# Sleep Quality and Athletic Performance According to Chronotype

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# Abstract

**Background:** When studying the quality of sleep in relation to athletic performance, the athlete's chronotype and habitual time were considered important factors. We aimed to investigate the sleep quality and athletes' performance according to chronotype in elite athletes.

**Methods:** Three hundred forty elite athletes (males = 261, females = 79) were recruited for the present study. All participants were screened for chronotype. Measurements of the Korean versions of the Morningness - Eveningness Questionnaire (MEQ-K), Pittsburgh Sleep Quality Index (PSQI), and Wingate Anaerobic Test (WAnT).

**Results:** PSQI global score, PSQI sleep quality, PSQI sleep onset latency, PSQI sleep disturbance, and PSQI daytime dysfunction were significantly difference in among the groups. Mean power, and peak power were significantly difference in among the groups. A negative correlation was found between PSQI score and mean power (W), mean power (W/kg), peak power (W), and peak power (W/kg).

**Conclusions:** This study indicates that related poor sleep quality and late type of chronotype may reduce the athletes' performance in elite athletes. In additional, significant better sleep quality in early type of chronotype more than late type of chronotype. Moreover, also significant higher athletic performance in early type of chronotype more than late type of chronotype.


# Background

The amount and quality of sleep may affect performance, elite athletes' understanding of sleep patterns is growing [1]. Sleep provides some important psychological and physiological functions that can be the basis of your recovery process [2]. In additional, a good night's sleep is essential to control athlete' hormones secretion and restoring metabolic processes in athletes [3].

Everyone has a biological or circadian rhythm, determined by various hormones [4]. Regulates the sleep/wake system and many other features such as blood pressure, hormone levels, body temperature, physical performance, alertness, mood and intellectual ability to fluctuate during the day [5]. Humans generally suggest that there are larger differences between inter individuals in the timing of behaviors [6]. Previous studies reported that the effects of partial sleep deprivation (i.e., cognitive, physical, hormonal, and inflammatory responses to on various aspects of athletic performances) depend on time during the day, since evening performances decreased, but morning ones were unaffected [7,8]. On the other hand, humans are known to follow a circadian rhythm that peak performance occurs early in the evening and deteriorates in the afternoon [9]. When studying the quality of sleep in relation to the athletic performance, the athlete's chronotype and habitual time were considered important factors [10].

All most athlete can perform wingate anaerobic test (WAnT) and compare with other athlete from "bad" to "excellent" for performance [11]. The standard 30 second WAnT's 5 second and 30 second power output measurements are designed to examine the first two of these energy reserves [12]. In typically, instantaneous results such as peak power (PP), which is the highest running in watts; mean power (MP) as the average power of the entire test in watts; Power Drop (PD) reduces power from beginning to end [13]. The WAnT is the most widely used test for evaluating the ability of human muscles to generate power in anaerobic energy systems [14].

However, there are no published relate sleep state and athletes' performance with chronotype in male and female elite athletes. Thus, we aimed to investigate the sleep quality and athletes' performance according to chronotype in elite athletes.

## Methods

# Participants

Three hundred forty elite athletes (males = 261, females = 79) were recruited for the present study. Athletes from basketball (n=12), rugby (n=22), wrestling (n=4), boxing (n=1), short track (n=5), swimming (n=14), squash (n=8), baseball (n=103), weight lifting (n=4), judo (n=6), soft tennis (n=11), rowing (n=34), canoe (n=9), tennis (n=1), fencing (n=6), field hockey (n=33), and handball (n=67) were recruited. All participants were screened for chronotype using the Korean versions of the Morningness - Eveningness Questionnaire (MEQ-K) by Horne and Ostberg [15]: no definitely morning type (DM), thirteen moderately morning type (MM) (males = 11, females = 2), one hundred sixty-nine neither type (NT) (males = 136, females = 28), one hundred eleven moderately evening type (ME) (males = 75, females = 33), and sixty-one definitely evening type (DE) (males = 39, females = 16). There were no significant differences in age, height, weight, BMI and careers.

All subjects who agreed to participate in the study described the study to fully understand its purpose and the methods used in the ethical standards of the Declaration of Helsinki. In addition, all subjects signed an informed consent form prior to participation. This study was approved by Kangwon National University Review Board for Human Subjects (KWNUIRB-2020-03-007-002).

# Morningness - Eveningness Questionnaire (MEQ)

The Korean Morningness - Eveningness Questionnaire (MEQ-K) from Horne and Ostberg was used to assess the circadian typology of each subject [15]. MEQ has 19 items related to preferred time to participate in habitual physical and mental activities. MEQ scores range from 16 to 86, from extreme morning type to extreme evening type. The standard scores of the MEQ proposed by Horne and Ostberg were used to categorize the subjects as definitely morning type (DM), moderately morning type (MM), neither type (NT), moderately evening type (ME), and definitely evening type (DE)[15]. Cronbach's alpha for the MEQ-K was 0.77, and the correlation coefficient between the MEQ-K scores for verifying the test-retest reliability was 0.898.

# Pittsburgh Sleep Quality Index Questionnaire

The Pittsburgh Sleep Quality Index (PSQI) is a self-report questionnaire that evaluates sleep quality and quantity. The PSQI self-report questionnaire comprises of 19 items, yielding 7 component scores: (1) subjective sleep quality, (2) sleep latency, (3) duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleeping medication, and (7) daytime dysfunction. Each component is graded on a 0–3 severity scale based on the frequency of each disturbance and yields a global score with a range of 0–21 [16]. A PSQI global score of 5 or greater indicates a clinically significant sleep disorder.

# Wingate Anaerobic Test (WAnT)

WAnT was used following experiments performed by Kikuchi et al [17]. The WAnT was performed on a cycle ergometer (Monark 824 E, Monark, Sweden) equipped a photoelectric sensor for recording 1.0 kg resistance basket and flywheel revolutions. Data for each 30-second WAnT were collected using POWER software (SMI, St Cloud, MN) and IBM-compatible microcomputer.

Each participant completed a self-selected stretching exercise and a five-minute cycle at the ergometer without applying a time limit. At the end of one minute of warm-up, each participant performed an "all-out" sprint for 4 to 5 seconds to simulate the actual test.

Before starting of the WAnT, the resistance for each participant was calculated using a body weight of kilograms multiplied by male 7.5% and female 5%, and the determined amount was placed in the basket. At the start of the test, the assistant lifted the resistance basket and no resistance was applied to the flywheel, and each participant was instructed to begin pedal to reach the maximum rpm at the end of the 5 second countdown. The resistance basket was released, and data collection began, subsequently ending after 30 seconds. After 30 seconds WAnT, participants were instructed to pedal against light resistance (1.0 kg) until they returned to their pre-test condition.

# Statistical analysis

The SPSS statistical package version 25.0 for Windows (SPSS, Inc., Chicago, IL, USA) was used to perform all statistical evaluations. Means and standard deviations were computed for all variables, and normality was checked with the Shapiro Wilk test. Non-normal data were converted using square root or logarithmic transformations which achieved normality for all variables. Sleep state and wingate anaerobic power by chronotype were verified through a one-way analysis of variance (ANOVA). The relationships among variables were analyzed using Pearson’s correlation coefficients. Post-hoc analysis (Bonferroni test) was used to compare specific differences when significance was found. Statistical significance was accepted at the 0.05 level.

## Results

## Sleep state according to chronotype

The sleep state according to chronotype shown in Table 2. One-way ANOVA showed that PSQI global score ($p$<0.001), PSQI sleep quality ($p$<0.001), PSQI sleep onset latency ($p$<0.001), PSQI sleep disturbance ($p$=0.002), and PSQI daytime dysfunction ($p$=0.005) were significantly difference in among the groups. However, no significant difference in PSQI sleep duration, PSQI sleep efficiency, and PSQI use of medications. Post-hoc analysis using Bonferroni test indicated that PSQI global score, PSQI sleep quality, and PSQI sleep onset latency in MM group were significantly lower than DE group.

## Wingate anaerobic power according to chronotype

The wingate anaerobic power according to chronotype shown in Table 3. One-way ANOVA showed that power drop (%) ($p$<0.001), mean power (W) ($p$<0.001), mean power (W/kg) ($p$<0.001), peak power (W) ($p$<0.001) and peak power (W/kg) ($p$<0.001) were significantly difference in among the groups. Post-hoc analysis using Bonferroni test indicated that power drop (%), mean power (W), mean power (W/kg), and peak power (W/kg) in MM group were significantly higher than DE group.

## Correlations coefficients between the PSQI score and wingate anaerobic power

Table 4 shown that the correlation coefficients of the PSQI score and wingate anaerobic power. A negative correlation was found between PSQI score and mean power (W), mean power (W/kg), peak power (W), and peak power (W/kg) ($p$<0.01; $p$<0.01; $p$<0.01; $p$<0.01, respectively).

# Discussion

The present study, we investigated the sleep quality and athletes’ performance according to chronotype in elite athletes. The main finding of the study that PSQI global score, PSQI sleep quality, PSQI sleep onset latency, PSQI sleep disturbance, and PSQI daytime dysfunction were significantly difference in chronotype. Also, WAnT various (power drop, mean power and peak power) were definitely significantly difference in chronotype. In addition, a negative correlation was found between PSQI score and WAnT.

Chronotype is an individual difference which reflects the time that an individual is "does his or her best" [18]. Reilly and Waterhouse describe that performance changes are simultaneously affected by other multi-factorial systems, such as external (exogenous), internal (endogenous), and psychobiological (lifestyle) mechanisms [19]. For athletes are very important these timing. Previous studies reported sixteen collegiate rowers had to perform a 2000-m rowing test, as result morning-type subjects rowed significantly faster than other type [20]. Henst et al. reported that endurance athletes who higher preference for the morning was related to the better individual best half marathon and the current marathon performance [21]. In additional, evening-type swimmers averaged 6% slower in the morning than evenings and had 50% higher α-amylase levels in the morning, morning-types required 5-7 times more effort in the evening test to achieve the same performance results as the morning test [22]. We were also used to group athletes according to chronotype by MEQ. Found that power drop (%), mean power (W), mean power (W/kg), peak power (W) and peak power (W/kg) were significantly highest in MM more than late other type (NT, ME, and DE). Cortisol, considered an indicator of psychophysiological stress and associated with poor sports performance, shows the peak of early morning under normal conditions [23]. Also, suggested that evening-types more time is needed to prepare for physical activities or training after waking up rather than in the morning [24]. In other reason that evening-type may have a shorter sleep time during daily activity than other chronotypes [25]. This may further delay the circadian rhythm since the evening-type is reluctant to advance bedtime [26].

In addition, sleep is an important factor in improving athletic performance. Human ability to cope with physiological and psychological stressors is important for the results of athletic performance [27]. It is affected by several factors, including natural fluctuations in physiological and behavioral processes (for example, sleep-wake cycle, body temperature, hormonal regulation) for 24 hours' period [28]. As a result, poor sleep quality and delay circadian sleep phase of athletes from adolescence to adulthood, suggests that the decreased athletic performance substantial [29]. In this study found that PSQI global score, sleep quality, and sleep onset latency were better in MM more than late other type (NT, ME, and DE). Moreover, a negative correlation was found between PSQI score and WAnT. Previous studies, the prolonged period of sleep deprivation is associated with increased sympathetic, decreased parasympathetic cardiovascular control, and spontaneous discomfort sensitivity in healthy adults [30]. Oda and Shirakawa reported that a delayed onset of sleep, significant physiological excitement of sleep time due to increased heart rate, results indicate that they may causes a large physiological excitement during sleep time and interfere with the onset of sleep [31]. This further supports the findings of Hausswirth et al. the decrease in sleep time can be caused by a decrease in efficiency, mainly due to the difficulty of staying stationary during sleep [32]. In additional, improved specific measures of basketball performance after extended sleep may help optimal sleep to reach peak athletic performance [33]. We were observed negative correlation between poor sleep state and athletic performance. Moreover, it may be due to the chronotype.

The present study has some limitations and points to suggestions for further research. We did not control such factors as their normal lifestyle, training schedule, and smoking. We assumed that because the subject has normally rhythm for athletes. Moreover, we also recommend that all participants avoid drastic changes in their lifestyle for about 1-2 weeks prior to the questionnaire. Another limitation is that did not distinguish between male and female. Further research on gender is needed.

# Conclusion

In conclusion, this study indicates that related poor sleep quality and late type of chronotype may reduce the athletes' performance in elite athletes. In additional, significant better sleep quality in early type of chronotype more than late type of chronotype. Moreover, also significant higher athletic performance in early type of chronotype more than late type of chronotype.

# Abbreviation

ANOVA: analysis of variance; BMI: body mass index; DE: definitely evening type; DM: definitely morning type; MEQ-K: korean versions of the morningness - eveningness questionnaire; MP: mean power; ME: moderately evening type; MM: moderately morning type; MEQ: morningness - eveningness questionnaire; NT: neither type; PP: peak power; PD: power drop; SPSS: statistical package for the social sciences; PSQI: The pittsburgh sleep quality index; WAnT: wingate anaerobic test;

# Declarations


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### Authors' contributions

Seung-Taek Lim and Eunjae Lee contributed to conception and design of the study.

Do-Yoon Kim and Seung-Taek Lim implemented the measurements and training sessions. Hyeong-Tae Kwon and Eunjae Lee analysed the participant data. All authors interpreted and discussed the results. All authors drafted parts of the manuscript. All authors read and approved the final manuscript


### Funding

Not applicable.


### Availability of data and materials

Full data for this research is available through the corresponding author upon request.

### Ethics approval and consent to participate

The study was approved by Kangwon National University Institutional Review Board, and conducted in agreement with the Declaration of Helsinki. In advance of their participation, all of the participants were fully informed about the purpose and experimental procedures of the study. All of the participants completed consent forms. The participants were informed that all data collected would be processed anonymously.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

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# Tables

Table 1.
The characteristic of the subjects

| Variable | MM (n=13) | NT (n=164) | ME (n=108) | DE (n=55) | Total (n=340) |
|---|---|---|---|---|---|
| Age (years) | 15.92 ± 1.50 | 16.79 ± 3.43 | 18.03 ± 3.93 | 19.13 ± 4.30 | 17.55 ± 3.81 |
| Height (cm) | 174.5 ± 8.93 | 172.9 ± 7.63 | 172.6 ± 8.16 | 173.6 ± 8.24 | 173.0 ± 7.89 |
| Weight (kg) | 75.35 ± 13.0 | 73.67 ± 15.1 | 72.10 ± 14.1 | 73.46 ± 19.9 | 73.19 ± 15.0 |
| BMI (kg/m2) | 24.55 ± 2.50 | 24.49 ± 4.00 | 24.04 ± 3.48 | 24.09 ± 4.52 | 24.31 ± 3.80 |
| Career (years) | 6.46 ± 2.70 | 6.09 ± 3.40 | 6.76 ± 4.28 | 6.70 ± 4.71 | 6.42 ± 3.92 |

MM; moderately morning type, NT; neither type, ME; Moderately evening type, DE; definitely evening type, BMI; body mass index

Table 2.
Sleep state according to chronotype

| Variable | Groups | | | | |
|---|---|---|---|---|---|
| | MM (n=13) | NT (n=164) | ME (n=108) | DE (n=55) | p-value |
| PSQI global score | 2.46 ± 2.26[a] | 3.14 ± 2.00[c,d] | 4.09 ± 2.15 | 5.05 ± 3.23 | <0.000 |
| PSQI sleep quality | 0.62 ± 0.51[a] | 0.83 ± 0.59[c,d] | 1.06 ± 0.58 | 1.21 ± 0.61 | <0.000 |
| PSQI sleep onset latency | 0.15 ± 0.38[a,b] | 0.62 ± 0.71[c,d] | 0.97 ± 0.87 | 1.16 ± 1.08 | <0.000 |
| PSQI sleep duration | 0.23 ± 0.83 | 0.30 ± 0.70 | 0.41 ± 0.76 | 0.48 ± 0.94 | 0.376 |
| PSQI sleep efficiency | 0.31 ± 0.85 | 0.16 ± 0.57 | 0.16 ± 0.48 | 0.34 ± 0.87 | 0.187 |
| PSQI sleep disturbance | 0.77 ± 0.44 | 0.85 ± 0.57[d] | 1.01 ± 0.50 | 1.13 ± 0.62 | 0.002 |
| PSQI use of medications | 0.15 ± 0.55 | 0.05 ± 0.33 | 0.02 ± 0.13 | 0.08 ± 0.38 | 0.337 |
| PSQI daytime dysfunction | 0.23 ± 0.60 | 0.33 ± 0.55[d] | 0.46 ± 0.66 | 0.64 ± 0.68 | 0.005 |

PSQI; Pittsburgh Sleep Quality Index, MM; moderately morning type, NT; neither type, ME; Moderately evening type, DE; definitely evening type, BMI; body mass index

a, MM vs DE; b, MM vs ME; c, NT vs ME; d, NT vs DE

Table 3.
Wingate anaerobic power according to chronotype

| Variable | Groups | | | | |
|---|---|---|---|---|---|
| | MM (n=13) | NT (n=164) | ME (n=108) | DE (n=55) | p-value |
| Power drop (%) | 30.42 ± 11.22[a] | 31.71 ± 9.02[d] | 32.89 ± 8.62[e] | 37.71 ± 5.12 | <0.000 |
| Mean power (W) | 570.7 ± 153.7[a] | 526.3 ± 136.8[c,d] | 477.3 ± 135.0 | 454.8 ± 103.0 | <0.000 |
| Mean power (W/kg) | 7.30 ± 1.38 [a] | 6.91 ± 1.12[c,d] | 6.47 ± 1.13 | 6.10 ± 0.75 | <0.000 |
| Peak power (W) | 703.2 ± 177.0 | 655.6 ± 171.1 | 612.2 ± 158.5 | 603.5 ± 151.4 | <0.000 |
| Peak power (W/kg) | 9.04 ± 1.75 [a] | 8.76 ± 1.23[c,d] | 8.28 ± 1.25 | 8.03 ± 1.04 | <0.000 |

MM; moderately morning type, NT; neither type, ME; Moderately evening type, DE; definitely evening type, BMI; body mass index

a, MM vs DE; b, MM vs ME; c, NT vs ME; d, NT vs DE; e, ME vs DE

Table 4.
Correlations coefficients between the PSQI score and wingate anaerobic power

| Variable | PSQI | MP (W) | MP (W/kg) | PP (W) | PP (W/kg) |
|---|---|---|---|---|---|
| PSQI | - | | | | |
| MP (W) | -0.256** | - | | | |
| MP (W/kg) | -0.270** | 0.804** | - | | |
| PP (W) | -0.220** | 0.949** | 0.693** | - | |
| PP (W/kg) | -0.248** | 0.770** | 0.894** | 0.791** | - |

PSQI; Pittsburgh Sleep Quality Index, MP; mean power, PP; peak power

**: *p*<.01