Investigation of physiological exercise parameters and sleep status of elite karate athletes

Ilknur Hayirli[a], Ahmet Ayar[a],*

[a]Karadeniz Technical University, Faculty of Medicine, Department of Physiology, Trabzon, Türkiye

Abstract

Aim: The aim of this study was to determine sleep quality and exercise-related physiological parameters (heart rate, heart rate reserve, cardiac output, blood pressure, maximum oxygen uptake capacity) of elite karate athletes.

Materials and Methods: Ten athletes, 3 girls and 7 boys, who are interested in karate at an elite level in Trabzon, participated in the study. Anthropometric measurements and body mass index measurements were made. Cardiopulmonary exercise test (CPET) was performed with a gradually increasing intensity (15W/min) bicycle ergometer test protocol. Sleep parameters of the athletes were obtained by using the physical activity measurement holter (Sensewear Armband).

Results: The mean age of the individuals was 17.8±1.39 years (n=10), the mean height was 169.0±8.1 cm (n=10), the mean weight was 63.99±7.64 kg (n=10), and the mean body mass index was 22.41 kg/m^2 (n=10). Average value for oxygen consumption (VO$_2$) at maximum workload level 43±8 ml/kg/min (n=10, 99±12% of predicted), average maximum power 197±27.50 Watts (n=10, 92%±% predicted) 14), mean minute ventilation (VE) 103±28 L/min (n=10, 95±22% of predicted), mean heart rate (HR) 181±12 beats/min (n=10, 93±7% of predicted) and mean oxygen (O$_2$) pulse at maximum workload level was 15.20±2.90 ml/beat (n=10, 115.1±17.75% of predicted). The average lying down time of the athletes was 8 hours 8 minutes ±2 hours 26 minutes (n=9), sleep time was 6 hours 9 minutes±2 hours 30 minutes (n=9), and sleep efficiency was 74±12%.

Conclusion: The findings of this study show that the participating athletes had a good aerobic capacity and a good training level for the sport branch they were engaged.

Introduction

Karate, a martial arts discipline originating from Japan, focuses on unarmed combat techniques such as kicks, strikes, and defensive arm blocking. Therefore, both upper and lower extremity muscle explosive power, along with aerobic capacity, are important factors for achieving high-level performance in karate sports [1]. Physical and physiological factors play a critical role in the performance of elite-level karate athletes.

Sleep is a unique state characterized by altered state of consciousness, reduced responsiveness to the sensory modalities and decreased voluntary muscle activity. Sleep plays a crucial role in facilitating recovery and promoting growth and is essential for maintaining health and overall well-being including emotional state, cognitive performance, and quality of life [2].

The sleep–wake cycle is periodically regulated process governed by the homeostatic physiology of the circadian rhythm. The circadian rhythm, which refers to the 24-hour, itself is regulated by an internal clock in the brain. This internal clock helps regulate cycles of wakefulness and sleepiness by responding to variations in light within our environment. The circadian rhythm sets alternating periods in 24-hour cycle consisting of physical, mental, and behavioral functions that ensure optimal functioning of body processes. Disruptions of the circadian rhythm can affect important bodily functions including hormone secretion, body temperature regulation and autonomic functions. Disturbances in the circadian rhythm can negatively impact an individual's sleep patterns. As a result of irregularities in the release and levels of steroid hormones, individuals may enter a catabolic state, leading to a decline in exercise performance for athletes. Thus, there is extensive documentation highlighting the critical role of sleep quality in athletic performance [3-5].

Sleep has significant physiological and cognitive effects on athletic performance, especially during submaximal and

prolonged exercise, and is considered important for elite athletes. Sleep deprivation can lead to changes in glucose metabolism, neuroendocrine function, carbohydrate metabolism, nutrient intake, and protein synthesis, resulting in negative effects on athletes' metabolic and endocrine status and a decline in athletic performance [4-6]. Sleep deprivation decreases values of physiological exercise parameters. High levels of lactate concentration in the blood during exercise and impaired ability to remove lactate during exercise affect muscle metabolism. Functions requiring attention, alertness, and motor coordination are negatively affected by sleep deprivation [7].

In general, insufficient sleep duration and poor sleep quality can cause metabolic, immunological, cardiovascular, and neurocognitive dysfunction, as well as imbalance in the autonomic nervous system and significant metabolic dysfunctions [3, 8, 9]. The aerobic system of athletes needs to be well-developed in order to achieve and sustain high performance during high-intensity training and competition [10-12]. Oxygen consumption starts to increase from the beginning of exercise and this increase continues throughout the exercise. When oxygen uptake and delivery increase in response to the energy expenditure during exercise, the tissues receive the necessary oxygen and the individual can sustain performance effectively. It is possible to significantly increase maximum oxygen uptake through training compared to the resting phase [13].

Sleep (daily sleep-wake cycles) is primarily regulated physiologically in a circadian rhythm by a brain region known as the "internal clock". One important factor influencing this internal clock is melatonin, a hormone that plays a role in regulating sleep patterns and circadian rhythms [14]. Other hormones such as insulin and stress-related cortisol also have an impact on this center [15,16]. Exercise also directly affects melatonin release (both acutely and chronically), with its timing and intensity determining this effect [17,18]. Cardiopulmonary exercise testing (CPET) is an important laboratory method used for assessing exercise capacity and cardiac status. This technique allows for the combined evaluation of pulmonary, cardiovascular, and musculoskeletal system responses to submaximal and maximal exercise [19].This study is a descriptive study conducted to determine the physiological parameters in elite karate athletes active in Trabzon, Turkey. The aim was to examine the physiological exercise parameters and sleep quality of these athletes and compare them with previous research in the literature. After determining sleep quality, physiological exercise parameters, anthropometric measurements, and demographic data using appropriate methods, they were analyzed. The data obtained from this study were compared with the results in the literature regarding the sleep quality and physiological parameter values of karate athletes.

Materials and Methods

Participant selection

The study included 10 athletes, 3 females and 7 males, who were engaged in elite-level karate sports in the province of Trabzon. Suitable and voluntary individuals were selected for sleep quality measurement and CPET. Prior to starting the study approval was obtained from the Scientific Research Ethics Committee of the Faculty of Medicine of Karadeniz Technical University (Protocol no: 2019/174). Each athlete was provided with an information and consent form to fill out. It was determined that there were no conditions that would pose a risk for performing the CPET, and the testing was initiated thereafter.

Procedures

Anthropometric measurements

Skinfold caliper was used for measuring subcutaneous fat thickness and diameter, while a measuring tape was used for circumference measurements. The measurements were taken while the individuals were in a standing position, and the measurements were performed on the right side. Each measurement was repeated twice. Body Mass Index: A body composition was measured by bio-impedance (Tanita Body Composition Analyzer TBF-300, FEED) was used. The measurement was taken one hour after individuals had their meal, in a fixed position.

Cardiopulmonary exercise testing

The test was conducted in the morning hours, at least one hour after individuals had any meal. For the CPET, a bicycle module (VIA Sprint 150P), equipped with 12-lead ECG (QRS-card), pulse oximeter, an ergospirometer, and a gas analyzer. Data were acquired and analyzed by using the LAB Manager version 4.0 (Cardinal Health, Höchberg, Germany). The gas analyzer was calibrated before each test. Breath-by-breath measurement method was employed, and respiratory gas values were recorded every 5 seconds. A 12-lead ECG was used for each individual. Blood pressure monitoring was performed by measurements at every two minutes. The test was started with a warm-up period of five minutes, with a constant load of 20 Watts. Then, the test continued with a protocol in which the workload was increased by 15 Watts every minute. The subjects were asked to pedal at a rate of 60 revolutions per minute until exhaustion. Then, the workload was removed, and the individual was asked to pedal at a rate of <30 revolutions per minute to continue the test. The recovery period continued until the Respiratory Exchange Ratio (RER) value dropped below 1.00 and/or the heart rate declined to <100 beats per minute. And, the test was concluded. The exercise related physiological parameters including pulmonary ventilation (VE), oxygen consumption (VO_2), carbon dioxide production (VO_2), anaerobic threshold (AT), RER and oxygen pulse was determined.

Sleep quality assessment

Data related to sleep quality were obtained by transferring the recorded information by a metabolic holter (Sensewear Armband), and analysed by software. The device was placed to the triceps muscle of the right arm for each individual for 24 hours. The SenSewear Armband is used to assess both physical activity and sleep parameters [20]. The Armband contains a 2-axis microelectromechanical accelerometer sensor that measures movement based on gravity, allowing for estimation of the Armband's position, such as lying down or getting out of bed. The Sensewear Armband also includes a galvanic skin response sensor,

a skin temperature sensor, and an ambient temperature sensor near the body. The sensor on the backside of the Armband, in contact with the skin, measures skin temperature [21]. Perceptual Fatigue Assessment: Assessment was conducted using the Fatigue Severity Scale developed by Armutlu et al., which consists of a total of 9 items scored between 0 and 7, and has established validity and reliability worldwide [22]. Fatigue was quantified by rating of perceived exertion (RPE) scale.

Statistical analysis

Data were analyzed statistically using Microcal Origin version 5.00 (Microcal Software, Northampton, MA, USA). The data were evaluated using the Descriptive Statistics test and obtained values were compared with respect to predicted values for their age, gender-matched elite group of athletes as percentage of regarded normative values.

Results

The average age of the athletes was 17.8±1.39 years (n=10), the average height was 169.0±8.1 cm (n=10), the average weight was 63.99±7.64 kg (n=10), and the average body mass index (BMI) was determined as 22.41 kg/m² (n=10). The measurements of subcutaneous fat thickness (skinfold), diameter (caliper), and circumference are presented in Table 1.

The exercise-related physiological capacity parameters of 10 elite karate athletes (VO$_2$ max, VE, RER, RPE, oxygen pulse, workload) were measured at anaerobic thresh-

Table 1. Anthropometric measurement findings of elite karate athletes.

	Female (n=3)	Male (n=7)
Subcutaneous fat thickness		
Triceps	16.33±3.21 mm	10.42±3.10 mm
Subscapula	12.16±2.46 mm	11.07±2.31 mm
Suprailiac	9.16 ±1.44 mm	7.71±3.94 mm
Gastrocnemius	20.66±2.51 mm	12.71±1.97 mm
Diameter measurement		
Elbow	5.83±0.28 cm	6.14±0.37 cm
Knee	9.33±1.04 cm	9.64±0.37 cm
Circumference measurement		
Biceps	25.66±2.08 cm	27.07±2.0 cm
Gastrocnemius	36.16±2.75 cm	35.42±1.81 cm

Table 2. Exercise related physiological parameters of elite karate athletes.

|	@ AT	@ Maximum Load	Predicted %
Heart rate (beats/min)	150.40±21.08	180.60±12.16	%93.20±7.17
VO$_2$ max (ml/kg/min)	30.52±11.13	42.94±8.28	%98.70±11.64
VE (L/min)	58.90 ±23.02	102.5±27.86	%95.20±21.95
O$_2$ pulse (ml/beat)	12.66±3.56	15.20±2.90	%115.1±17.75
Work Load (Watt)	130±52.65	197±27.50	% 92.20±14.11

AT: Anaerobic threshold.
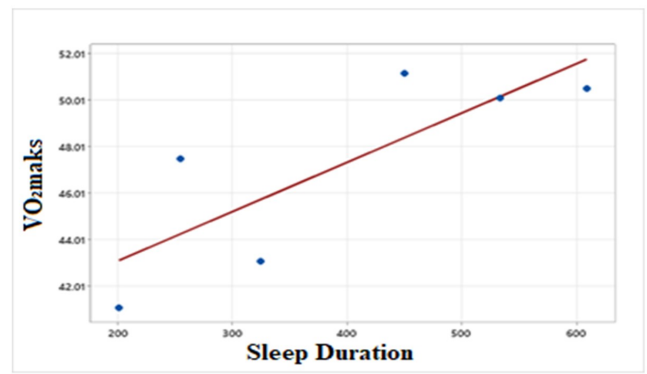
Figure 1. Relationship between sleep duration and VO$_2$ max values for male athletes.
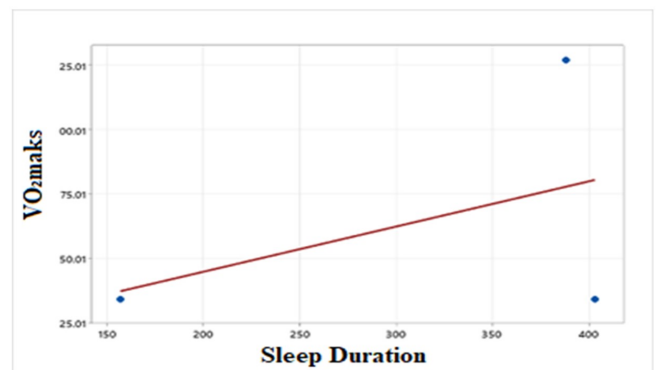
Figure 2. Relationship between sleep duration and VO$_2$ max values for female athletes.
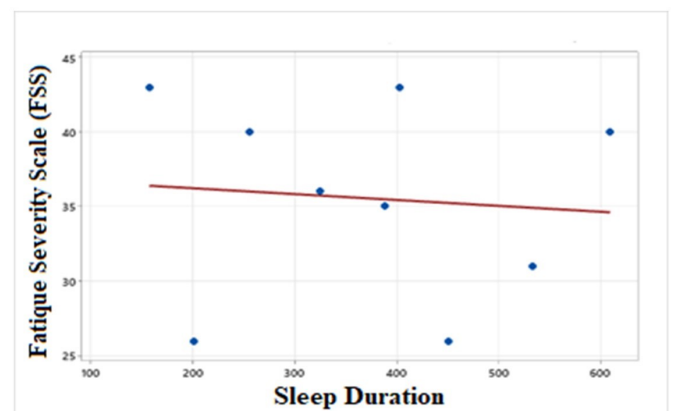
Figure 3. Association between the rated levels of exercise-induced acute fatigue and sleep scores among participants.

old (AT) and maximum workload levels, as presented in Table 2.

On average, the athletes spent 8 hours 8 minutes ± 2 hours 26 minutes (n=9) in a lying position, with a sleep duration of 6 hours 9 minutes ± 2 hours 30 minutes (n=9), and a sleep efficiency of 74% ± 12%. Male athletes had a lying duration of 8 hours 35 minutes ± 2 hours 2 minutes (n=6), a sleep duration of 6 hours 30 minutes ± 2 hours 40 minutes (n=6), and a sleep efficiency of 75% ± 10%. Female athletes had a lying duration of 7 hours 13

minutes ± 2 hours 2 minutes (n=3), a sleep duration of 5 hours 16 minutes ± 2 hours 38 minutes (n=3), and a sleep efficiency of 71% ± 17%. When examining the sleep duration and VO_2 max values of the athletes, a significant positive correlation was observed with the sleep duration. The relationship between sleep duration and VO_2 max values for male participants is shown in Figure 1, while the relationship between sleep duration and VO_2 max values for female participants is shown in Figure 2.

Association of the rated levels of exercise-induced acute fatigue and sleep scores are presented in Figure 3. There seems no obvious relationship between sleep duration and rated level of exercise-induced acute fatigue (Figure 3).

Discussion

In this study, using the CPET technique, the physiological responses of the cardiovascular, respiratory, and metabolic systems to gradually increasing exercise intensity were examined in an elite athlete group, in a protocol until they reached the point where they could no longer continue exercising.

During exercise, various adaptations occur in the cardiovascular system, pulmonary system, and musculoskeletal system, resulting in changes that affect the entire body. The physiological responses and adaptations that occur in the body are related to the type, intensity, and duration of the training. The effects of training involving isometric and isotonic exercises on the systems are different. Karate involves predominantly dynamic, isometric exercises that engage both the upper and lower extremities, but it also includes isotonic exercises, making it a combined sport [23].

When these data were compared with the data obtained from the voluntary athletes included in this study, it was found that our athletes physiological exercise capacities were comparable to values reported for their elite counterparts.

It is well-known that athletes' anthropometric characteristics are highly correlated with physiological parameters related to exercise performance. It has been observed that athletes with lower skinfold measurement, indicating lower subcutaneous fat thickness, tend to achieve better results in exercise tests [24, 25].

In this study, during the exercise test performed at the maximum workload level, the maximum heart rate (HR) measured was 180.60±12.16 beats per minute (bpm) (n=10). For male athletes, it was measured as 186.43±7.32 bpm (n=7), and for female athletes, it was 167±10.44 bpm (n=3). At the maximum workload level, the percentage of the target HR was determined as 95.57±5.99% (n=7) for male athletes and 87.67±7.63% (n=3) for female athletes. In a study conducted on elite male karate athletes, the maximum HR was reported as 191±7 bpm (n=5) [26]. Another study reported a maximum HR of 179.5±6.86 bpm (n=5) at the maximum workload level [26-28]. In a study conducted with nineteen elite male karate athletes using a bicycle ergometer protocol, the maximum HR at the maximum workload level was reported as 181.7±7.7 bpm (n=19). When comparing the results obtained in this study with the data from similar studies conducted on elite karate athletes in the literature, taking into account age

and other anthropometric characteristics, it is observed that the results obtained for maximum HR are similar. This suggests that the athletes in this study have comparable cardiovascular responses during exercise to those observed in other studies on elite karate athletes.

According to the results obtained in this study, the VO_2 max was determined to be 42.94±8.28 ml/kg/min (n=10), which corresponds to 98.70±11.64% (n=10) of the expected value based on the athletes' demographic characteristics. The VO_2 value at the anaerobic threshold was measured as 30.52±11.13 ml/kg/min (n=10). In a study conducted on elite male karate athletes during exercise tests specific to karate techniques, the reported VO_2 max value was 48.9±11.4 ml/kg/min (n=5) [27]. In another study investigating the cardiorespiratory responses to aerobic exercise training and its effect on aerobic capacity using a bicycle ergometer, the reported VO_2 max value was 41 ml/kg/min (n=10), and the anaerobic threshold VO_2 value was 22 ml/kg/min (n=10) [29]. In a study conducted on elite male karate athletes, the reported VO_2 max value was 44.8±7.1 ml/kg/min (n=19). It can be observed that the results reported in these studies are close and similar to the results obtained for the athletes in the current study.

In a study conducted with five elite male karate athletes, the reported VE (ventilation) value was 130.6±16.0 liters/min (n=5) [27]. In another research, during a taekwondo-specific test, the reported VE value was 80.4±6.8 liters/min [29]. In this current study, the VE value in response to maximum exercise was measured as 102.5±27.86 liters/min (n=10), which corresponds to 95.20±21.95% of the expected value based on the athletes' demographic characteristics. When comparing these results, it can be observed that the VE value at maximum exercise level is somewhat lower compared to the results in the similar study.

According to the exercise protocol applied to the athletes, the maximum workload achieved at the maximum exercise level was measured as 197±27.50 Watts (n=10), which corresponds to 92.20±14.11% of the expected value. In a similar study, the reported maximum workload based on exercise test results was 224 Watts (n=10) [29]. In another study, the maximum workload reached using a bicycle ergometer protocol in elite male karate athletes was reported as 223.6±48.2 Watts (n=19) [30]. When comparing these findings, it can be observed that the maximum workload value is somewhat lower compared to the results in similar studies.

Sleep duration and quality in athletes are closely related to athletic performance. Quality and effective sleep contributes to improvements in physiological functions such as attention and coordination during prolonged training. According to measurements related to sleep quality, the lying duration of athletes was found to be 8 hours 8 minutes ± 2 hours 26 minutes (n=9), sleep duration was 6 hours 9 minutes ± 2 hours 30 minutes (n=9), and sleep efficiency was 74% ± 12%. For male athletes, the lying duration was 8 hours 35 minutes ± 2 minutes (n=6), sleep duration was 6 hours 30 minutes ± 2 hours 40 minutes (n=6), and sleep efficiency was 75% ± 10%. For female athletes, the lying duration was 7 hours 13 minutes ± 2

minutes (n=3), sleep duration was 5 hours 16 minutes $\pm$ 2 hours 38 minutes (n=3), and sleep efficiency was 71% $\pm$ 17%. In a study conducted on 183 individual and 104 team athletes in Turkey, athletes' sleep qualities were examined using the Pittsburgh Sleep Quality Index, and a positive relationship was thought to exist between regular training and sleep quality [31]. Athletes with low sleep quality and quantity tend to experience higher levels of stress and cognitive complexity compared to athletes with higher levels of the same parameters [10]. Increasing sleep duration and quality lead to improvements in physiological exercise parameters and cognitive functions. Athletes who get enough sleep before a competition are likely to demonstrate their highest performance. Athletes experiencing sleep deprivation may experience impairments in important brain functions such as reasoning and decision-making during competitions [3].

We did not measure the levels of melatonin in the subjects but as they had regular exercise, as routine training and competition, their sleep status might have influenced by exercise-induced melatonin level modulation and associated circadian rhythm [16-18].

The performance of (elite) athletes across various professional sports domains is significantly influenced by sleep, encompassing both its quantity and quality. Optimal sleep stands as a pivotal component not only for health and well-being but also for elevating performance and achieving competitive success. Its profound effects extend to multiple facets pertinent to the sport's requirements. These encompass physical growth, drive, concentration, motor skills, sprint capabilities, recuperation post-performance, vulnerability to injuries, and the potential for undesired weight gain [32, 33].

Conclusion

In conclusion, this study primarily undertook a descriptive analysis rather than testing any specific hypotheses. Nonetheless, the study did provide original data acquired through laboratory measurements involving a select cohort of elite karate athletes in Turkey. Supplementary data obtained from estimative methods, as outlined in the discussion section, were also included. Such an approach enables the possibility of aligning the findings with international benchmarks, serving as a valuable resource for both athletes and coaches to gauge their existing capabilities.The measurements were taken from athletes engaged in karate during the specific period and in the region where the study was conducted. These athletes participated in national and international competitions. The physiological parameter values related to exercise performance for these athletes were found to be close to international averages. The results of this study demonstrate that the participating athletes possess good aerobic capacity and also implicating good level of training.

References

1. Chaabene H, Hachona Y, Franchini E, Mkaouer B, Chamari K. Physical and physiological profile of elite karate athletes. Sports Med. 2012; 42: 829-843.
2. Watson A. Sleep and athletic performance. Curr Sports Med Rep. 2017; 16: 413-418.
3. Vitale KC, Owens R, Hopkins SR, Malhotra A. Sleep hygiene for optimizing recovery in athletes: review and recommendations. Int J Sports Med. 2019; 40:535-543.
4. Halson SL. Sleep in elite athletes and nutritional interventions to enhance sleep. Sports Med. 2014; 44: 13-23.
5. Lin W, Saner NJ, Weng X, Caruana NJ, Botella J, Kuang J, et al. The Effect of Sleep Restriction, With or Without Exercise, on Skeletal Muscle Transcriptomic Profiles in Healthy Young Males. Front Endocrinol. 2022; 22: 863224.
6. Knowles OE, Drinkwater EJ, Roberts SSH, Alexander SE, Abbott G, Garnham A, et al. Sustained Sleep Restriction Reduces Resistance Exercise Quality and Quantity in Females. Med Sci Sports Exerc. 2022; 22: 1249.
7. Stavrou VT, Astara K, Tourlakopoulos KN, Daniil Z, Gourgoulianis KI, Kalabakas K, et al. Sleep quality's effect on vigilance and perceptual ability in adolescent and adult athletes. J Sports Med. 2021; 11: 5585573.
8. Fullagar HK, Skorski S, Duffield R, Hammes D, Coutts AJ, Meyer T. Sleep and athletic performance: the effects of sleep loss on exercise performance, and physiological and cognitive responses to exercise. Sports Med. 2015; 45: 161-86.
9. Mishra J, Panigrahi A, Samanta P, Dash K, Mahapatra P, Behera MR. Sleep quality and associated factors among undergraduate medical students during Covid-19 confinement. Clin Epidemiol Glob Health. 2022; 15: 101004.
10. Marques V, Coswig V, Viana R, Leal A, Alves F, Alves A, et al. Physical fitness and anthropometric measures of young Brazilian judo and wrestling athletes and its relations to cardiorespiratory fitness. Sports (Basel). 2019; 7: 38.
11. Jones AM, Carter H. The effect of endurance training on parameters of aerobic fitness. Sports Med. 2000; 29(6): 373-86.
12. Ambrozy T, Rydzik L, Spieszny M, Chwala W, Jaszczur-Nowicki J, Jekielek M, et al. Evaluation of the level of technical and tactical skills and its relationships with aerobic capacity and special fitness in elite jujitsu athletes. Int J Environ Res Public Health. 2021; 18(23): 12286.
13. Laughlin MH. Cardiovascular response to exercise. Am J Physiol. 1999; 277(6): 244-259.
14. Vasey C, McBride J, Penta K. Circadian rhythm dysregulation and restoration: the role of melatonin. Nutrients. 202;13(10):3480.
15. Brubaker PL, Martchenko A. Metabolic homeostasis: It's all in the timing. Endocrinology. 2022; 163(1):bqab199.
16. Chan K, Wong FS, Pearson JA. Circadian rhythms and pancreas physiology: A review. Front Endocrinol (Lausanne). 2022; 13:920261.
17. Buxton OM, L'Hermite-Balériaux M, Hirschfeld U, Cauter E. Acute and delayed effects of exercise on human melatonin secretion. J Biol Rhythms. 1997; 12(6):568-74.
18. Escames G, Ozturk G, Baño-Otálora B, Pozo MJ, Madrid JA, Reiter RJ, Serrano E, Concepción M, Acuña-Castroviejo D. Exercise and melatonin in humans: reciprocal benefits. J Pineal Res. 2012; 52:1-11.
19. Abouaini K, Egred M, Alahmar A, Wright DJ. Cardiopulmonary exercise testing and its application. Postgrad Med J. 2007; 83: 675-682.
20. Roane BM, Reen EV, Hart CN, Wing R, Carskadan MA. Estimating sleep from multisensory Armband measurement: validity and reliability in teens. J Sleep Res. 2015; 24: 714-721.

21. Bhammar DM, Sawyer BJ, Tucker WJ, Lee JM, Gaesser GA. Validity of SenseWear® Armband v5.2 and v2.2 for estimating energy expenditure. J Sports Sci. 2016; 34: 1830-1838.

22. Armutlu K, Korkmaz NC, Keser İ, Sümbüloğlu V, Akbıyık Dİ, Güney Z, Karabudak R. The validity and reliability of the fatique severity scale in Turkish multiple sclerosis patients. Int J Rehab Res. 2007; 30: 81-85.

23. Charlton GA, Crawford MH. Physiologic consequences of training. Cardiol Clin. 1997; 15: 345-354.

24. Sanchez-Puccini MB, Argothy-Bucheli RE, Meneses- Echavez JF, Lopez-Alban CA, Ramirez-Velez R. Anthropometric and physical fitness characterization of male elite karate athletes. Int J Morphol. 2014; 32(3): 1026-1031.

25. Garcia-Gill M, Torres-Unda J, Esain I, Dunabeitia I, Gill SM, Gill J, et al. Anthropometric parameters age and agility as performance predictors in elite female basketball players. J Strength Cond Res. 2018; 32(6): 1723-1730.

26. Alves J, Barrientos G, Toro V, Sanchez E, Munoz D, Maynar M. Changes in anthropometric and performance parameters in high-level endurance athletes during a sports season. Int J Environ Res Public Health. 2021; 18: 2782.

27. Nunan D. Development of a sports specific aerobic capacity test for karate – a pilot study. J Sports Sci Med. 2006; 5: 47-53.

28. Alm P, Yu JG. Physiological characters in mixed martial arts. Am J Sports Sci. 2013; 1: 12-17.

29. Catal AM, Chacon-Mikahil MPT, Martinelli FS, Forti VAM, Silva E, Golfetti R, et al. Effects of aerobic exercise training on heart rate variability during wakefulness and sleep and cardiorespiratory responses of young and middle aged healthy men. Braz J Med Biol Res. 2002; 35: 741-752.

30. Rocha FP, Louro H, Matias R, Brito J, Costa AM. Determination of aerobic power through a specific test for taekwondo- a predictive equation model. J Hum Kinet. 2016; 53(2016): 117-126.

31. Eliöz M, Çebi M, İslamoğlu İ. Investigation of sleep quality of team and individual sports. Turkish Studies. 2018; 13: 581-591.

32. Charest J, Grandner MA. Sleep and athletic performance: Impacts on physical performance, mental performance, injury risk and recovery, and mental health. Sleep Med Clin. 2020; 15: 41-57.

33. Ayar S, Karacabey K, Aksu A, Ayar A. Comparison of perceived and objectively measured sleep quality among elite rowing athletes. International Journal of Applied Exercise Physiology 2019; 8(3): 90-99.