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Diurnal variation in anaerobic performance: Effect of core body temperature

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Abstract

The purpose of this study was to investigate the effects of circadian rhythm on anaerobic performance and body temperature determined through three different methods. Ten elite male taekwondo athletes (average age: 23.9±2.7 years, height: 178.7±4.9 cm, body mass: 72.1±7.8 kg, training experience: 12.5±4.9 years) participated in the study. The body temperatures of the participants were measured in the morning of the first day, (between 09:00-10:00 a.m.), and in the early evening (between 16:00-17:00 p.m.) through three different methods (Core body temperature, tympanic temperature, and skin surface temperature). The participants performed Wingate test (WT) both in the morning and in the early evening. Core body temperature was significantly higher in early evening than it was in the morning ($p<0.05$), while tympanic and skin surface temperatures remained unchanged ($p>0.05$). However, there was no significant difference between morning and early evening for peak power, mean power, and fatigue index values ($p>0.05$). As a result, a significant increase was observed in core body temperature in early evening compared to morning, but this increase did not show a positive effect on anaerobic performance.

Keywords: Anaerobic Power, Circadian Rhythm, Wingate Test

INTRODUCTION

It is known that numerous biological and physiological variables are circadian (24 h) rhythm, and that the changes in this rhythm are influential on performance (22). It has been well documented that maximal short-term performances fluctuate in different periods of a day (7, 18, 21, 24, 25, 27, 28, 30). These daily variations have been found to be ranging from 3 to 21,2 %, depending on the population tested, the muscle groups, and the experimental design (16). Although the underlying mechanisms are not clear, some researchers suggest that daily variations in anaerobic power may depend on changes in body temperature (3, 15). Some studies have suggested that simultaneous increases in central body temperature and muscular power are causally related because the diurnal increase in central temperature may have a beneficial passive warm-up effect (3, 18). This passive warm-up may enhance metabolic reactions, increase the extensibility of connective tissue, reduce muscle viscosity, and increase conduction velocity of action potentials (25). In previous studies, it was demonstrated that the Peak and Mean Power values obtained from the Wingate test conducted in different periods of a day are higher in the afternoon compared to those obtained in the morning (4, 11, 13, 15, 18, 27). However, in studies conducted on the relation between the body temperature and anaerobic performance, it was reported that the body temperature values increased in the afternoon reaching the peak levels at 18:00 p.m., and the anaerobic power values also increased in line with the body temperature values in the afternoon (26, 27). It was reported that the body temperatures were measured in oral, rectal or intra-aural ways in most of these studies, (20, 27, 28, 30), and in another study, it was reported that muscle temperature was estimated from skin temperature using skin probe (18). On the other hand, no study was encountered demonstrating the impact of Core Temperature, which is measured from the intestinal region and shows the body temperature more accurately, on the performance. The purpose of the present study was to investigate the effects of circadian rhythm on anaerobic performance and body temperature determined through three different methods.

MATERIALS AND METHODS

The subjects visited the laboratory for 2 times for the tests. In their first visit, their body weights and heights were measured, which are among the physiological features. Subsequently, core, body, skin surface, and tympanic temperatures were measured. The core temperature measurements were taken in 9 different times; before the 5-minute warm-up period, after the warm-up period, during the Wingate test with 5-second intervals, and after the test. As per the skin surface and tympanic measurements, they were taken in 4 different times, before the warm-up period, after the warm-up period, just after the Wingate test, and 5 minutes after the test. In order to determine the anaerobic performance values of the subjects, peak power, mean power, and fatigue index values were measured in cycle ergometer using the Wingate test. The Wingate test and all of the parameters measured were repeated when the subjects visited the laboratory for the second time. The measurements were conducted with a 30-hour interval in 09:00 in the morning and 16:00 in the afternoon. The random cross experiment design was used in the formation of the groups. All of the measurements were conducted under 30±1.8°C temperature and 25-35% moisture conditions of the laboratory.

Subjects

Ten elite taekwondo athletes (average age: 23.9±2.7 years, height: 178.7±4.9 cm, body mass: 72.1±7.8 kg, training experience: 12.5±4.9 years) voluntarily participated in this study. The subjects followed an exercise program, in which they performed exercises 2.1 ± 0.9 hours in average in each day. They did not perform any exercise on the days of measurements. After receiving a thorough explanation of the protocol, they gave written consent to participate in this study. The study was approved from the Selçuk University Ethics Committee (#2013/01). They were categorized as "moderately evening type" (n = 1), "intermediate type" (n = 7), and "moderately morning type" (n = 2), on the basis of their answers to Horne and Ostberg's self-assessment version of morningness-eveningness questionnaire (12).

Procedures

Pre-experimental Protocol

The subjects suspended exercises for 55 hours between the tests conducted in the laboratories at 09:00 a.m., in the first day until the end of the last test, and they conducted no physical activities. They did not use alcohol, caffeine, or did not smoke between 09:00 a.m. and 16:00 p.m. The subjects had a light breakfast at 07:00 a.m., and had their normal diets at the lunch.

Body Temperature Measurements

Body Core Temperature: The core temperature was measured through the Body Temperature Monitoring System (CorTemp, Wireless sensing systems & design, HQ Inc, Palmetto, USA) with a 0,1 °C precision. This device collected and recorded the data wirelessly from the batteries, which were swallowed by the subjects in the shape of a pill. It was demonstrated in various research studies that the Cortemp telemetric measurement device was a reliable and valid system (9, 10, 17).

Skin Surface Temperature: In the measurement of skin surface temperature, thermistors with a 0,1°C precision were used that were placed in four regions (chest, thigh, leg, forearm) of the body. The temperature data coming from these thermistors were recorded through a recorder device (Tumer, TR), which can display in 4 different digital screens. Skin surface temperature was calculated by formula 1 using the temperature values of four regions (19).

Mean skin temperature (MST) = $(0.34*t_{chest}) + (0.33*t_{thigh}) + (0.18*t_{leg}) + (0.15*t_{forearm})$ *Formula 1;*

t_{chest}= Chest Temp, t_{thigh}= Thigh Temp, t_{leg}= Calf Temp, $t_{forearm}$= Forearm Temp.

Tympanic Temperature: Tympanic (in-ear/endaural) temperature was measured by touching the (Braun, Germany) device with a 0,1 °C precision to the tympanic area in the ear. The temperature value seen on the digital screen of the device was recorded.

Wingate Anaerobic Test

The seat height and handle bars were adjusted in the cycle ergometer appropriately for each subject. Before the Wingate test, each of the subjects warmed up for 5 minutes on 50 watt workload pedaling in the cycle ergometer. Then, the Wingate Anaerobic Test (WT) was conducted on a friction-loaded cycle ergometer (Monark model 864 Crescent AB, Varberg, Sweden) interfaced with a microcomputer. The Wingate test is consisted of a 30 s maximal sprint against a constant resistance related to body mass (0.075 $kg \cdot kg^{-1}$ body mass) as proposed by Bar-Or (1). The Wingate test began from a rolling start, at 60 rpm against minimal resistance (weight basket supported). When a constant pedal rate of 60 rpm was achieved, a countdown of "3-2-1-go!" was given, and the test resistance was applied. Subjects were verbally encouraged throughout the test to avoid pacing and to sustain a maximal effort throughout the test. Every second, power output was calculated by the computer and stored. The highest power output over 1 s (P_{peak}) and the mean power (P_{mean}), corresponding to the ratio between total work done and time to do it (i.e, 30 s), were recorded at the end of the test. The fatigue index (i.e., the percentage decrease in power output) was equal to the difference between the highest (P_{peak}) and the lowest power (P_{low}) divided by the highest power (30):

Formula 2;

Fatigue Index (FI) = $(P_{peak} - P_{low})/P_{peak}$

Statistical Analysis

Descriptive statistics (Mean±SD) were calculated for all variables, and the normality of their distributions was checked using the Kolmogorov-Smirnov test. The *t-test* was used for dependent samples to analyze differences between the morning and the early evening in anaerobic power outputs and body temperature. The alpha level was set at $p<0.05$.

RESULTS

Body Temperature

The body temperatures of the athletes measured through three different methods (body core, skin surface and tympanic) in the morning and in the early evening were presented in Table 1. While no significant difference was found between the morning and early evening concerning the skin surface and tympanic temperature values ($p>0.05$), it was found that body core temperature was significantly higher in the early evening than in the morning ($p<0.05$).

Table 1. Changes in body temperature of athletes

	Morning (09:00)	Early evening (16:00)	*t*-value
Core Temp (°C)	37.09 ± 0.24	37.37 ± 0.28	3.06*
Skin Temp (°C)	32.90 ± 0.86	32.84 ± 0.91	0.19
Tympanic Temp (°C)	36.01 ± 0.54	35.98 ± 0.49	0.40

*p< 0.05

Wingate Test

Power outputs obtained from the Wingate test performed by athletes in the morning and in the early evening were presented in Table 2.

Table 2. Anaerobic performance values (mean± SD) in the morning and in the early evening

	Morning (09:00)	Early evening (16:00)	*t*-value
Peak Power (W)	802.4±97.9	811.1±107.7	0.51
Peak Power ($W \cdot kg^{-1}$)	11.12±0.78	11.25±0.89	0.54
Mean Power (W)	601.5±67.8	594.7±66.1	1.28
Mean Power ($W \cdot kg^{-1}$)	8.35±0.45	8.26 ±0.32	1.20
Fatigue Index (%)	51.3±3.9	52.1±4.9	0.53

It was revealed that there was statistically no significant difference between anaerobic power outputs tested in the morning and in the early evening ($p>0.05$).

DISCUSSION

In this study, daily change of the core temperature and the impact of this change on the anaerobic performance were tested. In this purpose, body temperature was measured in the morning and in the early evening through three different methods (body core, skin surface, and tympanic) and the WT was applied. Among the measured body temperatures, it was determined that only the core temperature values fluctuated and it was detected to be higher in the early evening compared to those in the morning (Table 1). However, it was determined that there was no significant difference in the morning or in the early evening hours concerning the values of the peak power, mean power, and fatigue index, which are the indicators of anaerobic performance (Table 2). There are numerous studies demonstrating that the anaerobic performance (P_{peak}, P_{mean}) increases in parallel to the increase of the body temperature within a day (3, 5, 11, 13, 15, 18, 23, 26-29). As mentioned before, core temperature is used as the initial indicator for circadian rhythm (31) in physical performance and biological processes, and numerous performance indicators follow the circadian changes in the body temperature. Chtourou (4) reported that the times of the day of the 2 test sessions (07:00 and 17:00 hours) approximate, respectively, the bathyphase (trough time) and the acrophase (peak time) of the circadian rhythm of the oral temperature. Berg and Ekblom (2) and Souissi (27) demonstrated that, in the experimental studies conducted in warm and cold environments, a %5 decrease occurs in the maximal anaerobic power value per 1-degree decrease in the muscle temperature. In these studies, it was reported that the body temperature increases and partial cellular changes in the muscles might be effective on the daily muscular contraction characteristics (14, 18). It is considered that the increase in the body temperature causes increases in metabolic reactions, connective tissue elasticity, and muscle conduction velocity, and at the same time, a decrease in the muscle viscosity; as a result of all these changes, it is evaluated that the ability of muscular contraction increases (25, 27).

In this study, although the morning core temperature values were determined to be significantly higher than those measured in the early evening, it was observed that the anaerobic performance values were not in parallel with the body temperature. There are studies with similar findings in the literature demonstrating that the anaerobic performance values measured in the morning and in the afternoon were similar and no circadian fluctuation was determined (6, 8, 22). However, it was demonstrated that the low level of anaerobic performance observed in the mornings disappeared after the exercise program (4). Souissi et al, (30), bringing a different view to the issue, demonstrated that daily fluctuations in the anaerobic performance can be prevented through regulated warm-up protocols. In previous studies, it was reported that the P_{peak}, P_{mean} values, which are generally detected to be low in the morning hours, significantly increased after a 15-minute warm-up; contrary to this, it was reported that 5-minute and 15-minute warm-ups performed in the afternoon did not change the P_{peak}, P_{mean} values. Researchers reported that daily fluctuations in the anaerobic performance can be regulated through long warm-up protocols. However, it was demonstrated that applying an artificial 5 °C increase in the adductor pollicis muscles in the mornings did not influence the daily fluctuations in the muscle strength (14). Having no increase in the anaerobic performance despite the increase in the core temperature within a day demonstrates that the daily changes in the anaerobic performance cannot be explained by only the daily fluctuations of the body temperature. Moreover, it is reported that hormonal changes possible to appear within a day influence the circadian fluctuations in the muscle performance (14). In this case, in order to better apprehend the reasons behind the circadian changes in the anaerobic performance, it is suggested that the hormonal changes should also be observed in future research studies.

CONCLUSION

As the conclusion, it was determined that the body temperature changed in different hours of a day, increasing in the evening hours, but it did not influence the anaerobic performance.

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