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The effect of time of day on Special Judo Fitness Test in active judokas: Evaluation in terms of chronotype

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ABSTRACT

The present cross-sectional study aims to examine the effect of time of day on the judo-specific performance in judokas, considering their chronotypes. Twenty-four male judokas participated in the study where the Morningness-Eveningness Questionnaire was administered, and on it, they were divided into morning-type (MT:12-judokas) and evening-type groups (ET:12-judokas). Afterwards, the Special Judo Fitness Test (SJFT) was applied to both groups at three different times (morning: 09:00 h, afternoon: 13:00 h and evening: 17:00 h) with body temperature measured before and after every SJFT performance. As a result, the Group*Test Time interaction significantly affected overall throwing performance during SJFT [$F(2,44) = 29.437$, $p = 0.001$, η2p: .572]. Furthermore, a significant time effect was found for the SJFT index [$F(2,44) = 5.118$, $p = 0.010$, η2p: .189] and for the Group*Test Time interaction with the mean value of the index [$F(2,44) = 24.424$, $p < 0.001$, η2p: .526]. Furthermore, body temperature had a significant time effect [$F(2,44) = 301.454$, $p < 0.001$, η2p: .932] and the Group*Test Time interaction [$F(2,44) = 5.802$, $p = 0.006$, η2p: .209]. In conclusion, coaches and exercise experts should consider judo athletes' chronotype when planning special training programs to improve judo-specific anaerobic capacity. Furthermore, to minimize the impact of time of day and chronotype on athletes' performance in competitions, it is recommended that MT athletes develop their judo-specific anaerobic capacity in the evening hours, when their performance is lower, while ET athletes should do so in the morning hours when their performance is lower via randori training.

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Combat sports; specific preparation; diurnal variation; conditioning

Introduction

In sports, to help tailor athletes' training to maximize performance, we need to understand and take into account his/her individuality (Roden et al. 2017), as even the slightest gains in performance could benefit them in achieving elite results (Currell and Jeukendrup 2008). Therefore, we need to understand one of these individual factors: the individual chronotype, which is defined as a characteristic predisposition towards morningness or eveningness (Vitale and Weydahl 2017). Literature usually defines three main chronotypes: morning types (M-types), evening types (E-types), and neither/intermediate types (N-types) (Adan et al. 2012; Horne and Ostberg 1976; Lastella et al. 2016). It was highlighted that, in general, M-types have better athletic performances in the morning than N-types and E-types, as they are less fatigued in the first part of the day. In judo, chronotype has been used as inclusion criteria (Chtourou et al. 2018; M. Souissi et al. 2013; Souissi et al. 2014) for research and judokas have been reported to be classified to have an intermediate type chronotype (Abedelmalek et al. 2015; Dunican et al. 2019; Nafaa et al. 2014).

This factor is of great importance in judo as tournaments start in the morning for each weight category in preliminary rounds that finish in the afternoon (Öztürk et al. 2022). Then, after a 1 h to 2 h break (Ceylan et al. 2023), the competition continues the same day in the form of the final block, which starts in the evening (Öztürk et al. 2022). Therefore, in addition to chronotype, the time-of-day effect also plays an essential part in athletes' performance. It has been highlighted that time of day affects physical performance and should be considered by coaches, athletes, and sports scientists (Chtourou and Souissi 2012). In general, it has been reported that short-duration maximal exercise performance peaks between 16:00 and 20:00 h (Mirizio et al. 2020), as well as anaerobic performances (Chtourou and Souissi 2012). In judo, conflicting findings related to the

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time-of-day effect on judo performance were noted (Öztürk et al. 2022). It was reported that judokas' muscle power and strength were significantly higher in the afternoon than in the morning; however, the effect disappeared after the judo matches related to higher fatigue in the afternoon than in the morning (Chtourou et al. 2013). Similar findings were also reported as better anaerobic power in judo athletes in the afternoon compared to morning on the same day, with sleep deprivation affecting the diurnal effects (N. Souissi et al. 2013). Specific judo performance tested with the Uchikomi fitness test also revealed diurnal variation with judokas' better performances in the late hours (Eken et al. 2022). Later it was reported that caffeine ingestion is recommended in the morning to minimize the diurnal fluctuations of short-term maximal performance in judo athletes, which could help in better morning performance (M. Souissi et al. 2013). However, in one of the latest studies from the same group of authors reported before on this topic, short-term repetitive maximal performance in elite judo athletes showed no-strong dependency of time-of-day and authors suggested that it should not be considered necessary in elite athletes (Chtourou et al. 2018). Similar study findings were also confirmed on a sample of 14 Turkish male judokas where different times of the day did not affect judo-specific performance nor their physiological variables (Öztürk et al. 2022).

Various specific tests can evaluate specific judo performance (Kons et al. 2023). However, one of the most widely used specific tests developed in judo is the Special Judo Fitness Test (SJFT) (Franchini et al. 2015; Marques et al. 2017; Šimenko and Hadžić 2022; Sterkowicz-Przybycień et al. 2019; Wolska et al. 2016). It was developed to imitate judo-specific performance during judo bouts (Ceylan et al. 2022; Štefanovský et al. 2021). However, in relation to the time-of-day research, the SJFT test has been scarcely used and showed conflicting results. One study reported diurnal variation (Eken et al. 2022), while the other studies reported that SJFT performance was not time-of-day dependent (Ouergui et al. 2022; Öztürk et al. 2022). The gender and competition level of participants might explain these differences. However, further research is needed to explore these relationships and provide clear answers.

Direct testing in a judo fight is limited due to direct contact and competition rules restrictions; therefore, specific tests like SJFT are suitable to elicit the same level of responses. Additionally, research has highlighted that habitual training time-of-day and chronotype need to be taken into account when assessing its impact on performance (Rae et al. 2015); especially as judo competition is divided into preliminaries that start in the morning and final block that starts late in the afternoon. However, researchers in judo have not yet explored the time-of-day effect on the SJFT performance concerning athletes' chronotype. Therefore, this study aims to examine the effect of time of day (morning, afternoon and evening) on the judo-specific performance (SJFT) in active judokas, considering their chronotypes.

Materials and methods

Participants

Twenty-four male volunteers (Morning types (MT): 12 judokas; Evening types (ET): 12) who had practiced judo frequently for more than five years (MT: age: 19.50 ± 1.00 years, height: 173.50 ± 3.98 cm, body mass: 69.66 ± 4.99 kg, BMI: 23,16 ± 1,76 kg/m^2; resting heart rate: 70.41 ± 6.28 bpm; ET: age: 20.50 ± 1.00 years; height: 173.50 ± 3.91 cm; body mass: 70.25 ± 5.02 kg; BMI: 23,16 ± 1,76 kg/m^2; resting heart rate: 70 ± 6.66 bpm) participated in the study (Table 1.). The main criterion was that judoka needed to hold a black belt 1st DAN level belt degree. The additional inclusion criteria included the following: (1) active and consistent participation in all phases of the study; (2) the absence of any medical condition or musculoskeletal injury that could influence the results; (3) proficiency in the ippon-seoi-nage and sode-tsuri-komi-goshi techniques. Before the tests, judo athletes were instructed not to engage in supplementary activities, such as high-intensity exercise or high-intensity resistance training, apart from their regular judo training to prevent the test results from being influenced. Participating judokas regularly competed in national tournaments and had been engaging in resistance training twice a week for at least a year. They were selected in groups of three of the same weight category due to the demands of the SJFT test. The athletes were not undergoing any rapid weight loss or participating in a competitive period during the study.

Table 1. The demographic characteristics of the MT and ET group.

	Groups	N	M ± S.D.
Age (years)	MT	12	19.50 ± 1.00
	ET	12	20.50 ± 1.00
Height (cm)	MT	12	173.50 ± 3.98
	ET	12	173.50 ± 3.91
Body weight (kg)	MT	12	69.66 ± 4.99
	ET	12	70.25 ± 5.02
BMI (kg/m^2)	MT	12	23.16 ± 1.76
	ET	12	23.35 ± 1.85
RHR (bpm)	MT	12	70.41 ± 6.28
	ET	12	70.00 ± 6.66

ET: Evening Type, **MT**: Morning Type: **BMI**: Body Mass Index, **RHR**: Resting Heart Rate.

Moreover, the athletes reported that they didn't experience any anxiety or insomnia during the testing period.

The judokas were advised to obtain at least 8 hours of sleep the night before each test session and to arrive full of energy, provided that they consumed food at least two hours before the morning and early evening sessions. The participants were informed of the importance of continuing their regular judo training, avoiding strenuous exercise, and refraining from drug use, such as alcohol and caffeine (Reilly et al. 2007)

The minimum sample size for the present study was calculated using G-power software 3.1.9.7. (University of Dusseldorf, Dusseldorf, Germany) (Faul et al. 2007). According to this analysis; a priori and F tests were used to calculate power in accordance with the present study's design; ANOVA: repeated measurements, within-interaction analysis; α err prob = 0.05; minimum effect size = 0.30; number of groups = 2; number of measurements = 3; and power (1-β err prob) = 0.80. Based on two-way repeated analysis of variance measures, the minimum sample size for statistical significance by the software was determined to be 24 participants with an actual power of 81.2%.

Prior to the commencement of the study, the judokas were provided with comprehensive information regarding the study's scope, objectives, and methodology. In addition, all participants signed a written informed consent form. All tests and measurements conducted in this study were approved by the Inonu University Clinical Research Ethics Committee (Approval Number: 2022/4281) and were conducted according to the Declaration of Helsinki.

Experimental design

In this cross-sectional study, the judo athletes were trained on the testing methods during the week preceding the commencement of the experiment. During this initial visit, the judo athletes were familiarized with the SJFT and other testing tools that would be used by providing all necessary information and demonstrations. Additionally, their chronotype, sleepiness scale and anthropometric measurements were determined in this first session. Athletes were also instructed on how to measure their resting heart rate (RHR) in the morning before going out of bed. The resting heart rates were recorded using a Polar RS400 (Kempele, Finland) monitor and the Polar H9 chest belt, and they were instructed not to speak or move during the measurement. The measurements were done three days in a row before the testing, and the average value of 3 days was considered as the RHR.

The experimental design comprised three test sessions conducted at 09:00 a.m., 1:00 p.m., and 5:00 p.m., during which the judo athletes completed the SJFT. Prior to each test session, the judo athletes' temperature was measured, and the heart rate reserve (HRR) was calculated using the Karvonen formula to determine the running intensity of each judo athlete during the general warm-up phase. The target heart rate was calculated as follows: target heart rate = exercise intensity × (maximum heart rate − resting heart rate) + resting heart rate (Nes et al. 2013). Before the start of testing, each judo athlete jogged lightly for five minutes under the guidance of experts based on their 50% HRR result. Subsequently, they performed 11 specific warm-up (SWU) exercises consisting of foot sweeps (1 m work- 1 m rest), finger wrist and ankle rotations (30 s work-30 s rest), trunk side stretch (30 s work-30 s rest), trunk rotator stretch (30 s work-30 s rest), hip circles (30 s work-30 s rest), knee bends (30 s work-30 s rest), cartwheels on both sides (30 s work-30 s rest), forward rolls (15 s work-15 s rest), backward rolls (15 s work-15 s rest), forward rolls with legs spread (15 s work-15 s rest), and backward rolls with legs spread (15 s work-15 s rest), totalling 10 minutes (Eken et al. 2022). Figure 1 presents the flow chart of the study.

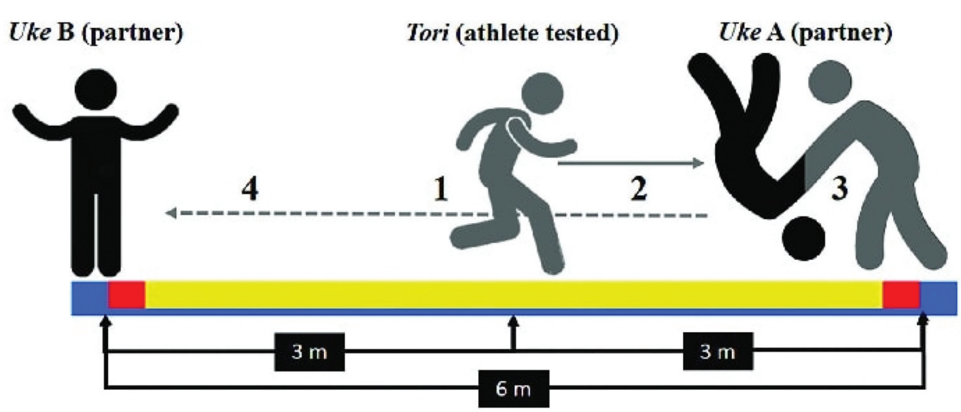

Figure 1. Study flow diagram.

RHR – resting heart rate; SJFT – Special judo fitness test; MCQ – Morningness-Eveningness Questionnaire.

Data collection tools

Chronotype

Morningness-Eveningness Questionnaire (MEQ) developed by Horne and Östberg (Horne and Ostberg 1976), adapted into Turkish by Punduk et al. (Pündük et al. 2005), was administered to the participants. The Morningness-Eveningness Questionnaire, consisting of 19 questions (Likert-type and time-scale questions) with four possible responses, was used to determine the circadian chronotype of the participants. Questions 1, 2, and 10 were answered using a 7-hour timetable divided into 15-minute subcategories, with each response option clearly defined. Based on the total score for all 19 questions, participants were classified into one of five circadian types: "absolutely morning type" (70–86 points), "near morning type" (59–69 points), "intermediate type" (42–58 points), "near evening type" (31–41 points), and "absolutely evening type" (16–30 points). The validity of the original questionnaire and circadian type classification was confirmed by changes in body temperature (Pündük et al. 2005). Based on MEQ, the participants were allocated to MT and ET groups.

Sleepiness scale

Participants completed the 8-item Epworth Sleepiness Scale, which evaluates their level of sleepiness in eight different daily life situations. In addition, participants graded the likelihood of falling asleep between 0 and 3, where 0 indicates that it never happens, 1 indicates that it occasionally happens, 2 indicates that it happens with medium frequency, and 3 indicates that it happens very often. The sum of the scores from the eight questions provided a measure of daytime sleepiness (Izci et al. 2008).

Body composition measurements

The judo athletes' body weight and height were recorded using an electronic scale (Tanita SC-330S, Amsterdam, Netherlands) with a precision of 0.1 kg and a stadiometer (Seca Ltd., Bonn, Germany) with a precision of 0.01 m, respectively. Subsequently, the body mass index (BMI) of all participants was measured and documented using the same electronic scale (Tanita SC-330S, Amsterdam, Netherlands) (American College of Sports Medicine 2018).

Body temperature

Prior to the warm-up protocols, the body temperatures of judo athletes in both the MT and ET groups were measured from the participants' foreheads with a Non-Contact Infrared Thermometer (IR thermometer XS-IFT005A, Ganzhou Xianshun Technology, Co. LTD, China).

Judo Specific Fitness Test (SJFT)

The SJFT, which was developed by Stanisław Sterkowicz and previously described by Franchini et al (Franchini et al. 1998; Sterkowicz 1995), requires three athletes of similar body mass: one participant (TORI) who performs the throwing technique and two other individuals who receive throws (UKE). The test consists of three parts (15 seconds for series A, 30 seconds for series B, and 30 seconds for series C) separated by 10 seconds of recovery time. The tori starts the test between the two ukes, who are 3 meters away from each other. Upon a signal, the tori runs to one uke and performs an ippon-seoi-nage throw on his dominant body side, then immediately runs to the other uke and performs another throw. The judo athletes must complete as many throws as possible within the test time. The total number of throws completed by the tori during each period is recorded, and the tori's heart rate (HR) is measured immediately after and 1 minute after the test using a Polar Team 2 HR monitor (Polar, Finland). The SJFT index is calculated using the following equation: Index = (HR after + HR 1 min after)/total number of throws. A lower index value indicates better test performance. The reliability of this test was reported as 0.97 (Sterkowicz et al. 2011). Figure 2 depicts the SJFT (Judo Training 2022).

Statistical analysis

All statistical analyses were performed using SPSS 26.0 (SPSS, Inc., Chicago, IL, USA). The throwing performance, SJFT index and body temperature of MT and ET groups in the morning, afternoon and evening hours were shown in bar charts as mean ± standard deviation. The normality of the data was performed by the Shapiro-Wilk test. According to this test, all variables were found to have a normal distribution ($p > 0.05$). Mauchly's test determined the sphericity assumption. Sphericity assumed was provided for the total number of throws, SJFT index and body temperature ($p > 0.05$) and Sphericity Assumed values were taken into account in reporting the data. Moreover, a 2 × 3 ANOVA (time group [MT vs. ET]*[morning vs afternoon vs. evening] with repeated measures was used to compare the pre- and post-tests of variables in different groups.

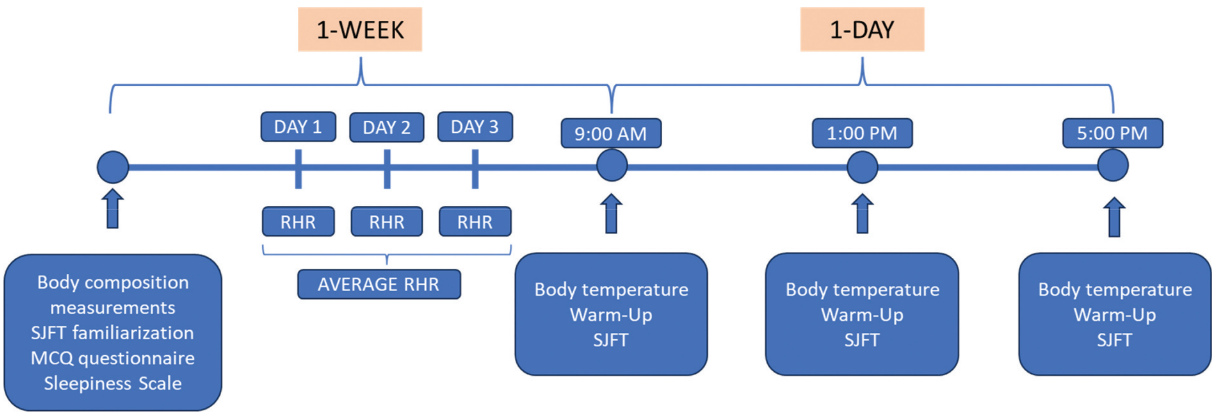

Figure 2. Special Judo Fitness Test setting.

Bonferroni post-test was used when a significant time or group-time interaction was detected. Cohen's d effect size (ES) with 95% confidence interval was calculated to define the magnitude of pairwise comparisons for pre- and post-test. The ES magnitude was defined as follows: <0.2= trivial, 0.2 to 0.6= small effect, >0.6 to 1.2 = moderate effect, >1.2 to 2.0 = large effect, and >2.0 = very large (Hopkins et al. 2009). The significance of statistical analysis was set as $p < 0.05$.

Results

Figure 3 presents no significant time effect for overall throwing performance during SJFT [$F_{(2,44)} = 1.737$, $p = 0.028$, η^2p: .007]. Moreover, the Group*Test Time interaction statistically significantly affected overall throwing performance during SJFT [$F_{(2,44)} = 29.437$, $p = 0.001$, η^2p: .572]. Bonferroni test showed that the MT group had a significantly better total throwing performance during the SJFT in the morning hours compared to the ET group ($t = 4.430$, $p < 0.001$, standardized effect size: 1.8 (.08; 2.7, 95% CI, large effect]. The total throwing performance of the MT group during the SJFT in the morning hours compared to the afternoon hours [$t = 3.954$, $p = 0.002$, Cohen's d: 1.14 (.03; 1.8, 95% CI, moderate effect] and evening hours [$t = 3.344$, $p = 0.007$, Cohen's d: 0.9 (.02; 1.6, 95% CI, moderate effect] was found to be significantly higher. For the ET group, total

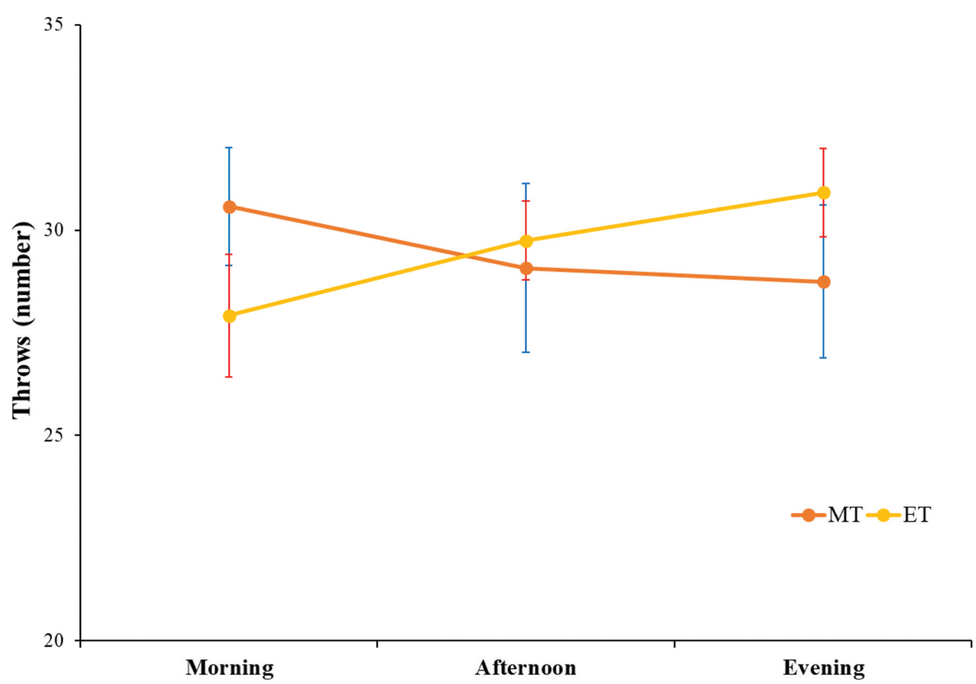

Figure 3. The throwing performance of MT and ET groups in the morning, afternoon and evening hours. **MT**– Morning type; **ET**– Evening type.

throwing performance was found to be significantly higher in the afternoon [t = −4.330, p = 0.001, Cohen's d: −1.25 (−2.0; −0.4, 95% CI, large effect] and evening hours [t = −6.760, p < 0.001, Cohen's d: −1.95 (−2.9; −0.9, 95% CI, large effect] compared to the morning hours. Moreover, the total throwing performance of the ET group compared to the MT group was greater in the evening hours [t = −3.480, p = 0.002, Cohen's d: −1.42 (−2.3; −0.5, 95% CI, large effect]

Figure 4 presents a statistically significant time effect for the SJFT index [$F_{(2,44)} = 5.118$, p = 0.010, η^2p: .189]. According to the Bonferroni test results; SJFT index scores were better in the afternoon [t = 2.837, p = 0.021, Cohen's d: .57 (0.0; 0.8, 95% CI, small effect] and evening hours [t = 2.699, p = 0.030, Cohen's d: .55 (0.0; 0.7, 95% CI, small effect] than in the morning hours, regardless of the group. From morning to evening, in other words, as the day progresses, we can say that SJFT performance improves. It was observed that the Group*Test Time interaction had a statistically significant effect on the mean value of the SJFT index [$F_{(2,44)} = 24.424$, $p < 0.001$, η^2p: .526]. According to this result, the SJFT index was found to be better in the MT group's morning hours than the ET group [t = −4.521, p < 0.001, Cohen's d: −1.8 (−2.7; −0.8, 95% CI, large effect]. The SJFT index scores of the MT group in the afternoon hours were better than those of the ET group in the morning hours [t = −3.042, p = 0.011, Cohen's d: −0.8 (−1.5; −0.1, 95% CI, moderate effect]. For the ET group, the SJFT index score was found to be significantly superior in the afternoon [t = 5.598, ***p*** < .001, Cohen's d: 1.6 (0.7; 2.4, 95% CI, large effect] and evening hours [t = 7.079, p < 0.001, Cohen's d: 2.0 (1.0; 3.0 95% CI, large effect] compared to the morning hours.

In Figure 5, there was a statistically significant time effect for the body temperature [$F_{(2,44)}$ = 301.454, $p < 0.001$, η^2p: .932]. Body temperature was found to be significantly lower in the afternoon [t = −11.860, p < 0.001, Cohen's d: −2.4 (−0.6; −0.3, 95% CI, large effect] and evening hours [t = −24.550, p < 0.001, Cohen's d: −5.0 (−1.0; −1.1, 95% CI, very large effect] compared to the morning hours, regardless of the group. In addition, body temperature was found to be higher in the evening hours than in the afternoon hours [t = −12.690, p < 0.001, Cohen's d: −2.5 (−0.6; −0.4, 95% CI, very large effect]. Considering the above results, it was observed that the body temperature increased as the day progressed (from morning to evening). It was determined that the Group*Test Time interaction had a statistically significant effect on body temperature [F(2,44) = 5.802, p = 0.006, η2p: .209]. According to the Bonferroni test results, body temperature was higher in the afternoon [t = −4.042, p = 0.002, Cohen's d: −1.1 (−1.8; −0.4, 95% CI, moderate effect] and evening hours [t = −10.019, p < 0.001, Cohen's d: −2.8 (−4.2; −1.5, 95% CI, very large effect] than in the morning hours of the MT group. The body temperature of the ET group in

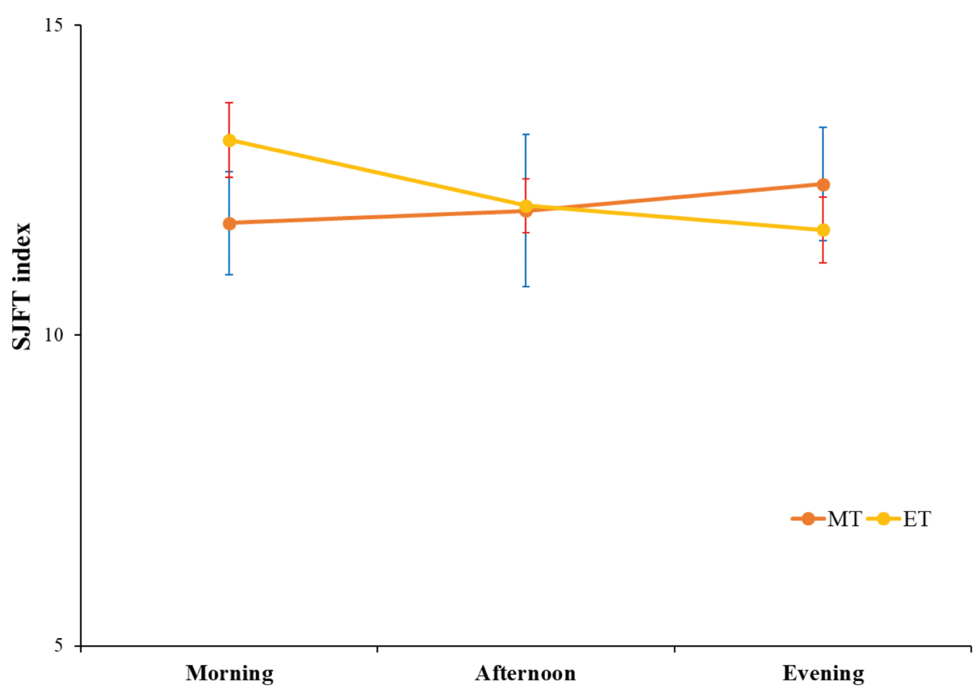

Figure 4. The SJFT index of MT and ET groups in the morning, afternoon and evening hours. **MT**– Morning type; **ET**– Evening type.

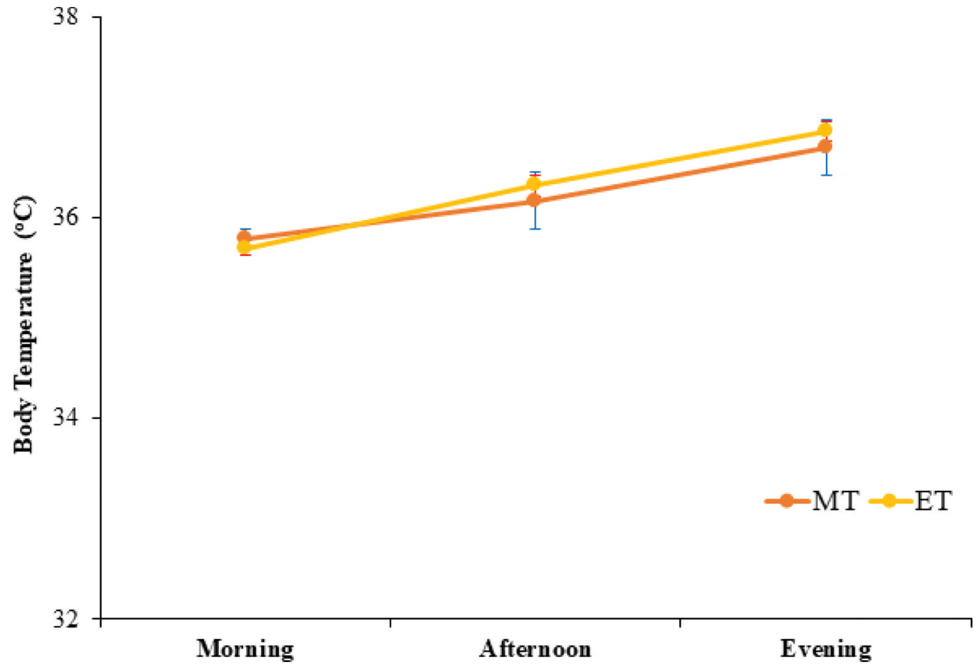

Figure 5. The body temperature (^{0}C) of MT and ET groups in the morning, afternoon and evening hours. **MT**– Morning type; **ET**– Evening type.

the afternoon [$t = -28.491$, $p < 0.001$, Cohen's d: −8.2 (−11.5; −4.7, 95% CI, very large effect] and evening hours [$t = -56.315$, $p < 0.001$, Cohen's d: −16.25 (−22.7; −9.5, 95% CI, very large effect] was found to be higher than the body temperature of the MT group in the morning. Body temperature was found to be higher in the afternoon [$t = -13.760$, $p < 0.001$, Cohen's d: −3.9 (−5.6; −2.2, 95% CI, very large effect] and evening hours [$t = -25.863$, $p < 0.001$, Cohen's d: −7.4 (−10.5; −4.3, 95% CI, very large effect] compared to the morning hours of the ET group. The body temperature of the ET group in the morning was lower than that of the MT group in the afternoon [$t = -5.609$, $p < 0.001$, Cohen's d: −1.6 (−2.4; −0.7, 95% CI, large effect] and evening [$t = -12.141$, $p < 0.001$, Cohen's d: −3.5 (−5.0; −1.9, 95% CI, very large effect] hours. Body temperature was higher in the evening hours compared to the afternoon hours of the MT group [$t = -37.623$, $p < 0.001$, Cohen's d: −10.8 (−15.1; −6.3, 95% CI, very large effect]. Compared to the afternoon hours of the MT group, the body temperature of the ET group was found to be higher in the evening hours [$t = -6.908$, $p < 0.001$, Cohen's d: −1.9 (−2.9; −0.9, 95% CI, large effect]. Finally, the body temperature of the ET group in the afternoon hours was lower than the body temperature of the MT group in the evening hours [$t = -3.947$, $p = 0.002$, Cohen's d: −1.1 (−1.8; −0.3, 95% CI, moderate effect]

Discussion

The present study aimed to investigate the effect of the Special Judo Fitness Test (SJFT) on performance indicators related to chronotype in active judokas, performed at different times of the day. Results indicate that the morning performance of the MT group was superior, while the ET group exhibited better performance in the afternoon and evening. Additionally, the total throwing performance of the ET group was higher than the MT group. Both groups had higher SJFT index values in the afternoon and evening. However, the SJFT index was greater in the MT group in the morning, while the ET group showed a higher SJFT index in the afternoon and evening. Notably, the ET group exhibited the highest SJFT index in the afternoon and evening. Furthermore, both groups found body temperature was higher in the evening and noon than in the morning. However, the evening body temperature was higher than that in the afternoon. The midday and evening body temperatures of the ET group were higher than the morning body temperature of the MT group. The midday body temperature of the ET group was lower than the evening body temperature of the MT group. Therefore, it can be concluded that the MT and ET groups exhibited different responses to SJFT performance at different times of the day. This study is the first to investigate the effect of SJFT on performance indicators related to chronotype in active judokas. Our findings provide insight into the importance of considering the timing of SJFT when assessing physical performance and highlight the need for further research in this area.

There are limited studies of circadian rhythms on judo athletes without revealed SJFT (Chtourou et al. 2013; Souissi et al. 2013). Chtourou et al. (2018) found that the time of day when the test was conducted did not significantly affect elite athletes' repeated sprint running performance and mood. The authors hypothesized that this outcome might be attributed to the routine practice of early morning exercise. Therefore, the interpretation posits that the efficacy of exercise may mitigate any potential negative impacts of circadian rhythms on athletic performance (Chtourou et al. 2018). Unlike our study, the study does not evaluate SJFT performances in judoka and does not include chronotype types. Chtourou et al. (2013) conducted a study to examine the impact of time of day on short-term maximum performance before and after a judo match in young judo athletes. The study's findings indicated that these athletes exhibited higher levels of muscle strength and power in the afternoon than in the morning, which was statistically significant. However, the diurnal patterns were reversed after the judo matches, and the athletes experienced more significant fatigue in the afternoon than in the morning (Chtourou et al. 2013). This study's methodology and measurement parameters differ from our research. Eken et al. (2022) conducted a study to examine the effects of various warm-up protocols on Uchikomi Fitness Test (UFT) scores among female judokas at different times of the day. The study revealed that UFT scores and heart rate significantly improved in the early evening compared to the morning. Notably, the specific warm-up (SWU) protocol demonstrated superior UFT performance enhancement compared to the no-warm-up (NWU) and linear+lateral warm-up (FWU) protocols. However, the interaction between the time of day and the warm-up protocol was deemed insignificant (Eken et al. 2022). In contrast to our investigation, the study in question concentrates on the impact of the warm-up protocols on diurnal variation, specifically assessing Uchikomi Fitness Test performance. The results of the study can be attributed to the following mechanism. The diurnal fluctuations in body temperature can result in improved motor coordination, leading to enhanced afternoon performance (Lericollais et al. 2009). The daily variations in muscle performance are attributed to improving muscle contractile properties rather than modifying neural impulses. To comprehend the causes of daily variations in performance, it is imperative first to determine the origin of these changes (Racinais et al. 2005).

The results of studies examining the effects of circadian rhythm and chronotype on SJFT are controversial. In their study, Eken et al. (2022) assessed the impact of varied warm-up protocols on SJFT performance among female judokas at distinct time intervals throughout the day. The principal outcome of the current investigation was the observation of a noteworthy enhancement in SJFT performance during evening sessions as opposed to morning sessions. Furthermore, significant linear reductions in heart rate were noted following no warm-up (NWU), dynamic warm-up (DWU), and specific warm-up (SWU) protocols in both morning and evening sessions (Eken et al. 2022). A study by Öztürk et al. (2022) explored the impact of time of day on judo-specific performance and the physiological load changes post-performance. The researchers observed no significant differences in the total number of throws and the SJFT index between morning and evening sessions. The study also noted that blood lactate (bLA), rate perceived exertion (RPE), and body temperature exhibited similar changes before and after testing. Nevertheless, heart rate (HR) measurements in the evening were consistently higher than in the morning, with no variation in SJFT throws (Öztürk et al. 2022). Unlike our study, this research does not analyze SJFT performance in relation to chronotype at various times of the day. Miarka et al (Miarka et al. 2011). conducted a study on circadian rhythms evaluating SJFT performance, assessing the acute effects and post-activation potentiation of judo athletes. Their findings suggested that performing contrast and plyometric exercises before SJFT could improve the test index and anaerobic power. In a study by Ouergui et al. investigating the specific performances of young judoka as a function of time of day, he reported that isometric and dynamic push-up performance depended on the time of day, but concluded that SJFT value did not depend on the time of day (Ouergui et al. 2022). Because of the relationship between internal circadian cycles and sleep needs, chronotype, which is an individual's physical and behavioural preference for earlier or later sleep timing (Jones et al. 2019), is influenced by many factors. Therefore, the study detailing the reason for these differences reported that the interaction between the human brain, chronotype, and time of day, including cortical excitability and neuroplasticity, which determines adaptive behaviour in both healthy individuals and clinical populations, is important (Salehinejad et al. 2021). Several studies have argued that non-invasive techniques may not be sufficient to induce cortical plasticity, which is essential for the time of day and chronotype (Huang et al. 2017; Ridding and Ziemann 2010). Our study found that participants' SJFT index score was higher in the afternoon and evening, regardless of the group difference. The SJFT index and overall shooting performance were higher in the MT group in the morning and higher in the ET group in the afternoon and evening. Although the results of our study are consistent with studies using non-invasive methods, different results will likely be obtained in studies with different outcomes, adequate sleep levels (Jones et al. 2019), adverse situations such as pandemics (Salehinejad et al. 2022) or where testing procedures are not standardized (Kantermann et al. 2007). To summarise, in practical terms, the coaches should focus on improving specific judo performance in the morning; especially if their athlete identifies as ET and tends to perform poorly in the preliminary phase of the competition, as she/he will not have a chance to compete in the afternoon in the final block. This would mean scheduling more randori sessions in the morning. The current state/recommendations show that usually in the training planning, in the morning, physical fitness is the dominant method being prescribed, and randori sessions (technical-tactical sessions) are primarily scheduled in the afternoon or evening practices (Broussal-Derval 2021; Jaworska et al. 2021). Perhaps adapting these training practices would benefit ET athletes. Additionally, this is something that could be researched in future research.

The present study needs to acknowledge some limitations. Specifically, the performance of the SJFT was assessed solely at three distinct time points throughout the day, thereby limiting the scope of temporal analysis. Moreover, the study included only male athletes, precluding the possibility of sex-based comparisons. To address these limitations, future research may employ more comprehensive protocol designs, encompassing a larger sample size of judo athletes that spans multiple weight categories and includes male and female competitors with elite and top-elite status across various age groups. Additionally, further research should try to use additional technologies and screening methods like EEG to understand better the brain functions connected to this topic.

Conclusion

This study is the first to investigate the effect of SJFT on performance indicators related to chronotype in active judokas. According to the results of our research, it was found that some performance indicators of the groups MT and ET differ depending on the circadian rhythm. In setting appropriate test conditions, it was found that the throwing performance of MT judo athletes was higher in the morning, while the performance of ET judo athletes was higher in the afternoon and evening. The results of our study show that not all performance indicators are affected by chronotype in the same way. For this reason, different performance indicators should be tested depending on chronotype, using the results of our investigation as a reference. Moreover, based on the results of our study, it was found that circadian rhythm led to similar results in the performance of both groups (the level of performance in the morning was lower than in the afternoon and evening), which gives important feedback to judo coaches to focus on better judo specific morning performance. The results of this study can also be used as a reference value for future studies on this topic. Furthermore, it is recommended to support such studies with methods (such as EEG) in which brain functions are analyzed in more detail.

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Availability of data statement

The data that support the findings of this study are available from the corresponding author, [JS], upon reasonable request.

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