ORIGINAL ARTICLE

Investigation of maximal strength performance in terms of training time routine

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Abstract

Background and Study Aim	In recent years, there has been a growing interest in understanding the relationship between daily training time, circadian rhythms, and athletic performance. The connection between daily training time, circadian rhythms, and athletic performance continues to be a subject of research debate. Therefore, the aim of this research is to investigate whether maximal strength performance is affected by daily training time routines.
Material and Methods	This cross-sectional study involved a total of 36 male bodybuilding athletes, who were divided into three equal groups (n=12); Noon Group, Afternoon Group, and Evening Group. The distinguishing feature amongst the groups was that they had been training at different times of the day for the past 6 months, and within each group, athletes had been training at the same time of day (Noon Group 12:00-14:00; Afternoon Group 17:00-19:00; Evening Group 21:00-23:00). A one-repetition maximum squat test was administered to each group with there being a 72-hour interval between the tests.
Results	The findings from the research indicate that there is a relationship between athletes' daily training time routines and maximal strength performance. Athletes perform at their best during the time that corresponds to their daily training routine. The analysis reveals a statistically significant advantage in 1-RM squat performance for athletes adhering to their daily training time routines at various times of the day (p <0.001). Notably, Group Noon, Group Afternoon, and Group Evening achieved their highest 1-RM squat performance when following their respective daily training time routines.
Conclusions	Results underscore the importance of aligning training schedules with athletes' natural rhythms, enhancing performance optimization strategies. It is believed that effective planning for training time by coaches and conditioning experts, taking into account competition times, would be a valuable strategy.
Keywords:	daily training time, circadian rhythm, athletic performance, maximal strength, workout timing, training routines

Introduction

In the realm of sports sciences, numerous studies have consistently highlighted the multifaceted nature of athletic performance, suggesting that it is intricately influenced by a combination of endogenous (internal) and exogenous (external) mechanisms [1, 2, 3]. Researchers in this field have made concerted efforts to elucidate these phenomena by drawing connections to the body's biological clock or circadian rhythm.

The central biological clock, residing within the suprachiasmatic nucleus (SCN) of the hypothalamus, serves as the cornerstone of these intricate processes [4, 5, 6]. This pivotal biological clock demonstrates remarkable adaptability, responding to environmental cues, particularly the light-dark cycle [4, 7]. Within the domain of biological rhythms, there exist various categories, with the circadian rhythm, which operates on a 24-hour cycle, standing out as the most prominent [4, 5, 6, 8].

While ultradian rhythms, featuring periods of shorter than 20 hours, and infradian rhythms, characterized by cycles exceeding 28 hours, also exist, it is the circadian rhythm that garners the most attention in research endeavors. This preference stems from the alignment of the 24-hour circadian rhythm with the natural life cycles of humans. Furthermore, a multitude of physiological processes, including blood pressure

regulation, body temperature fluctuations, hormonal secretion, and energy metabolism which are all intricately tied to nutrient intake, operate on approximately 24-hour cycles. Consequently, these processes are believed to wield considerable influence over athletic performance outcomes [6]. It is this interplay between circadian rhythms and physiological functions that has directed research focus towards the circadian rhythm as a paramount determinant of athletic performance within the realm of sports sciences.

Most studies in the literature investigating circadian rhythms and their impact on athletic performance, both among professional and amateur athletes, have consistently indicated that the time frame of approximately 16:30-19:00 in the afternoon is associated with peak athletic performance levels [9, 10, 11, 12]. This observed enhancement in athletic performance during this period is often attributed to the synchronization of various physiological, psychological, and metabolic rhythms [13, 8]. Consequently, it is widely acknowledged that, in alignment with circadian rhythms, the most optimal time for engaging in physical exercise falls within the window of approximately 16:30-19:00 [3, 14, 15].

While the temporal dimension of physical performance is of paramount importance, it is imperative to consider additional temporal factors that may influence athletes, such as chronotype – an individual's inherent propensity towards morningness, eveningness, or neither [16, 17, 18]. Ayala et al. [3], in a comprehensive review encompassing eight studies, underscored that the question of how chronotype interacts with the timing of physical activity and its effects on physical performance remains ambiguous and inconclusive within the existing body of research. Moreover, their review emphasized that the majority of chronotype-related studies have primarily focused on the distinction between morning-chronotype and evening-chronotype individuals, with limited exploration of intermediate-chronotype individuals.

Although sparse, there are notable exceptions. For instance, a study on weightlifters reported an improvement in strength performance at around 02:00, with a perceived decrease in effort exerted [19]. Conversely, Ayala et al. [3] have contended that the time of day exerts a more substantial influence on sports performance than athletes' training time routines. However, despite the existing body of research on circadian rhythms and chronotypes, a clear and well-established relationship between daily training time routines and athletic performance, particularly concerning maximal strength performance, remains elusive.

In light of this, it becomes evident that there exists a significant gap in the research literature regarding the intricate interplay between circadian rhythms, chronotypes, and strength performance. Consequently, this topic warrants further comprehensive investigation. Therefore, the principal objective of this study is to elucidate whether maximal strength performance is indeed impacted by the temporal aspects of daily training time routines. The hypothesis of this research is that 'Maximal strength performance in male bodybuilding athletes is influenced by their daily training time routines, with athletes who train during their preferred times of the day (Noon, Afternoon, Evening) demonstrating significantly higher maximal strength compared to those training at non-preferred times'.

Materials and Methods

Participants

The sample size for this research was determined using the G*Power analysis program (version 3.1.9.3, Germany). According to the results of the power analysis (confidence level= 0.95, alpha value= 0.05, beta value= 0.80, and effect size= 0.60) [20], it was determined that a minimum of 12 athletes should be included in each group. A total of 36 male athletes met the inclusion criteria and therefore participated in the study, with three groups designated as Group Noon (n=12), Group Afternoon (n=12) and Group Evening (n=12).

Research Design

This cross-sectional study was conducted following the approval of the Ethics Committee of Inonu University Faculty of Health Sciences (Decision No: 2023/4937) and in accordance with the Helsinki Declaration. Informed consent was obtained from all participants before the research commenced, and they were included in the study after providing their voluntary consent. Participants were divided into three groups based on predefined inclusion criteria. Demographic information, including age, height, and body weight, was collected from all participants. Each group performed the One-Repetition Maximum Squat Test (1-RM) on different days and at different times of the day, with a 72-hour interval between each session. Prior to the 1-RM test, all participants engaged in warm-up activities, including dynamic stretching techniques. The 1-RM performance data was obtained at different time intervals for each group and was recorded and subsequently analyzed. Experimental schematic design is shown in figure 1.

The inclusion criteria are as follows

For all groups, being healthy individuals over the age of 18 and being actively involved in bodybuilding for the last 3 years. In terms of groups, having trained regularly at noon (12:00-14:00) for the last six months for Group Noon, and having trained regularly in the afternoon (17:00-19:00) for the last six months for Group Afternoon, and having trained
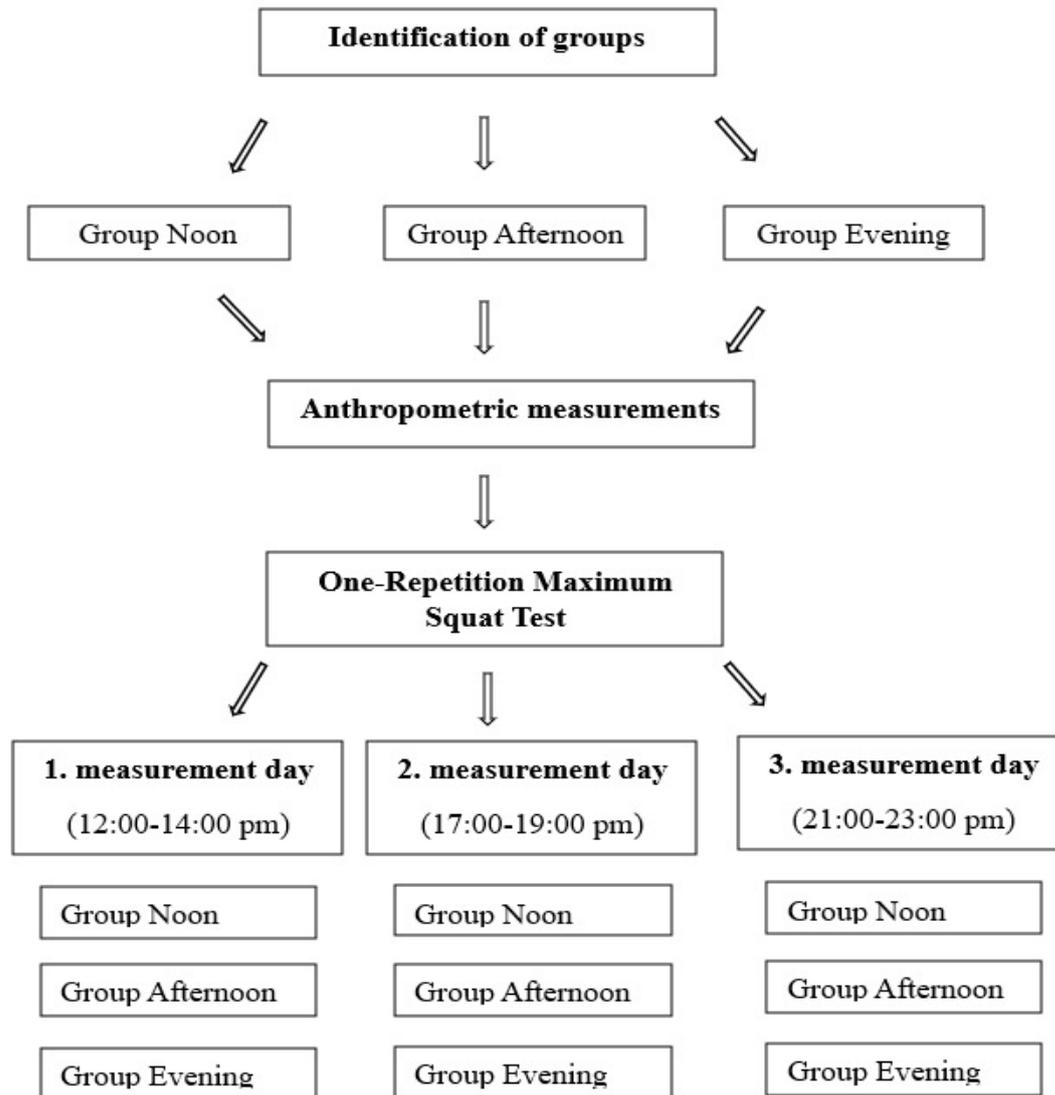
Figure 1. Experimental schematic design

regularly in the evening (21:00-23:00) for the last six months for Group Evening.

Anthropometric measurement

Body mass and height measurements were made in accordance with the ISAK (International Association for the Advancement of Kinanthropometry) protocol [21]. In this context, participants' heights were measured by a wall-mounted stadiometer (Holtain Ltd., England), and their body weights were measured by an electronic scale (Seca, Germany). All measurements were taken between 09:00-09:30 in the morning.

Height measurement: The subject stood upright with his back against a board. The subject's feet were together, and their heels, hips, shoulders, and back of the head were touching the wall. The subject's head was upright and they were looking straight ahead. The stadiometer was gently lowered over the subject's head and recorded in cm after ensuring that it was positioned at the highest point (vertex) [22].

Body Mass Measurement: The subject was in minimal clothing (underwear) and no shoes. The subject stood in the middle of the scale platform and distributed his weight evenly between both feet. The subject hung his hands freely by his sides and looked straight ahead. The subject's body mass was recorded on an electronic digital scale to the nearest 0.1 kg (or 100 grams) [22]. The results of the anthropometric measurements for the participants are presented in Table 1, which displays the mean and standard deviation for each group. Participants were given instructions to refrain from engaging in different types of exercises on the day preceding the measurements, to avoid consuming stimulating beverages such as tea, coffee, alcohol, and carbonated drinks, and to have their last meal at least 2 hours before the measurements were conducted, following the guidelines outlined by Kafkas et al. [23].

Maximal Repetition Squat Test (1-RM)

Prior to the 1-RM test, all participants engaged

in warm-up exercises which included dynamic stretching techniques, as outlined by Kafkas et al. [23]. Participants were given the autonomy to select their initial weights for the 1-RM test according to their personal preference. However, it was strongly recommended that the participants commenced the 1-RM test with approximately 30-40% of their body weight, following the guidelines proposed by Baechle and Earle [24]. This precautionary measure was taken to mitigate against the risk of potential muscle injuries occurring during the test. Participants executed the free squat movement with their chosen weights, and additional weight (ranging from 2.5 to 5 kg) was incrementally added based on the lifted weight and perceived level of difficulty, allowing them to perform the movement again. The process of adding weight continued until participants reached the point at which they could no longer complete a single repetition. The test concluded once participants indicated their inability to lift any more weight. All test results were documented in kilograms, in accordance with the procedures described by Kafkas et al. [23]. Each group conducted the 1-RM test on a separate day and at varying time intervals, with there being a 72-hour gap between each session. The squat test was performed using free weights.

Statistical Analysis

The data obtained from the research was analyzed using the IBM Statistics software (SPSS version 26.0, Armonk, NY). To determine the effect of different times of day on 1-MR squat performance, a "Repeated Measures ANOVA" was conducted, and for identifying which time of the day favored performance, multiple comparison tests such as the "Bonferroni" analysis were applied. Mauchly's Test was used to check the homogeneity of variances, and the Greenhouse-Geisser correction factor was employed for variance correction when necessary. Additionally, "partial eta squared" (ES) was calculated to determine the percentage of the effect size of the time of day on performance.

Results

Table 2 below presents the 1 maximal repetition squat performance values of the participants in terms of different time periods are presented. After analyzing Table 2, it has been determined that there is a statistically significant effect favoring the daily training time routine on the applied 1-RM squat

Table 1. Anthropometric measurement results of the participants on the basis of groups

Groups	n	Parameter	Mean±SD	Range Min. Max.
Group noon	12	Age	25.16±2.91	21.00-29.00
		Height (cm)	178.50±5.72	167.00-185.00
		Body mass (kg)	75.50±6.94	60.00-85.00
Group afternoon	12	Age	25.50±2.67	20.00-29.00
		Height (cm)	180.00±7.54	167.00-190.00
		Body mass (kg)	81.00±6.68	70.00-90.00
Group evening	12	Age	26.00±1.80	22.00-29.00
		Height (cm)	173.00±4.80	165.00-180.00
		Body mass (kg)	76.50±5.16	70.00-85.00

Table 2. 1 Maximal Repetition Values of Participants in Different Time Periods

Group	Time	Mean ± SD	F	p	Bonferroni	ES
Group noon	12:00-14:00 (1)	120.41±15.58	77.000	.001*	1>2 1>3	%87
	17:00-19:00 (2)	115.83±15.78				
	21:00-23:00 (3)	115.00±14.11				
Group afternoon	12:00-14:00 (1)	122.29±17.62	35.265	.001*	2>1 2>3	%76
	17:00-19:00 (2)	130.20±16.73				
	21:00-23:00 (3)	123.12±17.90				
Group evening	12:00-14:00 (1)	125.62±10.66	26.455	.001*	3>1 3>2	%70
	17:00-19:00 (2)	127.50±11.77				
	21:00-23:00 (3)	132.50±10.97				

Note:*=p<0.001

performance at different time periods of the day (p <0.001). In this context, it is observed that Group Noon, which featured those who have been training between 12:00-14:00 for the past six months, achieved their highest 1-RM squat performance when they followed their daily training time routine, which is between 12:00-14:00. Similarly, Group Afternoon, those who have been training between 17:00-19:00 for the past six months, achieved their highest 1-RM squat performance when they adhered to their daily training time routine, which is between 17:00-19:00. Finally, Group Evening, those who have been training between 21:00-23:00 for the past six months, achieved their highest 1-RM squat performance when they maintained their daily training time routine, which is between 21:00-23:00.

Discussion

In this study, which aimed to investigate whether the maximal strength performance of bodybuilders was influenced by their daily training time routines, a relationship between maximal strength performance and daily training time routines has been established. Based on the data obtained in the study, it has been statistically determined that the highest 1-RM squat performance in all groups occurred during their respective daily training time routines (p < 0.001). It is believed that the reason for the participants achieving their highest 1-RM squat performance during their daily training time routines is associated with their chronotype.

The Morningness-Eveningness Questionnaire (MEQ) scale is commonly employed to assess the chronotypes of individuals [16]. Although the MEQ scale was not utilized in this study, it is noteworthy that the participants had been consistently training at the specified times over the past six months. This can be viewed as an indication that the groups may have distinct chronotypes.

In several studies utilizing the MEQ to determine chronotypes, findings have indicated that individuals with an M-chronotype perceive less effort during strenuous physical activities conducted in the morning, whereas those with E-chronotype and N-chronotype tend to perceive greater effort and experience higher levels of fatigue during morning-intensive sports activities [25, 26, 27]. Additionally, it has been reported that individuals with an E-chronotype produce more torque in the afternoon or evening in comparison to the morning [28]. Vitale and Weydahl [4], in a comprehensive review, noted that individuals with an M-chronotype exhibited higher performance levels in activities such as half marathons and full marathons [29], 2000-m

rowing sprints [30], and 200-m swimming trials [27] when compared to individuals with "N" and "E" chronotypes. However, they also emphasized that this trend was not consistently observed during self-paced physical tasks [26] and maximal ergometer tests [31, 32].

While differences in psychophysiological responses to physical activity may be attributed in part to the distinction between objective and subjective variables [4], the mechanisms underlying chronotype remain incompletely elucidated. Nevertheless, it is evident that an individual's daily habitual training time can have an influence on physical performance [27, 29]. The findings from our study similarly support the notion that daily habitual training time can impact physical performance.

Considering the observed variation in the perceived difficulty of exercise amongst individuals with different chronotypes, the capacity to augment training intensity during their preferred time of day may serve as an indicator for enhancing training adaptation specific to that time window [7]. Furthermore, in a study conducted by Brown et al. [30], it was reported that nearly half of the rowing athletes experienced a deviation from their initial chronotypes after three training sessions, which was attributed to the early morning training regimen.

The limitations of this study include the exclusive focus on male bodybuilding athletes, with the absence of female participants. Additionally, the use of self-selected weights by participants, the lack of a standardized test protocol, and the restriction to a specific age range of participants are noteworthy constraints to consider.

Conclusions

As a result of this study, a significant relationship has been established between athletes' daily training time routines and maximal strength performance. Athletes demonstrated their peak performance during their respective daily training time routines. These findings highlight the substantial influence of training session timing on athlete performance, emphasizing the importance for coaches and conditioning experts to plan training schedules in alignment with competition times. Future studies should consider expanding participant group sizes, to include female athletes, and to assess the chronotypes of participant groups. Furthermore, it is advisable for future research in this field to encompass diverse sports disciplines and to customize investigations to target various athletic performance parameters.

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