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Do rhythms exist in elbow flexor torque, oral temperature and muscle thickness during normal waking hours?

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HIGHLIGHTS

- Circadian rhythms of strength are less apparent during normal waking hours.
- Circadian rhythms may be less pronounced when not disturbing sleep.
- Muscle thickness does not appreciably change throughout the day.

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ABSTRACT

The purpose of the current study was to examine the influence of "time" on isometric elbow flexion torque, body temperature and muscle size without interrupting the sleep wake cycle in college aged males. Two hours following the participants normal wake time, oral temperature was measured, followed by muscle thickness of the upper and lower body using ultrasound, as well as elbow flexor torque via a maximal voluntary contraction (MVC). Measurements were repeated every 2 h for 12 h (Time points 1–7). To examine the repeatability of the rhythm, participants returned and completed the same procedures as before within 14 days of their first circadian visit (Circadian visit 2). There was no time × day interaction for body temperature ($p = 0.29$), nor were there main effects for time ($p = 0.15$) or day ($p = 0.74$). For MVC, there was no time × day interaction ($p = 0.93$) or main effect for day ($p = 0.50$), however, there was a main effect for time ($p = 0.01$). MVC at time points 1 (86.4 ± 6.4 Nm) and 2 (87.1 ± 6.2 Nm) was greater than time points 4 (84.2 ± 6.6 Nm) and 6 (83.4 ± 6.8 Nm, $p < 0.05$). Additionally, time point 5 MVC was greater than time point 4. For upper body muscle thickness, there was no time × day interaction ($p = 0.34$), nor was there a main effect for day ($p = 0.38$), or time ($p = 0.06$). For lower body muscle thickness, there was no time × day interaction ($p = 0.57$), nor was there a main effect for day ($p = 0.75$), or time ($p = 0.13$). Cosinor analyses revealed no group level rhythms for oral temperature, muscle thickness or strength ($p > 0.05$), however, there were some individual rhythms noted for muscle thickness and strength. Results suggest that, when accounting for an individuals normal wake time, circadian rhythms of strength, temperature and muscle thickness are not apparent in most individuals.

1. Introduction

The manifestation of time is inherent in human physiology, typically referred to as "circadian rhythms' or oscillations in physiological variables. These oscillations are measurable in many cases and have been documented in different physiological systems. For example, oscillations in body temperature [11,19], endocrine function [20], heart rate and blood pressure [10] have all been previously observed. Less is known regarding times influence on muscle function, but it has been suggested that strength increases throughout the day, reaching peak levels in the evening. Wyse et al. [22] showed that isokinetic leg extension and flexion peak torque were greater in the evening (18:00–19:30) hours compared to the morning and afternoon hours in male collegiate athletes. Similarly, Guette et al. [13] examined isometric knee extensor strength, finding that the highest values occurred around 18:00 h in college aged males. Notably, within the literature a number of protocols are employed with variations of 3 to 7 time points [2,22] used for circadian analysis. Additionally, a number of different tests were employed which made it difficult to compare studies. For example, some studies have looked at Wingate cycle ergometer test outcomes [8,17], while others have measured maximal muscle contractions

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with [2,13] and without [12] electrical stimulation. Most notably, previous studies have disrupted the sleep wake cycle in order to obtain early morning measurements. This may be problematic as disrupting the rhythms of the sleep wake cycle may subsequently influence other rhythms.

Based on the current literature, strength related activities might be recommended in the evening when strength appears to reach its zenith. However, the discrepancies between the different methodological approaches make it difficult to reach this conclusion. Mechanistically, there is some suggestion that temperature may be related to performance outcomes [16], however, it is largely unknown why strength would fluctuate throughout the day. In addition, the cell nucleus in mice has been shown to fluctuate in volume throughout the day [4]. If large enough, these fluctuations may manifest with changes in muscle size. Thus, muscle function and architecture may both be subject to times influence. Therefore, the purpose of the current study was to examine the influence of "time" on isometric elbow flexion torque without interrupting the sleep wake cycle. We also examined rhythms in body temperature, which may influence performance, as well as skeletal muscle size (muscle thickness), which may reflect changes in cell volume throughout the day. Unlike previous studies we measured circadian rhythms of muscle size, strength and oral temperature during normal waking hours, on 2 separate occasions, matching diet and wake time on both testing days. We also familiarized participants with strength testing in the morning, afternoon and evening, to further account for the influence of time. We hypothesized that there would be a circadian rhythm in strength and oral temperature, with peak values occurring in the evening (18:00 h). In addition, we hypothesized that any changes in muscle size would be negligible, resulting in no presence of a circadian rhythm.

2. Methods

2.1. Participants

Eight resistance trained (regularly performing upper body resistance training for at least 6 months) males volunteered for the present study. This sample size is comparable to previous studies investigating circadian rhythms in strength [2,7,22]. Trained participants were used in order to decrease the possibility of a training effect due to repeated testing. Females were excluded given that the variables tested, particularly body temperature, change throughout the menstrual cycle [6]. One individual did not complete all of the testing sessions; therefore, their data was excluded from all further analyses. Thus, 7 individuals are included in the present analysis. Participants were instructed to refrain from exercise 24-h before all visits. All participants were free of injury and had no risk factors that could prevent them from testing. The study received approval from the University's Institutional Review Board and each participant gave written informed consent prior to participation.

2.2. Study design

All participants visited the laboratory on four occasions, separated by 7–10 days. Upon arriving for the first visit, participants filled out an informed consent document and a brief health history questionnaire. After confirming that they did not meet any exclusion criteria, each participant's height and body mass measured using a scale/wall-mounted stadiometer to the nearest cm and a digital scale to the nearest 0.1 kg. Participants were instructed on how to track their diet on the experimental testing days and given a week-long sleep log to determine their normal wake time (averaged over 1 week). At least a week prior to their first experimental testing day, participants were familiarized with strength testing in the morning, afternoon and evening. During the first circadian testing day participants arrived approximately an hour and a half following their normal waking time. The first measurements were taken at 2 h post waking. Measurements were taken every 2 h for 12 h (7 time points per circadian visit) and included the following in order: oral temperature, muscle thickness and isometric elbow flexor strength. Participants were asked to monitor all food and drink consumption throughout the day for replication on circadian visit 2. Food and drink consumption was not allowed 30 min prior to each measurement time point in order to minimize any effect that might have on the oral temperature measurement. In addition, participants remained seated in a quiet room between testing sessions and refrained from any physical activity outside of light walking. Circadian visit 2 was identical to circadian visit 1, separated by at least 1 week on the same day of the week. Diet was recorded using 2D food models to assist with portion size accuracy and repeated exactly during the second circadian visit. A trained research dietitian (T.M.H) analyzed the nutritional content of the food records using the USDA National Nutrient Database or specific food product nutrition facts panels for items not available in the USDA database [18]. This was done in an effort to make sure that on circadian visit 2 the participants consumed the same food and drink at the same time they did during circadian visit 1.

2.3. Oral temperature

Following 15 min of quiet seated rest oral temperature was taken using a thermometer (ReliOn 2 Digital Thermometer). Participants were instructed on the manufactures directions as follows:

> "Place the tip of the thermometer well under the tongue in the heat pocket (this is the area beneath the tongue, along the gums and next to the rear-most molar) to get a good, accurate reading. Keep mouth closed and sit still to help ensure an accurate measurement."

2.4. Muscle thickness

B-mode ultrasound (Aloka, SSD-500 with 5 MHz probe) was used to provide a one dimensional measurement of the anterior upper arm and the anterior upper leg on the participant's non-dominant side. The non-dominant arm was chosen to avoid potential work-induced swelling from the performance of the isometric strength test. Muscle thickness was measured using electronic calipers as the distance between the muscle-fat interface and the underlying bone. Two measures were taken during each testing session for both the upper and lower body. Muscle thickness measurements were taken at 70% the distance from the acromion process to the lateral epicondyle, measured with a standard tape measure and thigh muscle thickness was taken half the distance between the greater trochanter and the lateral condyle of the femur. All participants were asked to remain normally hydrated for all testing visits. The minimal difference (i.e. reliability) needed to be considered real for the anterior portion of the upper arm was calculated at 0.2 cm and the anterior upper leg was 0.16 cm [21].

2.5. Isometric maximal voluntary contraction

While seated on a dynamometer (Biodex System 4 Medical Systems, Shirley, New York, USA) participants performed two maximal 3 s isometric contractions (MVC) on their dominant arm at 60° elbow flexion, separated by 60 s rest. Two MVCs were performed at each of the 7 time points on circadian visits 1 and 2. Signals were gravity corrected for lever arm and body limb mass, and the seat back and lever-arm length were adjusted for each individual to make sure the elbow joint was in-line with the center of rotation. The highest value of the two MVCs was recorded as maximal peak torque. The minimal difference (i.e. reliability) needed to be considered real was calculated as 3 Nm for a single given time point [21].