



# The Influence of Chronotype on Strength Variables in Female University Students at different times of day: A Cross-Sectional Study

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## Abstract

**Background.** Chronotype influences physical performance through circadian rhythms that vary across the day. Strength and power often peak in the evening, suggesting timing impacts training outcomes. This study explores these effects in female university students, a group which is underrepresented in chronobiological research.

**Objectives.** This study aimed to examine how chronotype influences strength performance in female university students at different times of day. Specifically, it compared maximal strength, explosive power, and hand muscle strength between morning-type and evening-type individuals to identify optimal training or performance times based on chronobiological preference.

**Materials and methods.** The Horne and Ostberg Morningness–Eveningness Questionnaire was used to classify 56 Indian female university students (mean age = 22.2 years; weight =  $56 \pm 4.31$  kg; height =  $158 \pm 5$  cm; BMI =  $21 \pm 1.5$  kg/m<sup>2</sup>). Strength performance was assessed using three measures: one-repetition maximum (1RM) for maximal strength; countermovement jump (CMJ) for explosive power; and handgrip dynamometry for muscle strength. Testing was conducted under standardized conditions at each participant's chronotype-aligned time (morning or evening). Independent samples t-tests were used for analysis, with the Shapiro–Wilk and Levene's tests confirming the assumptions of normality and homogeneity.

**Results.** It was observed that the evening-type individuals expressed much better scores on all variables of being tested than morning types. The evening group produced greater values in 1RM squat ( $78.3 \pm 2.63$  kg vs.  $72.1 \pm 3.11$  kg;  $t_{(54)} = -8.08$ ,  $p < .001$ ,  $d = 2.16$ ), CMJ ( $30.1 \pm 2.32$  cm vs.  $26.1 \pm 2.32$  cm;  $t_{(54)} = -6.46$ ,  $p < .001$ ,  $d = 1$ ).

**Conclusions.** The findings of this study indicate that evening-type female university students have enhanced strength performance during evening hours, underscoring the need to consider chronotype when planning training and performance assessments in female athletes.

**Keywords:** chronotype, morningness – eveningness, maximum strength, explosive power, hand muscle strength.

## Introduction

Chronotype is the natural inclination to sleep at a certain time, reflecting deeper links between individual

biology and social time. Some people, called morning-types, wake early and function best in daylight, whereas evening-types tend to turn on mentally and physically later and often enjoy late-night work or leisure (Das et al., 2024). Such tendencies closely related with the body's circadian rhythm that coordinates many physical, mental and behavioural processes on a rough day-long schedule. That helps to maintain sleep and wakefulness, adjusts hormone levels,

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raises or lowers body temperature and modulates strength, focus, mood and energy. Individuals chronotype can be identified through self-report the Morningness-Eveningness Questionnaire (MEQ) or the Munich Chronotype Questionnaire (MCTQ) (Roenneberg et al., 2019). These Questionnaires ask about usual bed and rise times, changes in energy through the day, and how readily someone can perform work or study early, late or around the noon peak. Its expression arises from a blend of genetic predispositions, life-history events and current living conditions (Adan et al., 2012). Whether someone naturally rises early or stays up late therefore influences daily peaks and troughs in physical and mental performance (Morrow & Roenneberg, 2003). Among the many biological and mental factors that sway human performance, circadian rhythms stand out as especially powerful. In recent years, the idea of chronotype-preferred hours for exercise, competition or recovery has drawn increasing interest in sport and exercise science.

Researchers typically classify people into three main chronotypes: morning-type (MT), evening-type (ET), and intermediate-type (IT), with each group showing distinct peak times for physical and mental performance (Adan et al., 2012). Evidence indicates that chronotype influences athletic ability, especially in tasks demanding high force, explosive power and sustained endurance (Chtourou & Souissi, 2012). Morning-types tend to reach their best results early in the day, while evening-types shine later, often in the late afternoon or evening (Vitale & Weydahl, 2017). These time-dependent patterns are thought to follow daily changes in core body temperature, circulating hormones and the efficiency of neuromuscular pathways. Although interest in sex-related differences has grown, studies on chronotype and strength in young adult women remain surprisingly scarce. Moreover, most fitness tests and practices scheduled at fixed times, which can disadvantage students whose peak periods lie outside those slots (Facer-Childs & Brandstaetter, 2015).

General strength reinforces everyday tasks and protects the body by improving joint stability and muscular control, reducing the odds of minor or major injuries while moving (Garber et al., 2011). Explosive strength, sometimes called power, describes the body's knack for producing as much force as possible in the shortest possible phase, a quality that matters whenever a person sprints, jumps or throws an object with noticeable speed (Cormie et al., 2011). At the other end of the spectrum, muscular endurance is the ability to keep repeating a movement or to hold a position without early fatigue. However, it is essential in sustained physical work such as cycling, rowing or manual labour. Gains in any form of strength depend on size of the muscles recruited and consistently the nerves fire (Sale, 1988). A well-designed resistance program often recommended as the most straightforward way to increase both strength and power. Key training principles such as progressive overload, task specificity, and adequate recovery guide progress in athletes and rehabilitation clients alike (Kraemer & Ratamess, 2004). Personal factors, including age, biological sex, and even daily hormone cycles, can further shape how much and how quickly strength improves. However, factors such as chronological age, sex and even the timing of workouts relative to daily rhythms can shift how easily muscle strength is built and expressed. Numerous studies confirm that men tend to display higher absolute strength than women (Miller

et al., 1993). Understanding these circumstances, the present study will explore the influence of chronotype on strength variables in university female students at different times of day. The results will help create a better training schedule for both academic and athletic tasks that fits with each person's circadian rhythms.

## Materials and Methods

### Participants

Out of 100 university female students assessed using the Morningness-Eveningness Questionnaire, 28 morning-type and 28 evening-type students were selected through randomization, meeting the predefined inclusion criteria. These participants were then assigned to the morning group ( $n = 28$ ) and the evening group ( $n = 28$ ) for the study with a mean age of  $22 \pm 2$  years, weight of  $56 \pm 4.31$  Kg and height of  $158 \pm 5$  cm, and BMI of  $21 \pm 1.5$  kg/m<sup>2</sup>. The subjects maximum strength performance was measured by the 1 RM squat test, explosive power was measured by the counter movement jump test, and hand muscle strength performance was measured by the hand grip dynamometer.

The present study used a priori power analysis for the selection of sample size with the help of G\*Power 3.1.9.7 software with an alpha level = 0.05, power = 0.83, and an effect size of 0.80 for an independent samples t-test. It was determined that a minimum of 28 athletes should be included in each group. The study received approval from the departmental committee of Visva-Bharati University, West Bengal. Further Informed consent was obtained from all participants before they were included in the study and all procedures were conducted by the ethical guidelines of the latest version of the Helsinki Declaration. The tests were done under standardized conditions, either in the morning or in the evening sessions for each participant at their chronotype-aligned time of day. Before starting, they were given a brief explanation and demonstration of the categorized exercise test protocol. Testing took place at the gymnasium and the laboratory of the Department of Physical Education and Sport Science, Visva-Bharati University, Santiniketan, West Bengal in India.

### Study Design

In this work, a randomized cross-sectional, comparative research design was used as a way to examine the impact of chronotype on the strength-related physical performance of female university-level students. The participants were divided into two groups: morning type and evening type. Every group went through a single testing exercise where the maximum strength was indicated in the one-repetition maximum squat (1RM) test, explosive power was determined through the countermovement jump (CMJ), and the hand muscle strength was evaluated according to a handgrip dynamometer.

### Inclusion and Exclusion Criteria

The subjects were university female participants between the ages of 18 and 25 years, having regular undergraduate or post graduate classes, and a more or less regular sleep-wake

pattern. Participants were chosen without musculoskeletal injuries or medical conditions that can impair physical performance. Those who were already intermediate-type were not included in the study. Those with a history of neurological, cardiovascular, and orthopaedic disorders were also excluded. Participants using performance-enhancing substances, involved in competitive sports or strength training in the past three months, or with irregular menstrual cycles or hormonal disorders were excluded to ensure uniformity in strength performance measurements.

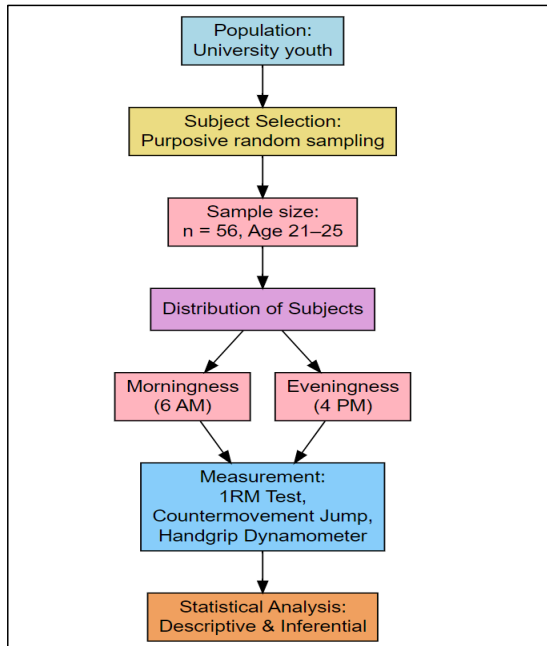


Fig 1. Flow diagram outlining the Study Design

### Testing Protocol

The researcher used Horne and Ostberg’s Morningness and Eveningness Questionnaires (MEQs) to identify the different chronotypes of the individual and MEQ scores ranging from 16 to 86. Scores range 42 to 58 imply “intermediate type,” while scores below 41 and below imply “evening type.” Scores of 59 and above imply a morning type (Khan et al., 2023).

**Maximal Repetition Squat Test (1-RM):** All participants performed a dynamic warm-up before the 1-RM squat test. They selected their starting weights, with guidance to begin at 30–40% of body weight to minimize injury risk. Using free squats, weights were progressively increased in 2.5-5 kg increments based on perceived difficulty until no further repetitions could be performed. Results were recorded in kilograms. Each group completed the test on separate days with 72 hours of rest between sessions. The test used free weights, following the protocol of İlbağ et al. (2024).

**Countermovement jumps (CMJ):** Before and after each set of the half-squat test, participants performed two maximal countermovement jumps (CMJs) on a contact platform (Newtest Oy, Finland) with a 3–7 second delay after squatting. Jumps were performed from an extended position to 90° knee flexion, with a 4-second gap between

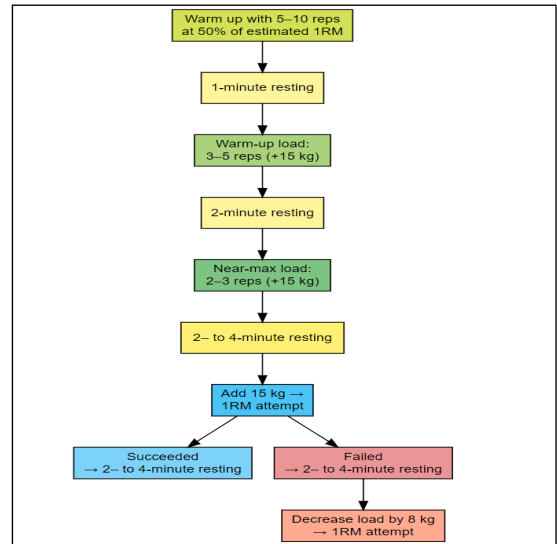


Fig. 2. The test protocol of the 1 RM test

jumps. Flight time was used to calculate jump height, and the higher of the two jumps was used for analysis (Izquierdo et al., 2002).

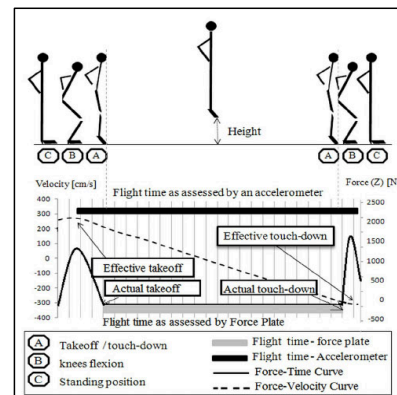


Fig 3. The test protocol of Countermovement jumps (CMJ)

**Grip Strength (Dynamometry):** Using a calibrated handgrip dynamometer (Takei TTK 5001, Takei Scientific Instruments Co. Ltd., Niigata, Japan), three maximal voluntary isometric contractions were measured to determine grip strength with the right and left hands, respectively. To measure this correctly, the participants had to stand with their arms parallel to their bodies, with their hands in a neutral position (Jurado-Castro et al., 2022).



Fig. 4. The test protocol of Grip Strength (Dynamometry)

**Statistical Analysis**

All statistical analyses were performed using Jamovi software (Version 2.4) to examine the impact of chronotype (Morningness vs. Eveningness) on maximum strength (1RM squat), explosive power (CMJ), and hand muscle strength (grip test). Descriptive statistics (mean, SD, SE) were calculated for each group to summarize performance levels and variability. The Shapiro-Wilk test confirmed normal distribution ( $p > 0.05$ ), supporting the use of parametric tests. Levene’s test showed no significant differences in variance between groups ( $p > 0.05$ ). Independent samples t-tests were used to compare performance across chronotypes, with statistical significance set at  $p < 0.05$ .

**Results**

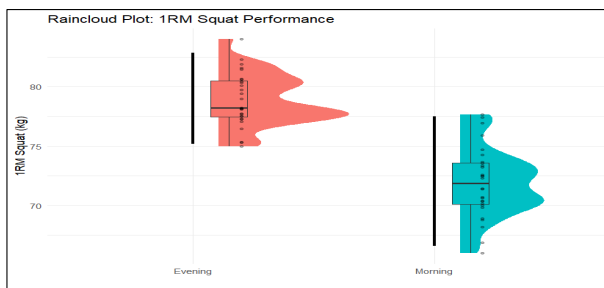
All performance variables were analyzed descriptively and inferentially between morning and evening chronotype groups. The evening group showed higher mean scores in 1RM squat ( $M = 78.3 \pm 2.63$  kg) compared to the morning group ( $M = 72.1 \pm 3.11$  kg), in CMJ ( $M = 30.1 \pm 2.32$  cm vs.  $M = 26.1 \pm 2.32$  cm), and in grip strength ( $M = 29.7 \pm 1.55$  kg vs.  $M = 27.5 \pm 2.04$  kg). The Shapiro-Wilk test confirmed normal distribution for all variables ( $p > .05$ ), and Levene’s test confirmed homogeneity of variances ( $p > .05$ ).

Independent samples t-tests revealed statistically significant differences favoring the evening group in all strength variables: 1RM squat ( $t_{(54)} = -8.08, p < .001, d = 2.16$ ), CMJ ( $t_{(54)} = -6.46, p < .001, d = 1.73$ ), and grip strength ( $t_{(54)} = -4.48, p < .001, d = 1.20$ ). These results suggest that evening-type individuals demonstrate superior performance, likely influenced by circadian rhythm effects.

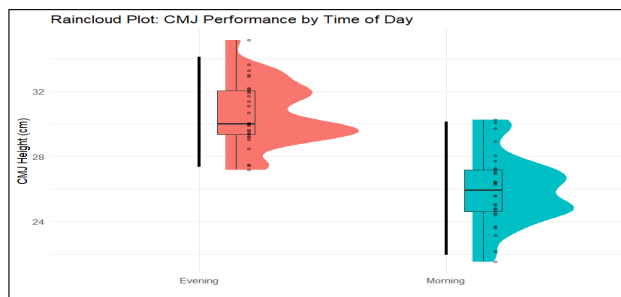
**Table 1.** Descriptive Statistics for Performance Tests

Test	Group	n	Mean	SD	SE
1RM Squat (kg)	Morning	28	72.1	3.11	0.587
1RM Squat (kg)	Evening	28	78.3	2.63	0.496
CMJ (cm)	Morning	28	26.1	2.32	0.439
CMJ (cm)	Evening	28	30.1	2.32	0.439
Grip Strength (kg)	Morning	28	27.5	2.04	0.385
Grip Strength (kg)	Evening	28	29.7	1.55	0.292

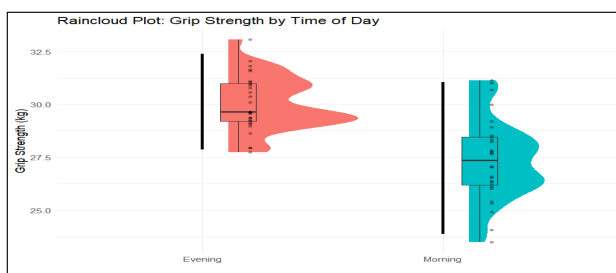
Fig. 5, Fig. 6, Fig. 7, a raincloud plot that shows respectively the distribution of 1RM, CMJ, and hand grip strength between the Morning and Evening groups. The visualization combines a violin plot, a box plot, and jittered raw data points to deliver a full picture of the performance variance of the time of day.



**Fig 5.** 1RM Squat Performance



**Fig 6.** CMJ Performance by Time of Day



**Fig 7.** Grip Strength by Time of Day

**Discussion**

The study examined the influence of test timing on strength measures in a group of female university students and findings consistently favour to evening sessions groups. Participants recorded higher scores in one-repetition maximum squats, countermovement jumps, and grip strength when assessed in the evening compared with morning testing. It is well known that core temperature of the body peaks in afternoon session which promotes greater muscle pliability, faster enzyme reaction times and improved nerve conduction. All the factors positively contribute to increased force production. Study of Souissi et al. (2022) and Thun et al., (2022) also express that raised body temperature

**Table 2.** Independent Samples t-Test Results

Variable	t	df	p-value	Mean Difference	SE Difference	Cohen’s d
1RM Squat (kg)	-8.08	54	< .001	-6.21	0.769	-2.16
CMJ (cm)	-6.46	54	< .001	-4.01	0.621	-1.73
Grip Strength (kg)	-4.48	54	< .001	-2.16	0.483	-1.20

Note. A negative mean difference indicates superior performance in the evening-type group. Statistical significance was determined at  $p < .05$ . Hypothesis tested:  $H_a: \mu_{\text{morning}} \neq \mu_{\text{evening}}$ .

correlates strongly with enhanced outcomes in both strength and endurance tasks (Souissi et al., 2022; Thun et al., 2022).

The late-afternoon to evening training window generally coincides with favorable endocrine and metabolic dynamics, marked by elevated serum growth hormone concentrations, muted cortisol release and refined blood glucose and lactate profiles that can bolster energy availability during high-intensity exertions (Fernandes et al., 2014). Repeated workouts during this time might facilitate greater hypertrophic response than morning sessions, probably because muscular and systemic temperatures tend to be higher and the coinciding hormonal milieu promotes protein synthesis (Küüsmaa et al., 2016). De Hoyo et al. (2016) observed consistently greater absolute strength levels in evening trials. Another study by İlbak et al. (2024) stated that athletes attain significantly higher 1RM squat scores after sunset. Evening training also benefits from naturally elevated core temperature, which enhances musculotendinous elasticity, speeds nerve conduction, and accelerates enzymatic turnover, collectively translating to improved explosive power and vertical-jump metrics (Heishman et al., 2017; Zelenović et al., 2018).

Muscle strength and power, as assessed by neuromuscular tests like the countermovement jump (CMJ), tend to show diurnal variation that peaks in the late afternoon or early evening (López-Samanes et al., 2017). This oscillation appears to stem from the interplay of circadian alterations in muscle temperature, hormone secretion and ion handling within fibres (Harrison et al., 2024). Evening sessions typically occur after a full day of eating, providing higher circulating carbohydrates and amino acids and often coincide with reduced plasma cortisol, both of which favour contractile capacity (Heishman et al., 2017). Reinforcing this pattern, recent investigations in both male and female athletes report significant increases in CMJ height and velocity when tests are moved from the morning to a later time slot, underscoring the role of timing in explosive strength assessment (Robles-González et al., 2023). Thus, the current findings agree with the wider literature, confirming that circadian timing can meaningfully influence performance metrics in sports science.

A recent observational study by Heishman et al. (2017) concluded that collegiate basketball players recorded higher countermovement-jump scores during afternoon practice sessions than in morning workouts. Similarly, elite male handball players displayed substantial gains in short-term jump height and sprint speed when activities were postponed until the evening (Pavlović et al., 2018). A larger investigation of team sport athletes confirmed that both countermovement-jump performance and agility tended to peak later in the day, supporting previous recommendations (Martín-López et al., 2024).

Hand gGrip strength also follows a diurnal pattern, usually peaking in the evening compared with the early morning, and several linked physiological factors have been identified. Elevated core body temperature later in the day appears to enhance muscle elasticity, improve blood flow, and speed up neural conduction—and these changes together fine-tune the strength-endurance balance required for stable, precise gripping. Neuromuscular recruitment tends to become more efficient as the day advances, producing smoother coordination and stronger contractions in skeletal muscles (López-Samanes et al., 2017). Morning cortisol concentrations, a well-documented stress marker, may temporarily impede muscular output, while evening levels

drop significantly, creating a more favourable endocrine profile for strength tasks (Heishman et al., 2017). Relatedly, grip strength exhibits a clear diurnal pattern, generally peaking in the evening and falling to lower morning measures (Patel et al., 2004; Reinberg et al., 1994). Recent work on Brazilian Jiu-Jitsu athletes likewise reported higher scores during late-day assessments, reinforcing the notion of time-of-day effects in combat sports (Kons et al., 2025).

Exercise performed during the evening, when core body temperature is elevated, tends to improve muscle flexibility, accelerate nerve conduction velocity, and boost enzyme activity, collectively increasing neuromuscular efficiency and power output (Lopez-Samanes et al., 2017; Heishman et al., 2017). Nighttime training is also associated with lower evening cortisol levels, which reduces neural inhibition; concurrently, anabolic hormones such as growth hormone become more secreted and can positively influence strength adaptations (Heishman et al., 2017). Evening sessions benefit from greater availability of circulating glucose and lactate, providing an extra energy reserve during high-intensity efforts (Fernandes et al., 2014). Taken together, these thermal, hormonal, and metabolic factors create a physiological environment especially favourable for strength and power activities. Over weeks or months, repeatedly training in this window may compound those individual benefits, yielding superior muscle hypertrophy and longterm performance gains (Kuusmaa et al., 2016). Consequently, the time of day an athlete chooses to lift weights emerges as an important yet sometimes overlooked variable in pursuit of maximum strength.

A recent investigation involving adolescent soccer athletes indicated that both strength and aerobic endurance were significantly improved during late-afternoon and evening testing windows (Duan et al., 2024). Complementary work has further documented elevated rates of energy expenditure and superior cycling times when efforts are scheduled for the evening, thereby reinforcing the hypothesis that human physiology is better primed for exertion later in the day (Souissi et al., 2022). Beyond the biological realm, psychological variables—specifically heightened alertness, motivation, and arousal—frequently peak in the evening and may amplify motor output even more than synchronised metabolism alone (Teo et al., 2011). Regular diurnal patterns of movement also contribute, as accumulated locomotion pre- or post-office hours can improve joint mobility and lower neural activation thresholds during formal exercise sessions (Chtourou & Souissi, 2012). Combined, these lines of evidence suggest that both explosive and isometric strength—indexed by tests such as the countermovement jump and hand-grip dynamometry—exhibit reliable evening maxima, underscoring the functional relevance of circadian timing for sports performance.

The current observations support earlier reports indicating that muscle force and power production peak later in the day, a pattern attributed to elevated tissue temperature, favourable enzyme kinetics and enhanced neural output (Reilly et al., 2007). An investigation of elite male handball players confirmed that strength, power, and throwing velocity improved more markedly during evening training, with positional role further modulating the magnitude of change (Cherif et al., 2022). Parallel work focused on university women in the Netherlands showed that participants with an evening chronotype scored higher in explosive strength and agility tests, linking circadian

orientation to performance outcomes (Das et al., 2024). A time-of-day study of female sprinters and jumpers also reported significant gains during evening trials compared to morning assessments, emphasising the potential of scheduling workouts later in the day (Klaus-Karwisch et al., 2023). Collectively, these lines of evidence suggest that strength-related training and competition may be optimised if scheduled for the evening hours. According to findings of Saha et al. (2025) matching natural sleep-wake pattern to work schedules can enhance overall performance.

According to the evidence, Strength performance is generally higher in the evening than in the morning, likely due to factors such as increased body temperature and hormonal fluctuations. Aligning training with an individual's circadian rhythm and chronotype may enhance results. Future research should explore how training time affects performance across different genders and sports. Athletes can use this knowledge to better structure their training for optimal strength gains.

## Conclusions

The results show that strength performance in female university students peaks in the evening across all measures—IRM squat, CMJ, and grip strength. This supports the role of circadian rhythms in enhancing physical and mental function later in the day. Coaches should consider both chronotype and time of day when planning training and assessments.

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## Conflict of Interest

The authors declare no conflicts of interest.

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## Вплив хронотипу на силові показники студенток університету в різний час доби: Поперечне дослідження

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Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 2 табл., 7 рис., 38 джерел.

**Історія питання.** Хронотип впливає на фізичну результативність через циркадні ритми, що змінюються протягом дня. Пік сили та потужності часто спостерігається ввечері, що свідчить про вплив часу на результати тренувань. У цій науковій роботі вивчається вплив зазначених факторів на студенток університету — групи, яка недостатньо представлена в хронобіологічних дослідженнях.

**Мета дослідження.** Мета дослідження полягала у вивченні впливу хронотипу на силову працездатність студенток університету в різний час доби. Зокрема, проведено порівняльний аналіз показників максимальної сили, вибухової потужності та м'язової сили кистей між особами ранкового та вечірнього типу з метою визначення оптимального часу для проведення тренувань або продуктивної діяльності на основі хронобіологічних переваг.

**Матеріали та методи.** Для класифікації 56 індійських студенток (середній вік = 22.2 роки; вага =  $56 \pm 4.31$  кг; зріст =  $158 \pm 5$  см;  $IMT = 21 \pm 1.5$  кг/м<sup>2</sup>) було застосовано опитувальник Хорна–Остберга щодо визначення схильності до ранкової або вечірньої активності ("The Horne and Ostberg Morningness–Eveningness Questionnaire"). Оцінка силових працездатності проводилася за допомогою трьох вимірювань: одне повторення з максимальною вагою (ІПМ) для визначення максимальної сили; стрибок із контррухом (КРС) для вибухової потужності; динамометрія кистьового хвату для оцінки м'язової сили. Тестування проводилося в стандартних умовах, в узгоджений час відповідно до хронотипу кожної учасниці (ранок або вечір). З метою аналізу використовувалися t-критерії для незалежних вибірок, а також критерії Шапіро-Вілка та Левене, що підтверджують припущення про нормальність та однорідність.

**Результати.** Відзначено, що особи вечірнього типу продемонстрували значно кращі результати за всіма досліджуваними показниками, ніж особи ранкового типу. Група вечірнього типу досягла значніших показників у присіданні з ІПМ ( $78.3 \pm 2.63$  кг проти  $72.1 \pm 3.11$  кг;  $t(54) = -8.08$ ,  $p < .001$ ,  $d = 2.16$ ), КРС ( $30.1 \pm 2.32$  см проти  $26.1 \pm 2.32$  см;  $t(54) = -6.46$ ,  $p < .001$ ,  $d = 1$ ).

**Висновки.** Результати цього дослідження показують, що студентки вечірнього типу мають підвищену силову працездатність у вечірні години, що підкреслює необхідність враховувати хронотип при плануванні тренувань та оцінюванні результативності спортсменок.

**Ключові слова:** хронотип, ранкова – вечірня активність, максимальна сила, вибухова потужність, м'язова сила кистей.

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