http://pjss.pau.edu.tr
http://psbd.pau.edu.tr
Pamukkale Journal of Sport Sciences
PJSS ISSN: 1309-0356
2016, 7(1), 12-24
Received: 05.03.2015
Accepted: 21.12.2015

The Effect of Circadian Rhythm on Some Physical and Physiological Parameters in Male Taekwondo Athletes

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Abstract

Circadian rhythm is a 24-hour psychological and physiological fluctuations. The present study examined the effect of circadian rhythm on several physical and physiological parameters in male taekwondo athlete. For the circadian rhythm, daily time period was divided in hours as 08^{30}-10^{30}, 11^{30}-13^{30}, 14^{30}-16^{30}, 17^{30}-19^{30}, 20^{30}-22^{30}. Athletes chronotypical structures and sleep qualities were determined by Horne-Ostberg's Morningness-Eveningness Questionnaire and Epworth Sleepiness Scale. Nine male athlete (age 19,22±1,9 year, stature 176,9±3,9 cm, body mass 66,9 ±11,9 kg) participated in this study. The athlete's resting heart rates, intra-aural resting body temperatures were measured and counter movement jump test, paldeung technique effect level test and Wingate anaerobic power and capacity test were applied. The normality assumption of the data was examined by Shapiro-Wilks test. Time periods were compared using analysis of variance (ANOVA) followed by a LSD post-hoc test. Pearson correlation coefficient analysis was used to examine the relations between variables. Value of significance was accepted as $p<0.05$. Significant circadian change differences were observed in resting heart rates, intra-aural resting body temperatures, counter movement jump heights, paldeung technique effect levels and, mean power in Wingate test. A negative correlation coefficient was found between resting body temperature and resting heart rate. As a result; there are many factors affecting sports efficiency and in order to improve individual sporting performance, chronotypical features and the effects of circadian rhythm must be considered in designing training and competitions.

Keywords: Taekwondo, circadian rhythm, Wingate anaerobic test, counter movement jump

INTRODUCTION

The term Circadian comes from Latin *(circa diem)* (Manfredini et al., 1998) and refers to the psychological and physiological fluctuations that occur during the 24-hour period (Hardin, 2000). Circadian rhythm has been studied in many fields (Bessot et al., 2006; Febbraio et al., 1996; Galliven et al., 1997). Likewise, sports scientists who studied the effect of circadian rhythm on sport performance have emphasized that many parameters change during the day (Afonso et al., 2006; Bougard et al., 2009; Briswalter et al., 2007; Burgess et al., 1997).

Taekwondo competitions start in the morning and continue during the evening. Circadian rhythm affects many physical and physiological features during the day; and therefore, may affect physical and physiological characteristics of taekwondo athletes both in a competition and in training sessions. Although there are studies carried out on circadian rhythm in different branches of sport in the literature (Chittababu, 2013; Kline et al., 2007; Özdamar, 2009; Reilly et al., 2007), no study has been found examining the effect of circadian rhythm particularly in taekwondo. For this reasons we aimed to evaluate Paldeung technique effect level *(PTEL)* -one of the most commonly used techniques in matches- resting heart rate *(RHR),* resting body temperature *(RBT)* and anaerobic parameters in terms of circadian rhythm between the periods of 08^{30}-10^{30}, 11^{30}-13^{30}, 14^{30}-16^{30}, 17^{30}-19^{30}, 20^{30}-22^{30} during the day (Hill and Smith, 1991).

METHODS

Participants

Nine elite male taekwondo athlete (age 19,22±1,9 year, sport experience age 7,78±6,3 year, stature 176,9±3,9 cm, body mass 66,9 ±11,9 kg) participated in the present study. The compatibility of the study with the "*Declaration of Helsinki, Ethical Principles for Medical Research Involving Human Subjects*" was confirmed by Ege University, Scientific Research Ethics Committee of Faculty of Medicine *(Approval no: 11-10/5).* Written consent was obtained from the participants via the "*Informed Consent Form*". The participants of the study were given Horne-Ostberg's "Morningness-Eveningness Type Questionnaire" (Pündük et al., 2005) and to determine their sleep quality, "Epworth's Sleep Scale" was applied (Johns, 1992). The participants were informed to avoid strenuous physical exercise, alcohol and caffeine 1 day before each data collection time period.

Study design and laboratory conditions

The athletes were divided into 3 groups (group A, B, C) randomly and visited the laboratory for measurements every two days as presented in figure 1. In this respect, all athletes were made to participate in measurements in all time periods and on five laboratory days (Figure 1). On each measurement day, the athletes were given resting heart rate measurement, resting body temperature measurement, countermovement jump test, Paldeung technique effect level measurement and Wingate anaerobic power and capacity test respectively. The laboratory environment was kept at the same temperature *(20-23 °C)* and humidity *(20-25%)* levels for each test day during the measurements (Hill and Smith, 1991).

Time periods	Laboratory measurements		Laboratory measurements		Laboratory measurements		Laboratory measurements		Laboratory measurements
1	grp-A	Rest (2 day)	grp-B	Rest (2 day)		Rest (2 day)		Rest (2 day)	grp-C
2	grp-B		grp-A				grp-C		
3	grp-C				grp-A				grp-B
4			grp-C		grp-B		grp-A		
5					grp-C		grp-B		grp-A

1= *08^{30}-10^{30};* ***2***= *11^{30}-13^{30};* ***3***= *14^{30}-16^{30};* ***4***= *17^{30}-19^{30};* ***5***= *20^{30}-22^{30} time periods;* ***grp***= *group.*

Figure 1: Study design

Measurements

Resting heart rate measurement (RHR): The RHR of participants were recorded *(beat·min^{-1})* as the lowest value obtained at the heart rate during 20-minute resting at sitting position *(RS 400 Polar Electroy, Kempele, Finland)* (Özdamar, 2009).

Resting body temperature measurement (RBT): After the participants rested for 20 minutes, 5 measurements were taken from the right ear in an intra-aural way *(Braun IRT 4520 Digital Clinical Intra Aural Thermometer),* the lowest and highest measurement were excluded from the records and the data obtained from the average of the remaining 3 measurements was recorded as the RBT value *(ºC)* (Özdamar, 2009).

Countermovement jump test (CMJ): The participants were asked to perform countermovement jumps in which the jumpers start from an upright standing position, make a preliminary downward movement by flexing at the knees and hips, then immediately extend the knees and hips again to jump vertically up off the ground as high as they could with their hands free. 2 jumps were performed to determine CMJ measurements and the highest result was recorded *(Bosco Contact Mat; New Test 1000)*. Using the formulas, CMJ heights of the participants were transformed into peak anaerobic power $CMJ_{(PP)}$ and mean anaerobic power $CMJ_{(MP)}$ (Johnson and Bahamonde, 1996).

$$\text{Peak power}_{(W)} = 78.5 \cdot CMJ_{(cm)} + 60.6 \cdot \text{body mass}_{(kg)} - 15.3 \cdot \text{height}_{(cm)} - 1{,}308$$

$$\text{Mean power}_{(W)} = 41.4 \cdot CMJ_{(cm)} + 31.2 \cdot \text{body mass}_{(kg)} - 13.9 \cdot \text{height}_{(cm)} + 431$$

Paldeung technique effect level measurement (PTEL): For this measurement, the distance of each participant to the hitting target and target height were identified. Trochanteric height was referred to when determining the distance to the hitting target. The reference for the target height was the midpoint between the participants' xiphoid process of the sternum and anterior superior iliac spine line (horizontal line). The kicking bag stand *(Adler)* was dressed with an electronic body protector to determine the effect level (bar). Two performances were made with the dominant foot using Paldeung technique at 30 second intervals and the highest effect level (bar) was recorded *(LaJUST Electronic Impact Detection & Scoring System)* (Falco et al., 2009).

Wingate anaerobic power and capacity test (WAnT): Each participant warmed up for five minutes without any loads at low speeds; each participant was given sprints of 4-6 seconds. After the warm up, load was placed on the bicycle (75 $g \cdot kg^{-1}$ load for body weight) and the test was initiated *(Monark 894 E Peak Bike Bicycle Ergometer)*. Following WAnT, the highest power performed by the athlete in 30 seconds in watt *(W)* was recorded as peak power $WAnTPP_{(W)}$ and watt per body weight $WAnTPP_{(W \cdot kg^{-1})}$ and the power performed in 30 seconds was recorded as $WAnTMP_{(W)}$ and watt per body weight $WAnTMP_{(W \cdot kg^{-1})}$ (Inbar et al., 1996).

Statistical analyses

The data were presented as means and standard deviations. The normality assumption was examined with Shapiro – Wilks test, the data were found to be normally distributed. Time periods were compared using analysis of variance *(ANOVA)* followed by a *LSD post-hoc test*. Pearson correlation coefficient analysis was used to examine the relations between variables. Data analyses were carried out with SPSS for Windows, Version 13 and the value of significance was accepted as $p<.05$.

RESULTS

Significant differences were found in resting heart rate ($p<0.05$), resting body temperature ($p<0.05$), $CMJ_{(PP)}$ ($p<0.05$), $CMJ_{(MP)}$ ($p<0.05$), PTEL ($p<0.05$) and $WAnTMP_{(W \cdot kg^{-1})}$ ($p<0.05$), no significant difference was observed in $WAnTPP_{(W \cdot kg^{-1})}$ ($p>0.05$) at different times of the day (Table 1).

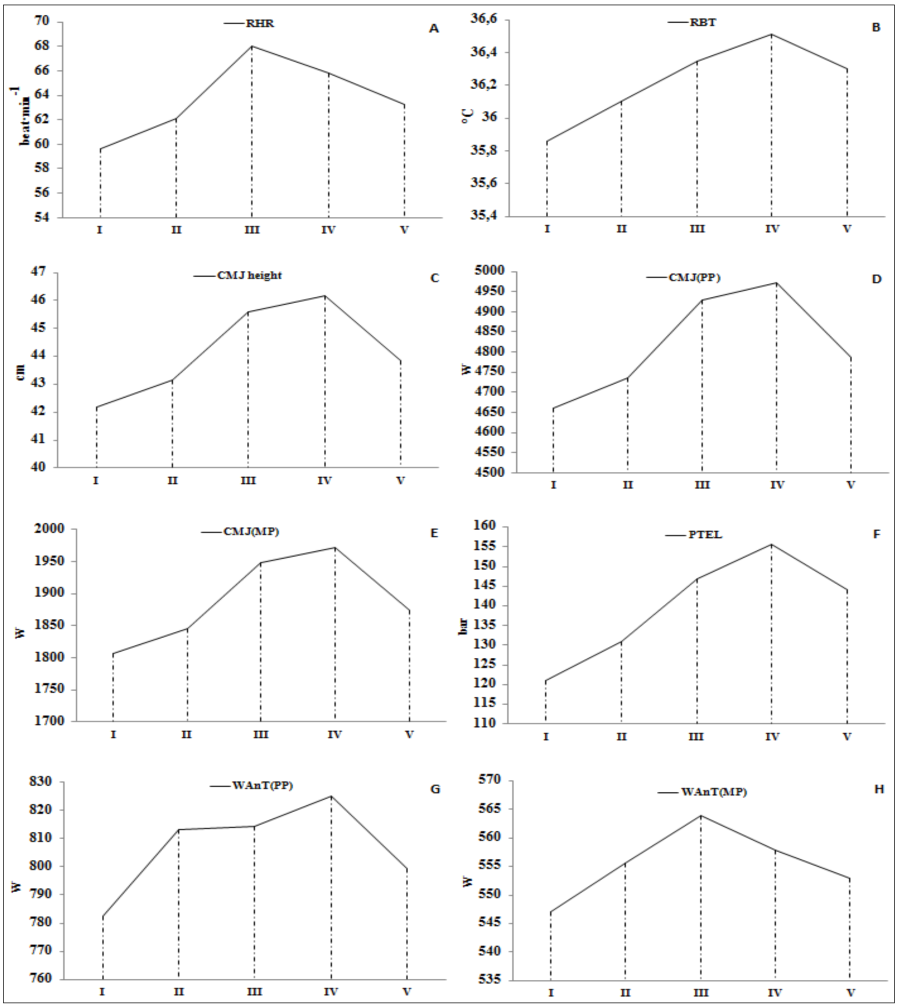
Table 1. Changes in physical and physiological parameters belonging to the five different time of the day

Variables	1	2	3	4	5	p	G	p
$RHR_{(beat \cdot min^{-1})}$	59,6±3	62,1±2,6	**68,0±2,5**	65,7±5,6	63,2±1,7	0.001	**1-2**	**,032***
							1-3	**,001***
							1-4	**,014***
							1-5	**,014***
							2-3	**,001***
							2-4	,159
							2-5	,269
							3-4	,295
							3-5	**,001***
							4-5	,186
$RBT_{(°C)}$	35,8±0,1	36,10±0,1	36,3±0,1	**36,5±0,1**	36,0± 0,1	0.001	**1-2**	**,001***
							1-3	**,001***
							1-4	**,001***
							1-5	**,001***
							2-3	**,001***
							2-4	**,001***
							2-5	**,009***
							3-4	**,023***
							3-5	,508
							4-5	**,003***
$PTEL_{(bar)}$	121±19,6	130,8±13	146,7±21,4	**155,5±22,8**	144,2±23,6	0.001	1-2	**,028***
							1-3	**,001***
							1-4	**,001***
							1-5	**,001***
							2-3	**,003***
							2-4	**,001***
							2-5	**,014***
							3-4	**,032***
							3-5	,571
							4-5	**,004***
$CMJ_{(PP)}$	4659,9±544,5	4734,9±603,4	4927,9±509,6	**4973±577,9**	4788,1±563,3	0.001	1-2	,495
							1-3	,102
							1-4	**,014***
							1-5	,228
							2-3	,137
							2-4	**,046***
							2-5	,483
							3-4	,709
							3-5	,130
							4-5	**,010***
$CMJ_{(MP)}$	1806,5±283,2	1846,1±308,4	1947,8±253,6	**1971,7±290,6**	1874,1±283,8	0.001	1-2	,495
							1-3	,102
							1-4	**,014***
							1-5	,228
							2-3	,137
							2-4	**,046***
							2-5	,483
							3-4	,709
							3-5	,130
							4-5	**,010***
$WAnTPP_{(W \cdot kg^{-1})}$	11,89±1,62	12,39±2,12	12,40±1,9	**12,54±1,5**	12,1±2,09	0,634	1-2	,467
							1-3	,379
							1-4	,344
							1-5	,606
							2-3	,972
							2-4	,654
							2-5	,447
							3-4	,665

							3-5	,289
							4-5	,448
WAnTMP$_{(W\cdot kg^{-1})}$	8,3±0,63	8,44±0,77	**8,56±0,66**	8,46±0,50	8,41±0,82	0,193	1-2	,214
							1-3	**,009***
							1-4	,263
							1-5	,315
							2-3	,062
							2-4	,889
							2-5	,634
							3-4	,354
							3-5	**,046***
							4-5	,747

*$p<0.05$, **RHR**= resting heart rate; **RBT**= resting body temperature; **PTEL**= paldeung technique effect level; **CMJ**= counter movement jump; **WAnT**= Wingate anaerobic test; **PP**= peak power; **MP**= mean power; **1**= 08^{30}-10^{30}; **2**= 11^{30}-13^{30}; **3**= 14^{30}-16^{30}; **4**= 17^{30}-19^{30}; **5**= 20^{30}-22^{30} time periods; **G**= group comparisons.*

The graphical presentations of the physical and physiological variable changes were shown in the Graphic 1.



Graphic 1. Graphical presentation of the variable fluctuations.

***A**= resting heart rate (RHR); **B**= resting body temperature (RBT); **C**= vertical jump height (CMJ); **D**= vertical jump peak power ($CMJ_{(PP)}$); **E**= vertical jump mean power ($CMJ_{(MP)}$); **F**= Paldeung technique effect level (PTEL); **G**= Wingate test peak power (WAnTPP); **H**= Wingate test mean power (WAnTMP); **I**= 08^{30}-10^{30}; **II**= 11^{30}-13^{30}; **III**= 14^{30}-16^{30}; **IV**= 17^{30}-19^{30}; **V**= 20^{30}-22^{30} time periods.*

Resting body temperature was found to have a significant positive relationship with $CMJ_{(PP)}$ and $CMJ_{(MP)}$ and a significant negative relationship with RHR whereas despite the relationship found in CMJ, PTEL, WAnTPP, WAnTMP, WAnTPP $_{(W \cdot kg^{-1})}$ and WAnTMP $_{(W \cdot kg^{-1})}$ it was not statistically significant (Table 2).

Table 2. Correlation coefficients *(r)* between resting body temperature and test variables

		RBT				
Variables		**1**	**2**	**3**	**4**	**5**
RHR	r	-0,078	0,613	0,400	**-0,795**	-0,121
	p	0,843	0,079	0,918	**0,024**	0,756
CMJ	r	0,110	0,145	0,940	0,089	0,511
	p	0,778	0,711	0,810	0,820	0,160
$CMJ_{(PP)}$	r	**0,776**	0,583	0,602	0,090	0,432
	p	**0,014**	0,100	0,086	0,817	0,246
$CMJ_{(MP)}$	r	**0,762**	0,564	0,586	0,075	0,469
	p	**0,017**	0,113	0,097	0,847	0,203
PTEL	r	0,391	0,569	0,614	0,106	-0,150
	p	0,298	0,110	0,079	0,786	0,970
WAnTPP	r	0,117	0,425	0,498	-0,090	0,252
	p	0,764	0,254	0,172	0,818	0,513
$WAnTPP_{(W \cdot kg^{-1})}$	r	-0,363	0,059	0,102	-0,221	0,168
	p	0,337	0,880	0,793	0,567	0,666
WAnTMP	r	0,231	0,424	0,631	0,530	0,153
	p	0,551	0,255	0,068	0,892	0,694
$WAnTMP_{(W \cdot kg^{-1})}$	r	-0,593	-0,164	0,115	-0,135	0,034
	p	0,093	0,673	0,769	0,730	0,932

p<0.05,* ***RHR**= resting heart rate;* ***RBT****= resting body temperature;* ***PTEL****= paldeung technique effect level;* ***CMJ****= counter movement jump;* ***WAnT****= Wingate anaerobic test;* ***PP****= peak power;* ***MP****= mean power;* ***1****=* 08^{30}-10^{30}; **2**= 11^{30}-13^{30}; **3**= 14^{30}-16^{30}; **4**= 17^{30}-19^{30}; **5**= 20^{30}-22^{30} *time periods*

DISCUSSION

The effect of circadian rhythm on sporting performance has been revealed by many studies. (Bougard et al., 2009). In addition, some other related variables have been dealt with such as maximal and resting heart rate (Afonso et al., 2006), maximum isometric power, hormonal adaptations (Sedliak et al., 2007), flexibility, reaction time, body temperature (Reilly and Waterhouse, 2009), isokinetic leg power (Wyse et al., 1994), oxygen intake kinetics (Briswalter et al., 2007; Burgess et al., 1997), anaerobic power and capacity (Hill and Smith, 1991). Body temperature is one of the basic variables of circadian rhythm and it has been stated that many performance elements follow body temperature changes (Waterhouse et al., 2005).

The change obtained at different times of the day between some physical and physiological parameters may also result from chronotypical differences (Kurt, 2009). In the present study, morningness-eveningness type questionnaire (Pündük et al., 2005) was used in order to determine the athletes' circadian types. The information informed from this questionnaire showed that the participants were rather close to the evening type *(40,7±9,6 points)*. The Epworth questionnaire, which measured the participants' sleep quality showed no sleep disorder with their sleep quality *(5,4±2,4 points)*.

According to Afonso et al., (2009) resting heart rate changes during the day Akkurt (1996) observed that RHR was higher in the afternoon in comparison to the morning, whereas in another study Özdamar (2009) found it for the evening period. In the present study, RHR was found higher in the period 3 *(68,0±2,5* $beat \cdot min^{-1}$*)*. According to *LSD post-hoc* analysis, the significant difference found between 1-2, 1-3, 1-4, 1-5, 2-3 and 3-4 time periods *($p<0.05$)*. Heart rate may adapt to physiological or environmental conditions at different times of the day. This difference occurring in RHR is considered to be related to body temperature and autonomic activity (Burgess et al., 1997).

The approximate increase of 1-2 °C in body temperature with the effect of circadian rhythm may increase heart rate nearly 5-10 beat·min^{-1} (Waterhouse et.al, 2007). In the present study, a statistically negative correlation between RBT and RHR was found only in the time period 4. Even though RBT is known as one of the basic indicators of circadian rhythm, there are studies that associate physical and many physiological parameters with circadian rhythm (Callard et al., 2000). Studies have shown that the lowest body temperatures occur in the morning and the highest values in the evening (Baxter and Reilly, 1983; Bernard et al., 1998; Chittababu, 2013; Guette et al., 2005).

The findings of the present study which were obtained in RBT at five different times of the day showed that measurements taken period 4 *(36,51±0,1°C)* were statistically higher *($p<0.05$)* than those taken in period 1*(35,86±0,1°C*). In addition, according to *LSD post-hoc* analysis, significant differences were found between 1-2, 1-3, 1-4, 1-5, 2-3, 2-4, 2-5, 3-4 and

4-5 time periods and the results observed were in compliance with prior studies carried out on the RBT. In the present study, a 0.65 °C difference was found in RBT in period 4 between period 1, and these difference accounts 1.8% of the participants' daily RBT averages. Some other studies have also shown differences of 1.7% (Hill and Smith, 1991) and 2% (İşler, 2006). This diurnal fluctuation that occurred in the present study between morning and evening periods is considered to be a result of endogenous and exogenous effects (Bougard et al., 2009). Moreover, mechanisms of heat production and heat loss may be responsible for the daily change in body temperature (Reilly and Waterhouse, 2009). The increase and decrease in RBT was found to be parallel with particularly short-term physical performance (Hill and Smith, 1991). A 1°C temperature raise in the muscle was observed to increase vertical jump performance by 4.2%, peak power by 4.4%, mean power 4.7%, leg power at $90°·s^{-1}$ by 4.7% at $180°·s^{-1}$ by 4.9% and bicycle performance by 5.1% (Oksa et al., 2010). In one study, tests including bicycle, jump and 50 meter sprint were compared at 09:00, 14:00 and 18:00 o'clock and performance indicators obtained at different times of the day were observed to increase depending on the increase and decrease in RBT (Bernard et al., 1998). In another study that examined circadian changes in anaerobic performance, no relationship was found between body temperature and anaerobic performance (İşler, 2005). In the findings obtained in present study, RBT was found to have a significant positive relationship with $CMJ_{(PP)}$ and $CMJ_{(MP)}$ and a significant negative relationship with RHR whereas despite the relationship found in CMJ, PTEL, WAnTPP, WAnTMP, $WAnTPP_{(W·kg^{-1})}$ and $WAnTMP_{(W·kg^{-1})}$ it was not statistically significant.

In the studies that have been carried out it can be seen that jumping performance show circadian rhythm and the lowest values are measured in the morning while the highest in the evening (Bernard ert al., 1998). In the findings obtained from the multi-jump test at 09:00, 14:00 and 18:00 o'clock, the values obtained at 14:00 and 18:00 were seen to be higher than those occurred at 09:00 (Briswalter et al., 2007). However, in another study which analyzed jump heights at 08:00 *(60±8 cm),* 13:00 *(62±10 cm)* and 17:00 *(60±10 cm)* o'clock in an environment at 28 °C temperature and 62.6% humidity, jump heights did not show any circadian changes (Racinais et al., 2004). The findings obtained from present study were observed to be in line with those of the other study. An 8.8% circadian change occurred in jump height at 5 different times of the day. In other studies, this difference was found as 5.8% (İşler, 2005) and 3% (Reilly and Down, 1986). Moreover, the fact that a significant circadian difference was found in $CMJ_{(PP)}$ and $CMJ_{(MP)}$ values and that anaerobic performance was evaluated with a performance which is frequently employed in taekwondo like jumping may yield better results in observing circadian changes.

Studies have been conducted on circadian changes in sport-specific performances as well, and better results were obtained at afternoon and evening periods in sport-specific skills (Bessot et al., 2006; Chittababu 2013; Reilly et al., 2007). As for the effect of circadian rhythm on PTEL in taekwondo, the measurements taken at period 1 *(121±19,6 bar)*, period 2 *(130,89±13,4 bar)*, period 3 *(146,78±21,4 bar)*, period 4 *(155,56±22,8 bar)* and period 5 *(144,22±23,6 bar)* showed that those taken at period 4 were significantly *($p<0.05$)* higher than the morning periods. In addition, the significant differences between time periods found by the *LSD post-hoc* analysis may show that important changes might occur in the effect level of a taekwondo-specific technique at different periods of the day.

Many studies that used WAnT for anaerobic peak and mean power showed a circadian change (Hill and Smith, 1991; İşler, 2006; Souissi et al., 2008). In a study which compared 03:00, 09:00, 15:00 and 21:00 periods, significant circadian changes were observed in the participants' peak power at 03:00 *(788±63 W)* and 21:00 *(863±67 W)* (Hill and Smith, 1991). In the findings obtained from the present study, the highest difference *($p>0.05$)* was seen between period 1 and period 4 in $WAnTPP_{(W\cdot kg^{-1})}$ whereas the highest difference *($p<0.05$)* was found between period 1 and period 3 in $WAnTMP_{(W\cdot kg^{-1})}$.

In conclusion, positive changes in some physical and physiological parameters caused by circadian rhythm in different time periods of the day designed concerning match schedules are considered to yield to a better performance in combined techniques including jump and paldeung of 1-5 seconds particularly in matches held in the afternoon or evening periods. Therefore, in order to improve individual athletic performance, chronotypical features and the effects of circadian rhythm must be considered in designing training and competitions schedule. For better results, these issues must be noticed when arranging training and competition times and programs for elite athletes.

Acknowledgements

The authors would like to express their gratitude to the athletes who participated to the study, and to the coaches for their assistance in organizing the testing sessions.

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