Time of day effect on isokinetic peak torque during knee flexion and extension

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BACKGROUND: The effects of circadian rhythms on exercise have been well documented using tests such as the Wingate, jumping, sprinting, and weight lifting, but little research has been conducted during isokinetic exercise.

OBJECTIVE: The purpose of this study was to examine how isokinetic peak torque of the knee extensors changes throughout the day.

METHODS: Twenty-five apparently healthy, college-aged recreational athletes with no history of injury to the right knee or diagnosed sleeping problems completed 1 familiarization and 3 experimental sessions, with start times of 08:00-09:00, 13:00-14:00, and 18:00-19:00. Subjects performed 3 sets of 4 maximal concentric discrete knee extensions at 60, 180, and 300°/s, with 1 minute of passive rest between each velocity set. Peak torque was recorded for each velocity. Data were analyzed using a two-way 3 (time) x 3 (velocity) repeated measures ANOVA (α ≤ 0.05).

RESULTS: There was no significant difference in peak torque by time of day at any of the 3 velocities (F = 0.258, p = 0.773).

CONCLUSIONS: Time of day may not be a necessary factor to control when creating rehabilitation or training protocols for college-aged subjects undergoing isokinetic exercise involving knee extension.
Keywords: isokinetic, peak torque, knee extension, time of day
1. Introduction

Circadian rhythms, or the body’s “biological clocks,” have been studied extensively in the scientific community. It is well known that numerous processes in the body follow consistent day-night patterns mediated by the suprachiasmatic nucleus within the brain, including body temperature, cardiorespiratory and ventilatory functions, metabolic factors, gastrointestinal processes, hormonal secretions, and mood and alertness [1-2]. In more recent years, after observing that record-breaking sport performances often happened in a predictable evening time frame, scientists began to examine how circadian rhythms affected exercise performance variables, including reaction time, accuracy, fine motor skills, psychomotor skills, flexibility, physiological responses, and muscle strength [2-3]. The effects of circadian rhythm on aerobic variables such as exercising heart rate, blood pressure, oxygen consumption, minute ventilation, cardiac output, and respiratory exchange ratio have been examined with cycling time trials and maximal and submaximal graded cycle ergometer tests [2, 4-6]. Anaerobic testing methods such as the Wingate, force-velocity tests on a cycle ergometer, weight lifting, jumping, sprinting, and swimming have also been utilized to study circadian rhythms of peak, mean, and average power output, isometric force, anaerobic endurance, and dynamic force [7-17]. Despite all of the anaerobic testing and established diurnal variations in movements such as grip strength [10], few studies have been completed examining circadian rhythms in isokinetic performance variables [1,18-25].

Isokinetic training and testing has benefits in athletics, fitness, and rehabilitation, and has been utilized by coaches, trainers, and physical therapists alike. Because the velocity of limb movement is constant on the isokinetic dynamometer, maximum force can be applied throughout the entire range of motion, unlike in typical resistance training. This allows for ideal strength
gain benefits and greater specificity during scientific testing with respect to velocity and what strength measures are examined [26]. Among the studies that have used isokinetic testing to examine circadian rhythms, conclusions, controls, tested muscles, and measured variables have differed. For example, Wyse et al. [25] examined peak torque for knee flexion and extension at 3 times of day, utilizing 2 velocities. This study concluded that for both velocities, peak torque was significantly greater in the evening than in the morning and afternoon. Guette et al. [21] also used isokinetic testing to examine isometric force production of the quadriceps femoris, but tested at 5 different times of day. They also found that torque produced by the quadriceps femoris in both dominant and non-dominant legs was significantly higher at approximately 18:00, compared to morning and afternoon times. In a study by Nicolas et al. [22], instantaneous torque of the knee extensor muscles at 3 different velocities was examined at 6:00 and 18:00. They also found that torque was significantly greater in the evening, but used different controls for sleep, food, and lab temperature than the previous two studies. Deschenes et al. [18] examined isokinetic peak torque, average power, maximal work, and total work during isokinetic exercise, but found that these variables only varied significantly with time of day at a faster velocity, contrary to the conclusions of the other described studies. Sinclair et al. [24] examined differences in peak torque during isokinetic knee flexion and extension at 3 times of day (09:00, 14:00, and 18:00) and using only 1 velocity, and found that torque was not significantly different among the 3 testing times. However, this study failed to account for sleep patterns, fitness level, chronotype (“morningness/ eveningness”), and diet.

Araujo et al. [1] sought to consolidate all the discrepancies in controls and methodologies in studies examining the effects circadian rhythm on isokinetic peak torque. Subjects were tested at 6 set times of day, starting at 06:00 and at every following 4-hour interval, and had strict
limitations on diet, caffeine and alcohol intake, sleep, and exercise. Both knee extensors and flexors were examined for peak torque, maximal work, and average power, but at only 2 different velocities. This was the first study to find a significant effect of circadian rhythm on muscle strength under a strictly standardized environment. The goal of the study was to establish the presence and exact patterns of circadian rhythms of the given strength indices in a highly controlled protocol, as opposed to other studies that aimed to find the general time frame where a regular person with an average sleep schedule and food or substance intake would benefit most from exercise.

The purpose of this study was to examine how isokinetic peak torque of the knee extensors changes throughout the day, while enhancing controls that were absent in previous studies such as Sinclair et al. [24] and increasing the number of examined velocities in order to expand upon the work by Araujo et al. [1]. The measurement of peak torque was used because it is known to be the most precise and reproducible measure of isokinetic movement and is particularly appropriate for isokinetic testing [1].

2. Methods

2.1 Subjects

Twenty-five subjects (14 female, 11 male) were recruited from the University of Puget Sound. Demographic information was as follows (mean ± SD): age: 20.68 ± 0.85 yrs, height: 172.44 ± 5.50 cm, and weight: 69.93 ± 9.22 kg. All subjects were recreational athletes, defined as never having participated or having concluded participation in NCAA athletics. All subjects met the following criteria: apparently healthy, college-aged, with no diagnosed sleeping problems or history of injury to the right knee. In order to account for chronotype, subjects took
the Horne-Östberg Questionnaire for morningness-eveningness. Subjects were not of an extreme chronotype, but instead were classified as “intermediate,” “moderate morning,” or “moderate evening” type. This ensured that there were no major shifts in sleep-wake cycles between subjects that could potentially affect circadian rhythm patterns of isokinetic strength variables. The Institutional Review Board of the University of Puget Sound approved the study and each subject signed an informed consent.

2.2 Equipment

A Cybex NORM Testing and Rehabilitation System (Lumex, Ronkonkoma, NY) with HUMAC/NORM software (version 12.1.28) by CMSI Solutions was used for warm-up, testing, and recording of peak torque. Gravity correction was included in all data collection. All testing was conducted in the Biomechanics Lab at the University of Puget Sound by a single investigator.

2.3 Warm-up

At the beginning of all sessions, subjects began with a 5-minute warm-up on a standard cycle ergometer (Monark, Sweden) with 0.25 kilopound resistance at a pace of approximately 60 revolutions per minute (using a stopwatch to maintain cadence). They completed an additional warm-up on the isokinetic dynamometer, consisting of 3 sets of 4 submaximal concentric discrete knee extensions at 60, 180, and 300°/s, with 1 minute of passive rest between each velocity set. Flexion was set at a constant speed of 300°/s.

2.4 Familiarization Protocol

The familiarization session took place at least 12 hours prior to the first experimental session. This session helped acquaint subjects with the testing procedures and reduced learning effects that could have affected experimental data collection. Upon arrival at the lab, subjects
read and signed the consent form and took the Horne-Östberg Questionnaire. Chronotype, age, gender, height, and weight were recorded. The Cybex NORM isokinetic dynamometer was adjusted to each subject according to the manufacturer’s standards for a 90° range of motion for right knee extension and flexion. The settings were recorded in the HUMAC/NORM Software for future test sessions. After completing the warm-up as previously described, subjects performed 4 maximal concentric discrete knee extensions at 60, 180, and 300°/s, with 1 minute of passive rest between each velocity set and flexion set to a constant speed of 300°/s. Peak torque (Nm) was recorded for each velocity. Verbal encouragement from the investigator and visual feedback were provided.

2.5 Experimental Protocol

Each subject completed 3 testing sessions with start times of 08:00-09:00, 13:00-14:00, and 18:00-19:00. Order of sessions was randomized and a maximum of 1 test was completed in a single day, resulting in a minimum of 12 hours between sessions. Number of days between sessions was not specified, and ranged from 1 to 18 days, but the familiarization and experimental sessions were all completed within at least 3 weeks. Subjects were asked to refrain from any alcohol consumption 12 hours prior to testing time, avoid heavy or strenuous exercise 24 hours prior, and to stop eating food 1 hour prior to the session in order to prevent postprandial thermogenesis. Subjects were requested to drink a typical amount of caffeine on test days (according to their usual consumption) and to stop drinking caffeine 1 hour prior to the session start time to avoid stimulation effects that may affect alertness. Subjects were also requested to get at least 6 hours of sleep the night prior to testing, in addition to waking up at least 1 hour prior to the session start time to avoid effects of sleep inertia. In general, caffeine and sleep were controlled in order to prevent any alterations of the sleep-wake cycle. The subjects were asked
about their compliance to all of the previously mentioned controls at the beginning of each testing session.

The experimental protocol was identical to the familiarization protocol, except for collection of demographic information. Subjects began with the cycle ergometer and isokinetic warm-ups, then ended with 4 maximal concentric discrete knee extensions at 60, 180, and 300˚/s.

2.6 Data Analysis

With IBM SPSS Statistics 23 software, data were analyzed using a two-way 3 (time) x 3 (velocity) repeated measures ANOVA (α ≤ 0.05). Peak torque was compared between the 3 times of day—morning (08:00-09:00), afternoon (13:00-14:00), and evening (18:00-19:00)—for each velocity.

3. Results

There was no significant interaction between peak torque in all 3 velocities and order of testing. There was no significant (p < 0.05) difference in peak torque by time of day among any of the velocities (F = 0.258, p = 0.773) (Fig. 1). Additionally, as expected, there was a significant difference in peak torque between the 3 velocities (p < 0.001), with the greatest mean peak torque occurring at the slowest velocity.

4. Discussion

This study examined the effect of time of day on isokinetic peak torque during knee extension, and found that in recreationally active college students, there was no significant difference in peak torque at different times of day for any of the 3 tested velocities. However,
findings in this study conflict with several previously completed studies analyzing circadian rhythm of isokinetic exercise (see Table 1 for summary of details of mentioned studies).

Araujo et al. [1] examined isokinetic peak torque, maximal work, and average power during isokinetic knee extension and flexion at 60 and 240°/s. Subjects completed 6 testing sessions at 02:00, 06:00, 10:00, 14:00, 18:00 and 22:00, with only 1 test executed per week. The authors used 8 moderately active male subjects in their late 20s. Subjects did not have any sleep disorders or history of major knee injury. The study was strictly controlled, and all isokinetic strength variables except average extensor power showed statistically significant differences throughout time of day at both testing velocities. Notably, Araujo et al. [1] found a significant 24-hour rhythm for peak torque of knee extensors, whereas this current study did not, despite similar controls and testing velocities. The analysis by Araujo et al. [1] showed that the highest levels of peak torque generally occurred between 14:00 and 18:00 and were significantly greater than the lowest values, which occurred around 06:00. The peaks and troughs of a circadian rhythm are connected by gradually increasing (trough to peak) or decreasing (peak to trough) values of the measured variable [1]. Considering that in the current study the morning session took place at least 2 hours after the proposed time of lowest peak torque (06:00) in the study by Araujo et al. [1], it is possible that values had increased enough to significantly lessen the difference between morning and afternoon or evening results, preventing detection of a circadian rhythm. An earlier morning session and a subsequent larger range of time covered by the 3 testing sessions within a single 24-hour period could result in significant difference in knee extensor peak torque.

Wyse et al. [25] used 9 male collegiate athletes to study isokinetic strength. Subjects underwent 3 separate testing sessions within a single day, at times very similar to those used in
the current study: 08:00-09:00, 13:00-14:00, and 18:00-19:30. Three testing days, each separated
by at least a week, were completed for each subject. Knee extension peak torque was examined
at 60 and 180˚/s. Like Araujo et al. [1], Wyse et al. [25] found that extension peak torque, in
addition to other strength variables, was highest in the evening session, once again contrary to
the findings of the current study. However, it is important to note that unlike the strict controls
maintained by Araujo et al. [1], Wyse et al. [25] did not mention any controls on diet, sleep, or
to caffeine and alcohol intake and did not take into account sleep disorders or chronotype in
subject inclusion criteria.

Deschenes et al. [18] examined 10 healthy, untrained, college-aged men and maintained
thorough controls on sleep, diet, exercise, and caffeine and alcohol use, similar to Araujo et al.
[1] and the current study. Subjects completed medical backgrounds, although potential causes for
exclusion from the study, including injury, extreme chronotype, or sleeping disorders, were not
mentioned. Subjects performed maximal concentric isokinetic knee extensions and flexions at
60, 90, 120, and 180°/s. Testing times of 08:00, 12:00, 16:00, and 20:00 were utilized, with at
least 96 hours separating each testing session. Among many tested variables, peak torque for
knee extension was found to be significantly greater in the evening (20:00) than in the morning
or afternoon, but only at a velocity of 180°/s. These findings partially agree with the current
study, as 3 velocities showed no significant change in peak torque of knee extension throughout
the day. However, the results also disagree with the current study, as 1 velocity was found to
elicit significantly different peak torques throughout the day. Once again, it is possible that the
choice of testing times in the current study did not allow for significant differences to be found.
The latest testing time in the current study was 19:00, whereas it was an hour later in the study.
by Deschenes et al. [18] (and this was the time at which significantly higher extension peak torque was observed).

In contrast, Sinclair et al. [24] found results that agree with the current study. Twenty-four college-aged subjects (12 male and 12 female) were tested at 09:00, 14:00, and 18:00. Isokinetic peak torque of both knee flexors and extensors was recorded at a single velocity of 60°/s. Although peak torque of knee flexors was found to be significantly greater in the evening compared with morning and afternoon sessions, there was no significant difference in peak torque of knee extensors at any of the 3 times of day, consistent with the current study. Sinclair et al. [24] controlled for caffeine intake, alcohol consumption, and exercise within the 24 hours prior to data collection, but failed to control for sleep patterns, fitness level, diet, and chronotype. One major similarity between Sinclair et al. [24] and the current study is the gender composition of the subject population. Specifically, these were the only studies that used both females and males, whereas the studies by Araujo et al. [1], Wyse et al. [25], and Deschenes et al. [18] used only male subjects. It is possible that the inclusion or exclusion of females from the subject population could have altered the results. To examine the possible effects of gender in the current study, additional statistical analyses were completed for male and female subjects. There was still no significant difference in isokinetic peak torque by time of day when separating the subject pool, but this does not eliminate the possibility of a gender effect in the other studies. In addition, Sinclair et al. [24] and the current study used 24-25 subjects, while the male-only studies used a much smaller number of only 8-10, which could have affected the results. Even when splitting the larger subject population of the current study into male and female groups of 11 and 14 subjects, respectively, the groups are still larger than those in the male-only studies.
The current study sought to improve the absence of controls in previously published work [24], while using a very similar protocol. Even with enhanced controls, the findings from the current study agree with those of Sinclair et al. [24]. The studies by Araujo et al. [1] and Deschenes et al. [18] had excellent controls, but found largely conflicting results when compared with Sinclair et al. [24] and the current study. It may also be noted that although the current study did not find any significant differences in peak torque throughout the day, Figure 1 shows a slight trend toward greater peak torques in the afternoon and evening compared to the morning, which is in agreement with results from Araujo et al. [1], Wyse et al. [25], and Deschenes et al. [18]. In order to consolidate much of the current research on circadian rhythm of isokinetic strength variables and to discover why such differences occur, future studies must be particularly mindful of the gender and fitness level of the subject population, continue to use strict controls on chronotype, exercise, diet, sleep, caffeine and alcohol use, and expand upon the number of velocities and times examined. Although not discussed extensively, it is also pertinent to assess the amount of time allowed between testing sessions and the total number of days or weeks in which the data collection is completed. This could contribute to potential fatiguing of the involved muscles or to changes in overall health and fitness throughout the course of the experiment, which may affect final results (see Table 1 for comparisons between studies).

Other studies that examined the effects of circadian rhythm on isokinetic variables either studied different muscle groups [20] or focused on isometric force production, which employs different physiological mechanisms of muscle contraction than concentric isokinetic force production, and, therefore, cannot be easily compared to the current study. However, it should be noted that previous studies examining isometric force of knee extension [21, 23] found that peak
torque was highest in the late afternoon or early evening, and declined in the morning, as reported by Araujo et al. [1].

For patients or athletes who are aiming to maximize the results of isokinetic strength training, the current study suggests that between the time frames of 08:00-09:00, 13:00-14:00, and 18:00-19:00, strength gains will not be significantly different. Findings from this study cannot be expanded to more general times (i.e., by stating that peak torque does not vary at any time within a 24-hour cycle), and are limited to these specific time periods. In addition, these results are based on healthy, college-aged subjects. Future studies should be expanded to examine different populations, and early morning and late night testing times, which may be applicable to patients or athletes who have to train early in the day or late at night before or after daily commitments. Additional research in this field should also continue to maintain strict controls so as to eliminate any confounding factors.

5. Conclusions

In conclusion, the data show that time of day may not be a necessary factor to control when creating rehabilitation or training protocols for college-aged subjects undergoing isokinetic exercise involving knee extension.

6. Acknowledgements

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7. References


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<th>Study</th>
<th>Subjects</th>
<th>Controls</th>
<th>Velocity (˚/s)</th>
<th>Times</th>
<th>Feedback</th>
<th>Significant* difference in peak torque?</th>
<th>Time of highest peak torque</th>
<th>Time between testing sessions (not including familiarization sessions)</th>
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<tbody>
<tr>
<td>Bowdle &amp; Warren (current study)</td>
<td>14 M, 11 F, Recreational athletes 20.68 ± 0.85 yrs No history of knee injury No sleep disorders Moderate chronotype</td>
<td>Sleep, Caffeine, Alcohol, Food, Exercise</td>
<td>60, 180, 300</td>
<td>08:00-09:00, 13:00-14:00, 18:00-19:00</td>
<td>Verbal, Visual</td>
<td>No</td>
<td>N/A</td>
<td>12 h minimum, 18 d maximum between sessions All tests completed within 3 weeks</td>
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<tr>
<td>Araujo et al. [1]</td>
<td>8 M, Moderately active, 27 ± 3.2 yrs No history of knee injury No sleep disorders Moderate chronotype</td>
<td>Sleep, Caffeine, Alcohol, Food, Exercise</td>
<td>60, 240</td>
<td>02:00, 06:00, 10:00, 14:00, 18:00, 22:00</td>
<td>Verbal, Visual</td>
<td>Yes</td>
<td>60˚/s: 14:00-18:00, 240˚/s: 18:00</td>
<td>7 d between sessions All tests completed within 7 weeks</td>
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<tr>
<td>Deschenes et al. [18]</td>
<td>10 M, Active, but no lower body resistance training for 6 months prior 21.1 ± 0.6 yrs Medical history form completed</td>
<td>Sleep, Caffeine, Alcohol, Food, Exercise</td>
<td>60, 90, 120, 180</td>
<td>08:00, 12:00, 16:00, 20:00</td>
<td>Verbal, Yes, for 180˚/s</td>
<td>20:00, for 180˚/s</td>
<td>96 h minimum between sessions All tests completed within 4 weeks</td>
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<td>Sinclair et al. [24]</td>
<td>12 M, 12 F, 22.5 ± 1.9 yrs No history of knee injury</td>
<td>Caffeine, Alcohol, Exercise</td>
<td>60</td>
<td>09:00, 14:00, 18:00</td>
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<td>N/A</td>
<td>7 d minimum between sessions</td>
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<tr>
<td>Wyse et al. [25]</td>
<td>9 M, Collegiate athletes 19.6 ± 0.5 yrs No history of knee injury</td>
<td>None mentioned</td>
<td>60, 180</td>
<td>08:00-09:00, 13:00-14:00, 18:00-19:30</td>
<td>None mentioned, Yes</td>
<td>18:00-19:30</td>
<td>All 3 sessions completed in 1 day, repeated 3 times with 7 d minimum between testing days</td>
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*p < 0.05
Table 1. Comparison of studies examining time of day effect on isokinetic peak torque during knee extension (studies may have also analyzed other variables, but only isokinetic peak torque during knee extension is considered in this table).

Fig. 1. Isokinetic peak torque during knee extension for tests taking place in the morning (08:00-09:00), afternoon (13:00-14:00), and evening (18:00-19:00). Mean ± SD are shown for each velocity/time combination (n=25).