diabetes, cardiovascular diseases and depression (Almoosawi et al., 2019; Hawley et al., 2020). Evening chronotypes, in particular, are more susceptible to circadian misalignment. This misalignment relates to poor glucose metabolism, increased fat accumulation and having risk of heart and mental diseases (Lucassen et al., 2013).

Additionally, studies indicate that evening type individuals are more prone to different health issues than the morning types (Knutson & von Schantz, 2018; Makarem et al., 2020). Lifestyle and behavioral factors influence the link between chronotype and health outcomes. Recent research shows that a person's ability to manage their behavior, especially regarding diet and physical activity, is important in determining their risk of obesity (Niezgoda et al., 2025; Lin et al., 2025). Good self-regulation leads to healthier eating habits and helps turn intentions into actions (Kliemann et al., 2016). However, people with evening types are likely to adopt unhealthy lifestyle habits. These include skipping meals, eating fewer fruits and vegetables, and consuming more sugary drinks and alcohol (Maukonen et al., 2016). These behaviors, along with irregular eating schedules and minimum physical activity, lead to a higher BMI and metabolic issues. Recently, research was aiming to understanding the link between chronotype and BMI, especially among young adults and college students. Research show that individuals who are evening types often have higher BMI and are more likely to gain weight than the morning types (Lucassen et al., 2013). This connection is often linked to misaligned biological clocks, poor eating habits, and less physical activity. Furthermore, when biological rhythms do not match social or academic schedules, it can disrupt energy balance and metabolism, increasing the risk of obesity and related issues (Garaulet et al., 2013; Garaulet & Gómez-Abellán, 2014). College students are particularly at risk due to irregular daily routines, academic stress, changes in sleep patterns, and unhealthy diets which can impact both circadian rhythms and BMI, making them important for studying the relationship between chronotype and health. In this context, students from the Department of Zoology at Raghunathpur College can be a suitable group to study these links because various academic and lifestyle challenges may affect their circadian preferences and body composition. Examining sex-based variations in anthropometric traits (height, weight, and BMI) and evaluating their relationship to chronotype as identified by the MEQ is the primary goal of this study. It also seeks to determine whether differences in morningness-eveningness patterns can be predicted by age and body composition.

2. Material and Methods

This study employed a cross-sectional observational design using data collected as part of an academic exercise conducted among 3rd year Zoology students at Raghunathpur College, Purulia, West Bengal, India. A total of 21 participants were included in the study, comprising 16 females and 5 males. Data collection was undertaken solely for educational and research purposes. Participation in the study was voluntary, and all participants provided informed consent before data collection. They were informed about the purpose of the study, the nature of their participation, and their right to withdraw at any time without penalty. Personal information was kept confidential, and all data were anonymized prior to analysis. The study was conducted in accordance with the ethical principles for research involving human participants. All 21 participants completed the Morningness–Eveningness Questionnaire (MEQ) developed by Horne and Östberg (1976). All the statistical analysis were performed using Python software. We grouped participants by sex for comparison. Two-tailed Welch's t-tests compared males and females based on height, weight, BMI, and MEQ scores, considering unequal variances followed by Tukey pairwise post-hoc tests to assess differences between groups. To examine how age and BMI predict chronotype, we applied Analysis of Covariance (ANCOVA) separately for male and female groups, using MEQ score as the dependent variable and age and BMI as covariates. Additionally, we conducted Principal Component Analysis (PCA) to explore the dataset's underlying structure and identify patterns among age, height, weight, BMI, and MEQ scores. We analyzed the proportion of variance explained by each principal component and the loading patterns of variables to interpret relationships within the data.

3. Result and Discussion

The results of MEQ scores indicate that the subjects (N=21) could be assigned three major types, i.e., moderately morning type (10), neither type (09), definitely morning type (01) and moderately an evening type (01). Two-tailed Welch t-tests were used for comparisons of height, weight, BMI and MEQ scores between males and females (Figure. 1), as this test is appropriate for small samples and does not assume equal variances. Tukey pairwise post-hoc analysis were also computed and results were given the Table 1. Mean height was significantly higher in males (171±6.44) than in females (157.62±5.65; p = 0.0057). Similarly, males had a significantly greater mean body weight (68.2 ± 9.93) compared to females (46.75±7.55; p = 0.0053). Body Mass Index (BMI) was also significantly higher in males (23.26 ±2.66 kg/m²) than in females (18.81±2.64 kg/m²; p = 0.0127). In contrast, no significant difference was observed in Morningness–Eveningness Questionnaire (MEQ) scores between males (mean = 59.0±2.45) and females (mean = 59.19±10.43), with a p-value of 0.9479, indicating comparable chronotype distributions across genders.

Table 1 ***Gender based comparison of height, weight, BMI and MEQ scores (Female, n=16; Male, n=5).***

Variable	Female Mean	Female SD	Male Mean	Male SD	Welch p	Post Hoc Tukey
Age	20.75	1.18	21	1.00	0.65	0.675
Height	157.62	5.65	171.0	6.44	0.0057	0.0003
Weight	46.75	7.55	68.2	9.94	0.0053	0.0001
BMI	18.81	2.64	23.26	2.58	0.0127	0.0038
MEQ SCORE	59.19	10.43	59.0	2.45	0.9479	0.9691

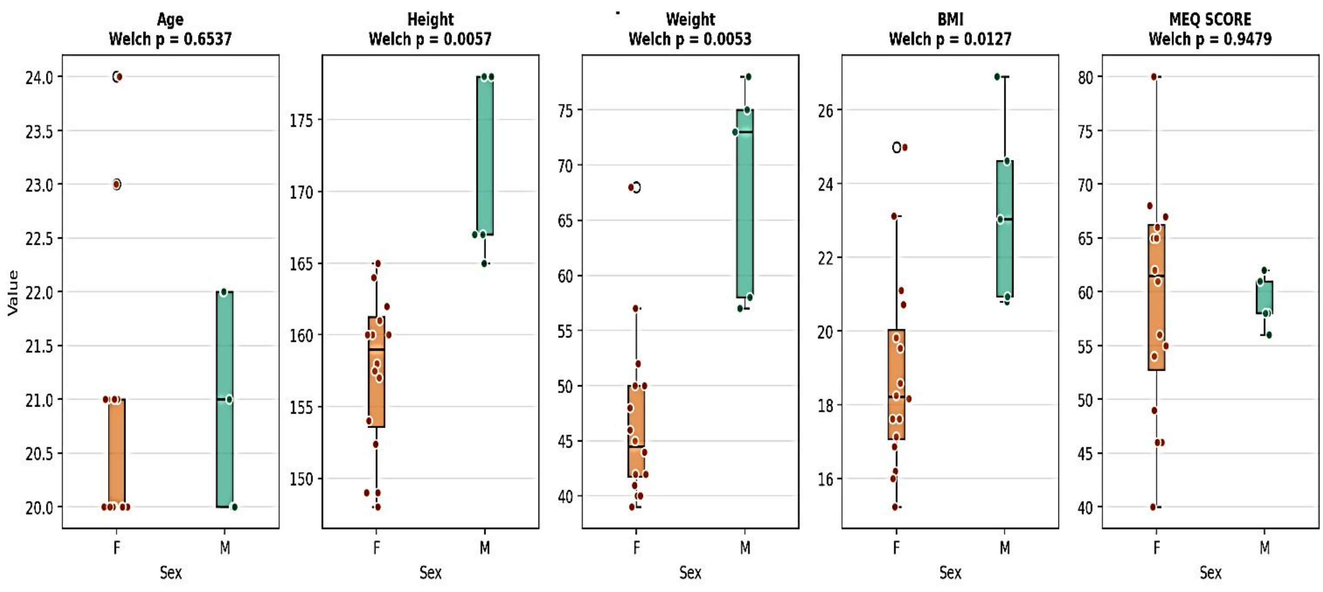

Figure 1 ***Gender based comparison of height (cm), weight (kg), BMI (kg/m^2) and MEQ scores (F=Female, n=16; M=Male, n=5).***

ANCOVA (for continuous predictors with sex grouping) was performed and the results indicates that BMI and age do not significantly predict MEQ in the female group and male group (Female: R^2=0.0322, Adjusted R^2=-0.2098, F=0.133, p=0.9385; Male: R^2=0.582, Adjusted R^2=-0.672, F=0.4641, p=0.7616).

ANCOVA was selected because both age and BMI have been reported in previous studies as factors that may influence chronotype and therefore could confound comparisons if not considered. However, given the limited sample size, particularly within the female group, these analyses should be regarded as exploratory rather than confirmatory. Principal Component Analysis (PCA) was applied to examine the underlying structure of the dataset and to identify key patterns among the variables Age, Height, Weight, BMI, and MEQ score (Figure 2). PCA was used as an exploratory data reduction technique to summarize correlations among variables and visualize overall patterns. The first principal component (PC1) accounted for the largest proportion of variance (50.30%) and was strongly positively correlated with weight and BMI, with a moderate contribution from height. This suggests that PC1 primarily represents a body size or anthropometric dimension. The second principal component (PC2) captured additional variability (21.5%) and was characterized by a positive loading for Age and a negative loading for MEQ score, indicating an inverse relationship between these variables. The PCA biplot also showed a clear distinction between male and female participants along PC1, with males mainly found in the positive area, aligning with larger body size measurements. Females showed more spread out positions and were often found in the negative part of PC1. The angles between the vectors show a strong positive relationship between weight and BMI, whereas age and MEQ score are negatively correlated. The findings demonstrate clear sex-based differences in physical characteristics, with males have significantly higher height, weight and BMI than females. This is in accordance with biological and physiological differences between sexes, whereby males possess larger lean body masses and bone size due to hormonal effects such as testosterone (Janssen et al., 2000). Although this difference in BMI is statistically significant, it is also clear that both groups are in healthy ranges. Therefore, it is proposed that this difference is largely due to body composition.

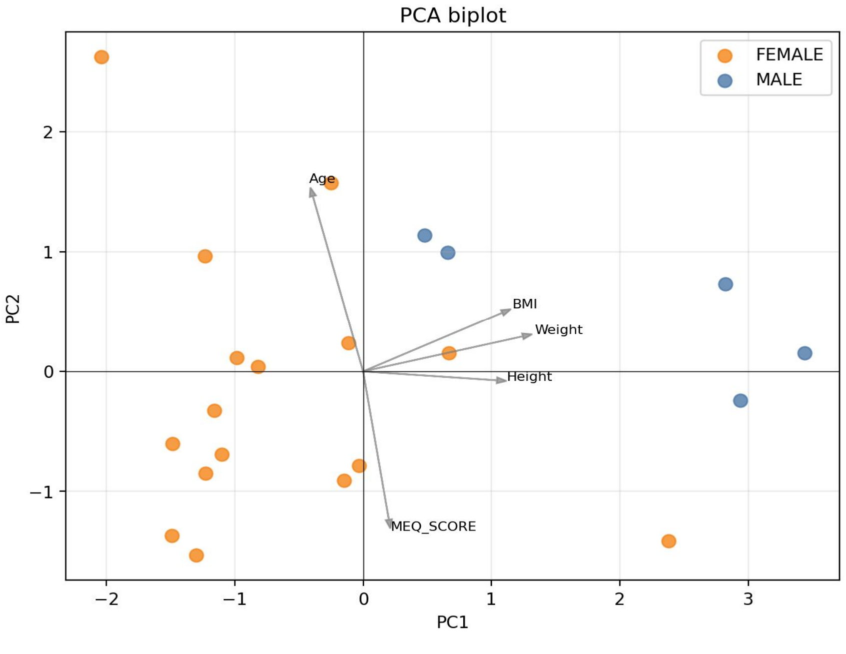

Figure 2 ***Principal Component Analysis (PCA) shows the structure of the dataset and to identify key patterns among the variables Age, Height, Weight, BMI, and MEQ score.***

This study reveal a distinct disparity between physiological dimorphism and behavioral circadian patterns among the sampled group. The marked variations noted in height, weight and Body Mass Index closely correspond with existing study of human sexual dimorphism. The notably higher average values in male subjects reflect overarching biological and physiological trends influenced by hormonal changes throughout development. In males, increased adolescent testosterone exposure promotes enhanced growth of lean body mass, muscle density, and bone structure compared to females. Importantly, while the male group showed a noticeably higher average BMI compared to the female group, both distributions remain well within normal healthy ranges. This validates that these variations indicate normative differences in musculoskeletal and tissue composition instead of signs of metabolic pathology. Despite the significant differences in physical characteristics, the circadian phenotypes of both groups were functionally the same.

The average MEQ scores for both males and females yielded a high p value, indicating that biological sex had no significant impact on the morningness–eveningness trait in this sample. This parity adds to a persistent discussion in current chronobiology research. Although certain traditional population studies indicate a slight bias, where females show a preference for an earlier sleep-wake phase or stronger morning orientation during early adulthood (Duarte et al., 2014; Jocz et al., 2018), other study stated that these differences often become insignificant when looking at particular age groups or very specific socio-environmental contexts. The structural equivalence noted here strengthens the idea that behavioral synchronizers, common academic schedules, and external environmental zeitgebers can significantly overshadow internal biological sex differences in influencing individual chronotypic expression (Tonetti et al., 2024). The exploratory Principal Component Analysis (PCA) offered insight into the fundamental organization of the dataset. The distinct division of participants along the first principal component highlights the importance of physical attributes (weight, BMI, and height) in distinguishing the groups. The second principal component effectively separated behavioral and ontogenetic variance, revealing a negative loading relationship between age and MEQ scores. This opposite correlation suggests age-related phase changes that remain independent of basic body size characteristics. The ANCOVA further stated this distinction, indicating that neither BMI nor age served as statistically significant predictors of MEQ variations in either gender group. Although earlier extensive studies propose that changes in fat distribution, age, and overall metabolic condition can influence circadian clock gene expression, the lack of predictive power in these models implies that within a closely matched, age-homogeneous population, anthropometric differences do not fundamentally interfere with chronotype classification. A primary limitation of this study is the relatively small sample size ($n = 21$), comprising 16 female and 5 male participants. The unequal distribution between sexes further limits the statistical power of between-group comparisons and increases the likelihood of Type II errors, whereby true differences may not be detected. The small sample also reduces the precision and generalizability of the findings, as the participants were drawn from a single cohort of third-year Zoology students at one college. The results should be considered as preliminary and should not be representative of broader student populations or individuals of different ages, educational backgrounds, or geographic regions. Further research including larger, more diverse, and more balanced samples across sexes are needed to validate and extend these findings.

4. Conclusion

This study used the Morningness–Eveningness Questionnaire (MEQ) and anthropometric measures to examine sex differences in anthropometric traits and chronotype among third-year Zoology students at Raghunathpur College. The results show that the majority of individuals were categorized as either neither type nor somewhat morning type, with only one person each falling into the categories of certainly morning and moderately evening chronotypes. This distribution indicates that the study population has a preponderance of intermediate to moderately morning preferences. Anthropometric traits showed significant sex-based disparities. Due to recognized biological disparities in body composition and physical development between the sexes, male participants have significantly higher height, body weight, and BMI than female participants. The mean BMI for male and female participants remained within the healthy range despite these statistically significant variances, suggesting that normal physiological variations are more seems to be responsible for the observed discrepancy. There was no significant differences of MEQ scores between male and female individuals, indicating that chronotype was generally same for both sexes. So it can assumed that preference for morningness or eveningness may not be significantly influenced by sex alone. Rather, a variety of biological, behavioral, environmental, and other factors that were not included probably have an impact on chronotype. Age and BMI were not significantly correlated with MEQ scores in either male or female subjects, as per the ANCOVA analysis. However, given the analyses were performed on a small sample with unequal group sizes, which reduced statistical power and limited the ability to detect potentially relevant relationships. The clustering of male participants along the positive axis of the first principal component also indicate the observed sex-related differences in body size. Nevertheless, because PCA is an exploratory technique and the present dataset was limited in size, these multivariate patterns should be regarded as descriptive rather than definitive. Larger and more diverse populations with equal representation of both sexes and a wider range of age groups should be considered in future studies. Detailed knowledge of the factors influencing chronotype might be possible by include other variables such sleep length, sleep quality, physical activity, dietary habits, academic workload, socioeconomic status, and light exposure.

Acknowledgments

The authors are deeply grateful to the Principal of Raghunathpur College, Purulia, West Bengal for his support. The authors are also thankful to all the respected faculty members and students of the Department of Zoology for their support to complete this work.

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