The Effects of Time of Day and Chronotype on Anticipation Timing Performance in Team Sports Athletes

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Abstract

The aim of this study was to determine whether anticipation of timing performance (AT) of team athletes changed according to the time of day and chronotype. Forty-six male team athletes who exercise regularly at least 3 days a week, participated in the study voluntarily. The athletes were divided into two groups: morning type (MT, n = 23) and evening type or close to evening type (ET, n = 23). The AT performance at high stimulus speed of athletes (12 mph) was measured in two different time periods of the day (08.00-10.00 h, 20.00-22.00) at least 2 days interval in the laboratory environment using the counter-balanced research design. As a result of the statistical analysis, it was determined that the absolute error score (12 mph) was superior in the AT task in the morning hours (13.64±5.44 ms) compared to the evening hours (16.08±3.77 ms) (t = -2.361, p = .023, effect size: 0.34). The absolute error score in the AT task in the morning hours compared to the evening hours of the MT group was found to be significantly lower (t = -9.293, p = .000, effect size: 1.93). When the absolute error scores of the ET group measured in the AT task in the morning and evening hours were compared, a statistically significant difference was detected in favor of the evening hours. (t=3.133, p=.005, effect size: 0.65). In addition, while the absolute error scores of the MT group were found to be lower than the ET group in the morning hours (t = -5.345, p = .000, effect size: 1.57), the absolute error scores of the ET group in the evening hours was better as compared with MT group (t=4.420, p=.000, effect size: 1.30). It is extremely important that coaches or exercise specialists should take into account the concept of chronotype in order to achieve optimal cognitive performance of athletes, especially in planning specific perceptual-cognitive exercises.

Keywords: Anticipation Timing, Chronotype, Team-Sports Athletes, Time Of Day

2. Introduction

The biological rhythm of humans and other mammals is regulated by environmental signals called zeitgebers. The most important and strongest of these signals is the light and dark cycle. Therefore, all the molecular, physiological, cognitive, behavioral, and endocrinological functions required for healthy life are controlled by an internal body clock that measures the time at approximately 24-hour intervals depending on the light and dark cycle. The rhythms produced by the clock are called circadian rhythms (1,2,3,4). In humans, the circadian rhythm is managed by the central clock located in the Suprachiasmatic Nucleus (SCN) in anteroventral hypothalamus (5). SCN is the main actor in the production and regulation of rhythms, and controls the peripheral clocks in other tissues and cells in the body through the neural and humoral nerves (5,6). At the same time, the central pacemaker of the SCN takes direct input from the retina with respect to the fothic (light) signals depending on the solar cycle (7). In line with this information received through the retino-hypothalamic pathway, SCN organizes daily behavioral and physiological rhythms (hormone release, body temperature, neural activation, autonomic effects, gene expression) according to the solar time and sleep-wake cycle (8,9). The circadian system is highly sensitive to environmental cues such as light (10), sleep (11,12), nutrition (13,14), exercise (13,15,16) that synchronize the inner rhythms to external cycles, and also effected by characteristic of inter-individual variability called as chronotype which is the differential expression of circadian rhythms (16,17)

The chronotype is modified according to partially genetics, age, gender, activity, and environment, and also expresses individuals' choices in the timing of sleep and wakefulness or individual differences in subjective wakefulness throughout the day (18,19). In other words, it indicates when the person feels best or feels sleepy on a normal day or when he/she prefers to start the day (early or late awakening preference). Circadian rhythm expression differs among individuals, and three chronotype concepts can be mentioned in the formation of circadian typology. These; morning type (larks), evening type (owls) and intermediate

(intermediate). Morning-type individuals sleep and wake up early, achieve the highest mental and physical performance in the early hours of the day, their level of arousal is maximum in the morning, but the high level of arousal in the evening is replaced by fatigue. On the contrary, evening type- individuals go to bed, and wake up late (wakes up in the morning with difficulty), they perform their best performance at the end of the day, especially in the evening hours (2,18,20). In the literature, the morningness-eveningness survey which was developed by Horne and Ostberg (21), is used to determine these chronotype

In studies, the effect of circadian rhythm on physical performance was adequately researched, and it was shown that rhythmicity in physiological and behavioral processes was closely related to the highest physical performance times (22). For example; body temperature is the major endogenous determinant of the individual's congenital circadian rhythm (23). It was reported that core body temperature peaked around 18.00 p.m, and the lowest values around 04.00-06.00 a.m. (24,25). In a study, it was observed that the body temperature reached the peak values at 16.00 h in morning types, and 17.08 h in evening types. Therefore, it was stated that the body temperature in the morning type reached the acrophase 68 minutes before the evening types (26). High body temperature is extremely important for high physical performance. Most of the current research showed that the peak values in many performance characteristics related to physical capacity coincided with the highest core body temperature in the afternoon-evening hours (16.00-18.00 h) (8,27,28). In a study on field hockey players, a significant difference was found in the peak performance of the players according to the circadian phenotype (chronotype). The peak performance values were observed in 12.19±1.43 h (around mid-day) in morning types, 15.81±0.51 h (around mid-afternoon) in intermediate types, and 19.66±0.67 h (in the evening) in evening types. It was also indicated that the the peak performance of morning type, intermediate type, and evening type was at 5.60±1.44 h, 6.54±0.74 h, 11.18±0.93 h after entrained wake-up time, respectively. Finally, it was remarked that circadian phenotype, and especially time since entrained awakening were the most important and reliable predictor of optimal or peak performance, rather than the time of day (29).

In both individual and team sports, it is not enough for athletes to have a good physical capacity for high level performance. The optimal performance requires high level physical and cognitive performance (22,15,30,31). Especially in team sports, players face unexpected situations in an unpredictable dynamic environment, and need to make the right decision within seconds of events. Despite these situations, which are varied within the game and cause additional stress on players, it is very important for team performance that players exhibit high-level perceptual-cognitive skills or proactive behavior such as reading the game, creative thinking, and quick response. The perceptual-cognitive skills are used to perceive, analyze the situation, and make correct-efficient decisions in team sports, and include anticipation, reaction, use of local information hints, visual scanning, positioning or status information of teammates, opponents and ball (32). One of these perceptual cognitive skills is anticipation timing (AT) performance, which is the ability to forecast events before it happens, and to synchronize the motion response according to these events. This ability depends on necessary clues taking from the direction/speed of the ball, and the opponent players or teammates. In short, it is called the ability to read the game, and forms the basis for high-end performance (33,34,35,36). AT performance is extremely important for the timing and synchronization of different motor actions occurring both in daily life, and in the game in team and individual sports (37)

The accurate and successful AT performance depends on the timely prediction of a rapidly moving object in a dynamic environment (estimation of the speed and direction of the ball), appropriate body movements towards the object (foot movements or correct positioning), and the position of the object when the response was complete. Otherwise, biased or wrong detection of moving object may cause temporal error (38). Developing skills such as visual recognition, pattern recognition and status information enhances an athlete's ability to predict the game from the general framework (36).

Contrary to physical performance, there are quite a limited number of studies showing that circadian rhythm causes daily fluctuations in the measurement of perceptual cognitive skills, and these skills vary according to the time of day and chronotype. In studies, it was reported that the time of day had an impact on perceptual-cognitive skills such as reaction time, selective and constant attention (31), orienting or executive attention (39,40,41), positive alertness ratings or working memory (42,43), and these studies was shown that perceptual cognitive skills were better in the morning hours compared to evening hours. Besides, the previous studies also demonstrated that the there was chronotype effect on perceptual-cognitive skills, such as psychomotor vigilance, executive function (22,41), working memory (42), inhibitory control (20), decision-making (44), and individuals achieved their peak cognitive performance at their most appropriate hours of the day according to the specific chronotype (morning type: morning hours, evening type: evening hours). This is the first study to examine the effects of time of day and chronotype on anticipation timing in team athletes. This shows the importance of the study in terms of literature. Our hypothesis in this study was that the time of day and chronotype had an effect on the AT performance, and chronotype was a factor to be considered in planning training programs.

2. Method

2.1. Participants

Forty-six male athletes studying at the Faculty of Sports Sciences, exercising regularly for at least 3 days a week, without having any health problems, engaged in team sports such as football, basketball, volleyball, korfball, and handball, participated in the study, voluntarily. Before the study started, the detailed explanation was given to the athletes about the content, purpose and methodological model of the research. The Informed Consent Form was signed to the athletes who reported that they were volunteers to attend in the study. Later, the chronotype of the athletes were determined by applying the Morningness-Eveningness questionnaire, and they were divided into two different chronotype groups: morning type (MT, n = 23, mean age: 20.52 ± 1.87 years) and evening type (ET, n = 23, mean age: 20.47 ± 1.37 years). The 18 athletes of MT group were morning type, the remaining 5 athletes were close to the morning type, and the ET group was made up of 19 evening type, and 4 close to evening type athletes. The AT performance at high stimulus speeds (12 mph) of two chronotype groups was determined in two different time periods of the day at least 2 days in the laboratory environment interval using the counter-balanced research design.

2.2. Collection of Data

The measurements of the study were performed in 5 sessions in the Sports Sciences Performance laboratory. In the study, AT measurements of MT and ET group both in the morning and evening hours were performed at least two days apart (31), and a counterbalanced research design was used (Table 1). Counter-balanced research design is a research design frequently used in the literature to neutralize the sequence effect in the application of measurements or sessions, especially in studies related to circadian rhythm, performance and chronotype (1,15, 40,42,45)

Table 1. *Data collection process*

1.session	2.session	AT measurements		
Information about the study Implementation of the questionnaire	Anthropometric measurements	3. session: EM of the MT group 4. session: ME of the ET group	Break for 2 days	5th session: EM of the ET group 6th session: MM of MT group

MT: morning type, ET: evening type, MM: morning measurements, EM: evening measurements

In a study conducted on athletes, short-term sleep deprivation was reported to negatively affect reaction time performance from perceptual-cognitive characteristics (30). Therefore, the participants were asked to sleep at least 8 hours before each test session, and to come to the light full stomach provided that they were received nutrients at least two hours prior to performed in the morning and evening hours (3rd, 4th, 5th, 6th session) (15). In addition, participants were provided with the necessary information about maintaining their habitual physical activities throughout the study period, not doing high-intensity exercises, and not using substances such as alcohol and caffeine before each test measurement (30). It was also noted that the laboratory, where the measurements took place in all sessions, was the same in terms of environmental factors such as light, temperature and noise.

2.3. Data Collection Tools

Height and body weight measurements: The body weight of the participants were measured with Seca (Germany) electronic scale (bare feet, shorts and T-shirt) with a sensitivity of 0.01 kg, and their height was determined with a metal meter that stands fixed on this scale, and has a precision of 0.01 cm (46).

Chronotype: In this study, the Morningness-Eveningness questionnaire form, which was developed by Horne and Ostberg (1976), and adapted to Turkish language by Punduk et al. (47), was used to determine the morning and evening types of athletes. The questionnaire, is a Likert scale type including of 19 questions, which detect the circadian type of the athletes, possible answers are presented as 4 options. Each response option is clearly schematized. The timetable is utilized in the answer to the questions 1, 2 and 10. This ruler is splitted into a 7-hour timeframe, and is stated in 15-minute sub-slices. The answer options of the other questions are in the form of boxes. Five different circadian type classification is performed according to the total scores obtained for 19 questions; "absolutely morning type" in the range of 70- 86 points, "close to the morning type" in the range of 59-69 points, "intermediate type" in the range of 42-58 points, "close to the evening type" in the range of 31-41, "absolutely the evening type" in the range of 16-30. The validity of the original questionnaire, and the classification of the circadian type were examined with changes in body temperature.

AT performance: The AT measurement of athletes at high stimulus speeds (12 mph) was performed with the Bassin Anticipation Timer (Lafayette Instrument Company, Model 35575). This device was developed by Stanley Bassin to measure the area of visual acuity related to hand-eye coordination and prediction time performance. The studies were reported that this device was highly valid and reliable to measure the performance of AT performance in different sports branches (34,48,49,50,51). Rodrigues et al. (52) defined the stimulus speed of 12 mph (536.4 cm/s) as "fast". Therefore, the criteria of Rodrigues et al. (52) were taken in selecting 12 mph stimulus speeds in AT performance measurements in this study. The anticipation device consists of 3 parts; control console, the response button, and the runway (set; ground on which the LED lights move, 2.24m) where the LED lights (49 lamps, 1st lamp yellow lamp = warning lamp) move in a linear pattern. The LED lamps light up sequentially in a linear pattern in a right-to-left movement (53).

Before the measurements, the athletes waited ready in the laboratory at least 15 minutes before the specified time periods. The device was installed on the table, approximately 87 cm above the ground. First, detailed explanations were given to the athletes by the researchers about how to measure the AT performance on the Bassin Anticipation Timer device, and the points to be considered during the measurements. Before the measurements started, the start and end speeds of the device were set to 12 mph, and the target light was specified as the 8th lamp of the 3 sets. The warning light was set randomly with a delay between 1 and 2 seconds to minimize the possibility of participants predicting the time of the light (49). Next, athletes were individually taken to a quiet, calm, and low-light room for AT measurement. Before the actual measurement, each athlete familiarized with the using the Bassin Anticipation Timer, and had 5 trials at 12 mph stimulus speed. After, the athlete waited ready at the beginning of the device, and the signal was sent by the researcher. The athlete was asked to press the button using the dominant hand as close as possible to the time of arrival of the stimulus at the target location (target light) (34,49,53). Ten measurements were taken from each athlete at 12 mph stimulus speed. The results were registered in milliseconds, depending on whether the reaction of athlete was early or late. The raw scores obtained were converted to absolute error scores, and evaluated for statistical analysis. While performing CAT measurements, the athletes were not verbally instructed, and also were not informed about stimulus speed.

Absolute error score: It is a type of error frequently preferred in the evaluation of EC performance in the literature. It refers to the absolute value of each raw value regardless of whether the response of the participant is early or late, and gives information about the accuracy of the performance of participant during the tests (34,54,55). High absolute error scores indicated that more errors were made during the measurements, and poor AT performance.

Statistical Analysis: The data obtained from the study were recorded in SPSS (20.0) program. Firstly, it was determined whether the data had normal distribution or not. According to the results of Shapiro-Wilk test, all data showed normal distribution. The Paired Samples t Test was used to compare the absolute error scores of the participants according to the time of day (morning and evening hours). The comparison of the absolute error scores of the groups (within the group) measured in the morning and evening hours was analyzed with the Paired Samples t test. The comparison absolute error scores measured in the morning and evening hours in terms of chronotype were determined by Independent Sample t Test. In addition, the effect size of the absolute error score of the two groups according to the time of day and chronotype was calculated. Cohen's d (56) values were taken into consideration for the effect size. Significance level was evaluated as p <0.05, p <0.01 and p <0.001.

3. Results

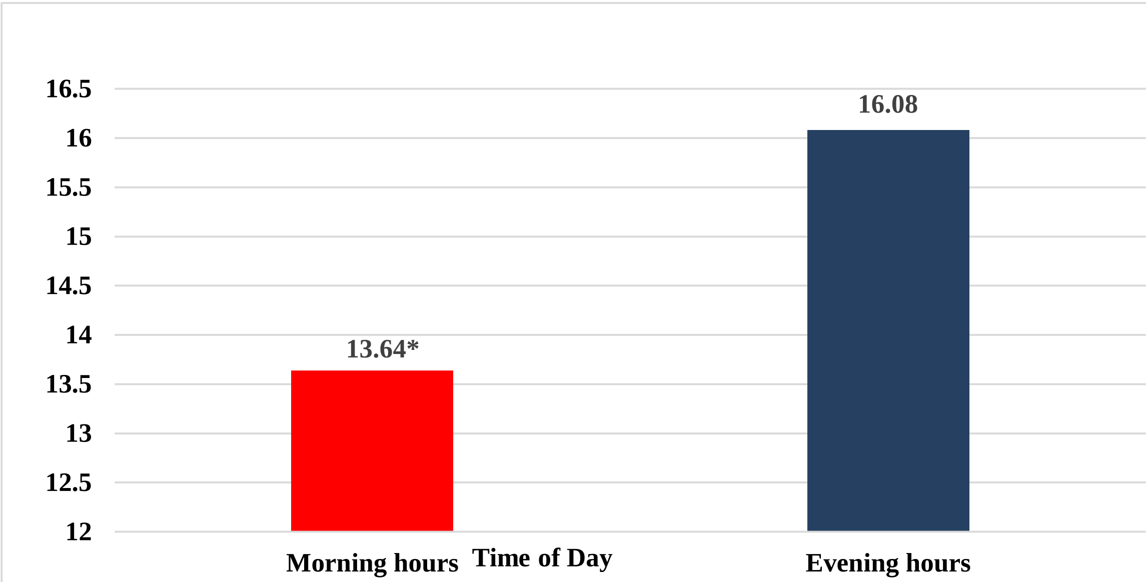
Table 2. *The values of age, height, body weight, and Morningness-Eveningness Questionnaire of the MT and ET group*

Variables	Groups MT (M±S.D.)	ET (M±S.D.)
Age (years)	20.52±1.87	20.47±1.37
Height (m)	1.76±.07	1.74±.08
Body weight (kg)	75.76±8.55	70.61±7.14
Morningness-Eveningness Questionnaire	70.73±5.69	26.52±6.58

MT: Morning Type, ET: Evening Type

In Table 2, the age, height, and body weight values of the MT and ET group were determined as 20.52±1.87 years, 20.47±1.37 years, 1.76±.07 m, 1.74±.08 m, 75.76±8.55 kg, 70.61±7.14 kg, respectively. In addition, according to the results of the Morningness-Eveningness Questionnaire; the score of the MT group was found to be 70.73±5.69, and the score of the ET group was 26.52 ± 6.5.

Graphic 1. *The comparison of absolute error score (12 mph) (ms) by the time of day without discriminating between groups*



As shown in Graphic 1, the absolute error score (12 mph) was found to be lower in the CAT task in the morning hours (13.64 ± 5.44 ms) compared to the evening hours (16.08 ± 3.77 ms) without any group discrimination (t = -2.361, p = .023, effect size: 0.34, small effect). This suggested that the AT performance was better in the morning hours.

Table 3. *The comparison of absolute error scores (12 mph) (ms) of MT and ET group by the time of day.*

Groups	Time of Day	M±S.D.	N	t	p	Cohen's d
MT	Morning hours	10.79±4.44	23	-9.293	.000***	1.93
	Evening hours	18.15±3.56	23			
ET	Morning hours	17.87±4.55	23	3.133	.005**	0.65
	Evening hours	14.01±2.73	23			

**p<0.01, ***p<0.001, MT: Morning Type, ET: Evening Type

In Table 3, the absolute error score (12 mph) of MT group in the morning hours was significantly better than the evening hours (t=-9.293, p=.000, effect size: 1.93, large effect). When the absolute error scores of the ET group in the morning and evening hours were compared, a statistically significant difference was found in favor of the evening hours (t=3.133, p=.005, effect size: 0.65, medium effect).

Table 4. *The comparison of the absolute error scores (12 mph) (ms) measured in the morning and evening hours in terms of chronotype*

Time of Day	Groups	N	M±S.D.	t	p	Cohen's d
Morning hours	MT	23	10.79±4.44	-5.345	.000***	1.57
	AT	23	17.87±4.55			
Evening hours	MT	23	18.15±3.56	4.420	.000***	1.30
	AT	23	14.01±2.73			

***p<0.001, MT: Morning Type, ET: Evening Type

In Table 4 showed that the absolute error score of ET group was significantly higher than MT group in the morning hours (t = -5.345, p = .000, effect size: 1.57, large effect). The MT group reached their peak AT performance in the hours. In the evening hours, the absolute error scores of the ET group compared to the MT group were found to be superior, and ET group achieved their peak AT performance in the evening hours. These results specified that the AT performance of the athletes differed according to the chronotype, and that the chronotype had a great effect on AT performance

4. Discussion and Conclusion

AT performance has a very important place in both individual and team sports. Considering the dynamic characteristic of team sports, predicting the game, positions, team-mate or opponent's movements in advance helps the athletes save time, react quickly, and make an effective and correct decision, and also has an advantage over other players. The aim of this study was to determine whether the AT performance, which is included in the perceptual-cognitive features, varied according to the day time (08.00-10.00 h, 20.00-22.00), and the chronotype (morning type, and evening type).

The cognitive performance parameters, including simple and choice reaction time, have a circadian rhythm that reflects the presence of 24-hour periodicity in the nervous system (15). According to the results of this study, it was ascertained that the absolute error score (12 mph) was lower in the morning hours (13.64±5.44 ms) compared to the evening hours (16.08±3.77 ms) without group discrimination (Graphic 1). This demonstrated that the AT performance differed according to the time of day, and was better in the morning hours. When the literature is examined, there are limited studies examining the time of day effect on AT performance. The AT performance directly affects the speed of the reaction time, and there is a very close relationship between them. The results of this study were in line with the results of Jarraya et al. (31). They reported that reaction time, selective, and constant attention were the best at 08.00 a.m. in the morning compared to other times of the day (20.00 h, 00.00 h). They also stated that deterioration in perceptual-cognitive performance such as reaction time was observed as the day progressed (especially in the afternoon and evening), and the reason for the reaction time performance to slow down in the afternoon was probably due to the accumulation of fatigue. A similar interpretation can be made in this study. Knight and Mather (39) reported that younger adults exhibited a significant alerting effect (cueing participants to be vigilant for an upcoming target) on the morning (08.00-10.00 h, M = 35.16±22.95) and afternoon test (14.00-17.00 h, M = 24.10±23.81) in Attentional Network Test. Hasler et al. (45) specified in their study on healthy adults that the reaction time was better, although not significant, in the morning hours (697.70±125.01 ms) compared to evening hours (711.86±176.39 ms). Unlike the results of this study, Kline et al. (57) found that the reaction time was superior at noon (14.00-20.00) than at the beginning of the day. Reilly et al. (15) observed in their study on non-professional experienced footballers that cognitive performance characteristics such as positive alertness (best at 20:00 h), fatigue self-ratings (worst at 20.00 h), and simple reaction time (medium performance, 16:00 h) showed diurnal rhythm. It was remarked that the reason for different results seen in studies examining the time of day effect on cognitive performance depended on specific parameters containing the cognitive area, duration and difficulty of the task, methods, measured parameters, time of day the test was performed, and chronotype (58). In this study, AT performance was better in the morning hours than in the evening hours, and as the day progressed, AT performance deteriorated. The reason of this situation can be explained as follows; the highest physical performance observes later in the day, parallel with body temperature unlike mental performance. The previous studies stated that cognitive performance were not affected by core body temperature (1,15,31), neuro-endocrine factors may explain the reason of the peak cognitive performance in the morning hours (for example; cortisol hormone which is peaked in the morning hours, increases alertness of individual) (30).

The "chronotype" refers to when individuals sleep or awake are on normal days without feeling any restrictions. Besides to the circadian process, sleep-wake behavior of individuals is affected by how long they have been awake (3,19). The underlying physiology that differentiates individuals of the MT and ET is the length (tau) of the circadian times or "periods". MT individuals have shorter (tau) values that are near a 24-hour period, while ET individuals have midly longer (tau) values than a 24-hour period (41). The intrinsic circadian period also was an important component in the pathophysiology of circadian-related sleep disorders (44). The phase shift is observed in the circadian rhythms of the MT and ET individuals, that is, the peak and lowest values of physiological indicators just as melatonin and body temperature appear earlier (phase delay) in the MT, and later (phase delay) in the ET (58). The circadian phenotype, that is, the drifting state of the circadian system, is also an important decisive of physical performance (29), and cognitive performance (3). In addition to chronotype, entrained wake-up time seem to be the most reliable determinant for high-level performance. (29).

In this study, the absolute error score of the MT group was found to be significantly lower than the evening hours, while the absolute error score of the ET group in the evening hours was superior than the morning hours (Table 3). In addition, the absolute error scores of the MT group were found to be better than the ET group in the morning hours. In the evening hours, the absolute error scores of the ET group compared to the MT group were found to be superior (Table 4). These results noted that the chronotype of athletes had a decisive effect on AT performance measured at different time periods of the day. In the literature, there are no studies evaluating the AT performance according to the chronotype. In studies, different perceptual-cognitive characteristics or cognitive performance parameters were examined in terms of chronotype. Correa et al. (1) showed that the MT group had the best reaction time in the morning hours (10.00 h) by showing higher temporal orienting in the temporal preparation task, and the ET group reached peak reaction time in the evening hours (21.00 h) compared to the morning hours by showing higher temporal orienting in task. The reason for this was supported by the fact that the MT group had higher alertness levels in the morning hours, while the elevated alertness level of ET group was in the evening hours. Correa et al. (1) also stated that the temporal preparation was affected by the chronotype-dependent day time rather than the temporal anticipation. Facer-Childs et al. (22) detected significantly diurnal differences in Psychomotor Vigilance Task (simple task) which indicate the attentional condition of an individual (PVT). The task performance for ET individuals in the morning hours was significantly worse than in the evening hours but not for MT individuals. The diurnal changes in their performance of MT and ET group were 3.5% and 9.1%, respectively. In the morning session (08:00 h), MT group performed 8.4% better than evening type, their performance was found to be better in the morning hours than in the afternoon, and in the evening hours, and also MT group in the morning hours exhibited 5.9% better than ET group in Executive Function (EF) complex tasks. As a results, they observed that MT group displayed at their best earlier in the day compared to ET group. In addition, PVT and EF task (not significant) performance scores augmented from morning to evening hours in ET group but not for MT group, and cognitive performance of MT group in EF complex tasks score reduced in the evening hours as compared with morning hours. A possible reason for this might be due to the complexity, and nature of the task (22) It was reported that the amplitude of diurnal changes between chronotype could be effected by the nature of tasks, i.e. simple vs complex (18,22,58)

The synchronous effect was observed in the evaluation of AT performance results of this study according to the chronotype (20,58). In this study, the reason for the synchronous effect can be explained as follows; West et al. (43) demonstrated the time of day effect on subjective alertness rating in younger and older adults. They stated that alertness ratings were elevated in the morning hours (09.00 h) for older adults (morning type), and in the evening (17.00 h) hours for younger adults (neutral type). In a study, it was reported that the ET group had higher subjective sleepiness (not enough awake) compared to MT groups in all cognitive performance measurements performed in the morning hours (08.00 h), and they performed poorly because they were drowsy. It was noted that this might be an important issue for ET group that often need to "perform" before their usual wake-up time. Combined with the high sleepiness of the ET group (08.00 h) in the morning hours (43), it was also consistent with studies in the literature that partial sleep deprivation negatively affected the parameters associated with cognitive performance (30,59,60). It was also pointed out that the time since entrained awakening could be utilized effectively to forecast performance in cognitive tasks in healthy individuals. For MT individuals, cognitive performance was the highest immediately after entrained wake-up time, whereas ET individuals did not achieve their peak performance until at least 12 h after entrained wake-up time. This showed that ET individuals a much more limited opportunity to perform their peak performance during the day which might possess important effects for athletes with ET who need to practice earlier than their biological summits (22). In another study, MT and ET participants was performed the stop-signal task in morning (08:00-12:00 hours), and evening (19:00-23:00 hours) sessions. Compared to ET individuals, the activation level of MT individuals associated with inhibition was significantly higher in the morning hours, but the differences between the chronotype groups decreased in the evening hours. On the other hand, compared to ET individuals, arousal-promoting brain structures of MT individuals in the evening hours were less stimulated to enable to maintain optimum alertness with increased homeostatic sleep pressure. This suggested that activity or performance in MT individuals was impaired in the evening hours due to the negative effect of sleep homeostasis on the hypothalamic constructions including in circadian regulation. It was reported that the differential neurocognitive vulnerability to homeostatic sleep pressure accumulated on chronotype might be a possible commentary of the underlying inter-individual differences in retaining cognition-related cerebral activity (20). Schmidt et al. (42) indicated that MT group displayed greater subjective sleepiness, and lower objective vigilance in the evening hours as compared with the ET group, and the evening circadian alerting signal moved less strongly in MT group than in ET individuals due to the disproportionately increased homeostatic sleep pressure in the MT group. They also showed that MT group performed greater activity than ET group in the middle frontal gyrus during the morning session, while ET group displayed superior thalamic activity than MT group in the evening hours, and also they propounded that higher task complexity caused a transient augment in thalamic related arousal levels in evening types, which could support the best performance under this task condition. Simultaneously, the performance of MT group in morning hours might be promoted by augmented strategic or attentional recruitment of prefrontal areas. Correa et al. (1) claimed that the individuals were the most vigilant at the most appropriate time of the day according to their special chronotype. The results of this study, which showed that AT performance of the MT groups in the morning hours was better than the ET group, and their performance decreased in the evening hours compared to morning hours, whereas the AT performance of ET group in the evening hours was superior than the MT group, their performance increased in the evening hours as compared with morning hours, can be based on the results of the studies which conducted by Correa et al. (1), Facer-childs et al. (2), Schmidt et al. (42), and Song et al. (20)

There is no study to evaluate the AT performance according to time of day and chronotype in team athletes. In conclusion, the first time study showed that AT performance was differed according to time of day and also was found better in the morning hours than in the evening hours. Our main finding which is not in the literature were that cognitive responses related to AT performance was determined to be superior in the morning hours of the MT group, and in the evening hours of the ET group. These results support our hypotheses. It is recommended that specific training that enhance perceptual-cognitive characteristics should be planned by coaches or exercise specialists primarily by considering the concept of chronotype (morning type: morning hours, evening type: evening), that is, the time period when athletes feel best, in order to achieve maximum team performance by providing maximum efficiency from the athletes in the training. The sample group of this study consisted of team athletes who participated in competitions in amateur leagues and university leagues. In these leagues, matches are played under high light (especially in the evening hours) in a dynamic environment filled with distracting signals in the morning, afternoon and evening hours. Therefore, it is extremely important for athletes to have a high perceptual cognitive capacity in these environments, and to maintain their skills throughout the match. In the literature, The MT and ET individuals reached the peak cognitive performance in the morning or towards afternoon hours, and at the afternoon or evening hours, respectively. In addition, in order for the athletes to reach optimal cognitive performance, and to minimize the time of day effect on cognitive performance, it is extremely important to train MT athletes in the evening hours when their cognitive performances were poor, and ET athletes in the morning hours when their cognitive performances were low. In the future studies, the AT performance, reaction time or different perceptual cognitive characteristics of the athletes in different sports branches can be evaluated in terms of three different time periods of the day (morning, afternoon, and evening hours), and three chronotype (morning, intermediate, and evening type).

Conflict of Interest

The authors declare that they have no conflict of interest.

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