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Chronotype and athletes' performance in sports: A narrative review

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ABSTRACT

The circadian system is managed by the suprachiasmatic nucleus, which is also called a master clock, and peripheral clocks spread all over the body. A complex system of neuronal, hormonal, and autonomous signals coordinates these clocks. However, this narrative review aimed to discuss the influence of circadian rhythms on the athlete's performance, rate of perceived exertion, resynchronization, and aerobic and anaerobic exercise. An adequately timed wake-up is believed to play an essential role in an athlete's performance. Based on the literature, chronotype appears to correlate with ratings of perceived exertion and fatigue scores, and morning types are less fatigued in the morning. When chronotype was evaluated, fatigue and vigor had time-by-group interactions. Swimmers with morning-type profiles showed lower fatigue scores before the (06:30 hour) time test than before the (18:30 hour) time test, while those with neither-type profiles had similar fatigue scores in both sessions. Vigor scores were also higher in the morning types than in the neither-types (17.9±7.1) before the morning test and (15.6±5.5) before the evening test. Studies have also shown that exercise enhances aerobic capacity based on the day. However, several reasons can lead to conflicting evidence regarding the chronotype effect on performance studies. Thus, more research is needed regarding the chronotype effect on athletes' performance and the impact of time of day on muscle strength.

Keywords: athletic performance, chronotype, rate of perceived exertion, diurnal preference

INTRODUCTION

Throughout the day hours, the circadian system regulates physiological, psychological, and behavioural processes [1, 2]. Chronobiology is a branch of biology that studies the rhythmic nature of all living things - the internal cycles within which each living organism can be found [2]. In terms of biological rhythms, there are three classifications: circadian, ultradian, and infradian, the circadian being most appropriate because it acts for some time equal to 24 hours [3]. The ultradian is defined as timescales less than 20 hours and the infradian as timescales more extended than 28 hours; the infradian is further split into circaseptan (seven days), circatrigintan (30 days), and circa-annual (360 days) [3]. However, the circadian system is managed by a central clock; the suprachiasmatic nucleus (SCN) is also called a master clock, and peripheral clocks spread throughout the body [4]. In addition, a complex system of neuronal, hormonal, and autonomous signals coordinates these clocks [4]. As a result, clocks generate output signals that affect physiology, psychology, and behavior [4].

Nevertheless, a zeitgeber synchronizes the clocks associated with the circadian system (master and peripheral) [4]. The zeitgeber is a German term for an external (exogenous) stimulus that aids in the maintenance of circadian rhythms' regularity [1]. Exogenous stimuli include the light and dark cycle, sleep-wake transition, physical activity, social cues or behaviour, and nutrition [1, 5]. Light is the most crucial synchronizer, as light stimuli excite or inhibit SCN via the retinohypothalamic pathway [1, 4]. Therefore, chronological changes may be affected by factors such as the timing, intensity, duration, and spectral makeup of light [4].

Biologically, individuals prefer to rest and do activities at specific times of the day, referred to as chronotype [6]. This is a person's tendency toward morning or evening times, assessed by self-assessment questionnaires [6]. The morning chronotype describes the tendency to complete activities in the morning and go to sleep early, while the evening chronotype places activities in the afternoon and delays sleep. A population with an intermediate chronotype is the most common among adults [6]. The most popular survey is the morningness-eveningness questionnaire (MEQ), which allows the classification of chronotypes into the morning, evening, and neither type. In addition to subjective characteristics, chronotype involves physiological variables, synchronization to jet lag, personality, and cognitive functions [6].

Furthermore, as the chronotype measured by the questionnaire, diurnal preference (morning versus evening) has been correlated to endogenous circadian rhythms of core body temperature and melatonin levels [7, 8]. Peaks in cortisol levels, melatonin, and temperature are earlier in the morning than in evening activity preferential individuals [7]. It has been shown that physical performance or performance indicators were highest in the afternoon or evening [7, 9]. However, the chronotype is still a developing research science, but it may offer athletes a way to better predict and access their physiological performance gaps throughout the day. A strategy for this would be manipulating environmental inputs into the circadian system based on whether the individual was morning, evening, or somewhere in between. Therefore, this narrative review aims to discuss the impact of circadian rhythms on the athlete's performance, rate of perceived exertion, desynchronization, and aerobic and anaerobic exercise.

IMPACT OF THE CIRCADIAN RHYTHMS ON PERFORMANCE

Several studies have explored the influence of chronotype on the diurnal variation in athletes' performance [9-14]. In [10], it was evaluated the influences of morning and evening sleep on varsity collegiate rowers' performance on two-leg muscle strength-demanding tasks. 16 collegiate rowers (eight males and eight females; mean age=19.6±1.5 years) with 36 months of team club skill performed a 2,000-meter rowing test and a standing broad jump test through the before noon and afternoon training schedules (from 05:00-07:00 h and 16.30-18:00 h, respectively). The researchers found that participants rowed more slowly in the evening than in the morning (p=0.001). The performance of 13 of the 16 rowers slowed by an average of 2.4 seconds from morning to evening (0.52%). There was also a significant correlation between each individual's morning to evening rowing speed changes and the participant's scores on the basic language morningness (r=0.880; p=0.001) and MEQ (r=0.863; p=0.001) scales. Furthermore, after analyzing the substantial chronotype three-periods interface (p=0.001), it was found that morning types substantially reduced their rowing speediness from morning to evening sessions by 4.8 seconds (1.1%), double the mean speed (p=0.001). The performance of the evening types and neither type substantially reduced over time (p=0.001, p=0.014, respectively). Evening-type rowers (p=0.907) and neither-type rowers (p=0.04) did not show significant differences in rowing speed from morning to evening. Further, these last two groups have not significantly changed in performance throughout the day (p=0.390). In particular, three participants (all evening types) performed on average 1.9 seconds faster than in the morning (0.47%). In contrast, a research study has been performed to investigate the impact of chronotype on in-game basketball performance during (18:00 h) nightfall competitions. A sample of 11 professional male basketball players was recruited and classified by chronotypes (morning: n=4, neither: n=6, evening: n=1). Throughout the season, the team played seven competitions at 18:00 h (15:00 h-1; 16:00 h-2; 16:30 h-1; 17:00 h-1; 17:30 h-1) and 24 competitions at >18:00 h (18:30 h-10; 19:00 h-7; 19:30 h-7). The results showed no significant differences (p=0.21 for most performance measures) between morning types and neither type. Among professional male basketball players, performance in evening games was not affected by chronotype (i.e., morning vs neither). The author suggested that sports practitioners may not require to consider athletes' chronotypes when evolving competition approaches and conveying roles when dealing with more morning and neither-types [14].

However, Henst and Jaspers [12] have also investigated whether the start time of a marathon affected the chronotypes of marathon runners as well as whether a connection existed between race chronotypes, genotypes, habitual training habits in South Africa (n=95, mean age=38±12 years) and Dutch (n=90, mean age=40±12 years) runners. MEQ scores were negatively correlated with the greatest half marathon and existing marathon race periods of South African runners, who were more morning-oriented than Dutch runners. Nevertheless, the study suggests that runners who prefer morning start periods in South Africa might better handle early-morning marathon start periods.

Similarly, according to Rae, Stephenson and Anderson [19, Murray [13] studies, there were significant alterations in swimming performance based on the time of day and circadian rhythm of the swimmer. For example, in a study by Rae and Stephenson [9], 26 trained swimmers (18 males and eight females, ages=32.6±5.7 years) were compared at 06:30 and 18:30 hours to assess morning and evening time-trial performance. As a group, the swimmers performed no differently in the morning or the evening (06:30 hour: 158.8±22.7 s, 18:30 hour: 158.5±22.0 s, p=0.611). In contrast, grouping swimmers according to chronotype enabled the detection of significant diurnal variation in performance, with morning-type swimmers and those training in the morning performing better in the 06:30 o'clock trials (p=0.036 and p=0.011, respectively). Furthermore, it was evaluated whether alleles or genotypes associated with eveningness, such as PER3-G and PER34/4, affected athletic performance [13]. A total of 27 swimmers and divers: eight males (average weight, 78 kg, and height range, 1.75-1.93 m) and 19 females (average weight, 62 kg, and height range, 1.55-1.83 m), aged 18 to 22 were recruited. Each athlete performed swimming in (200 meter) the time trials at 7:00 and 19:00. The results of swimming performance and effort showed significant differences depending on time of day and circadian chronotype; evening types of participants, on average, 6% slower with greater α-amylase levels in the before noon than they did in the nightfall, whereas morning types performed with 5-7 times further exertion to achieve the same performance result in the evening trial.

According to the literature, attuned wake-up time is key to an athlete's peak performance [11]. It was investigated different aspects of circadian chronotypes in examining the physical performance across chronotypes [11]. The researchers used a novel chronometric questionnaire (the RB-UB chronometric test), which was created to examine sleep- and wake-related variables and performance parameters in competition-level field hockey athletes. The athletes were categorized into early circadian chronotypes (ECT), intermediate circadian chronotypes (ICT), or late circadian chronotypes (LCT); 28% were ECTs (n=34), 48% were ICTs (n=58), and 24% were LCTs (n=29). A total of 20 athletes were chosen from the original sample to perform the Bleep test at six different times (07:00, 10:00, 13:00, 16:00, 19:00, and 22:00 hour). The average BLEEP test performance of athletes indicated that the lowest average performance was at 7:00 AM, the intermediate and highest were at 10:00 AM, 1:00 PM, and 10:00 PM, with a substantial alteration of 11.2% between the lowest and highest average performance. However, concerning circadian chronotypes, there were substantial alterations in the highest performance, with ECTs performing best at 12.19+1.43 hours, ICTs performing best at 15.81+0.51 hours, and LCTs performing well at 19.66±0.67 hours. The time-of-day fluctuations in performance for ECTs were 7.62%±1.18%, compared to 10.03%±1.62% for ICTs and striking 26.2%±3.97% for LCTs. Nevertheless, this study suggested that the biggest predictor of peak performance is the duration of attuned awakening since it provides the greatest reliable signal of the highest performance and up to 26% of individual performance fluctuations throughout the day [11]. Accordingly, the time of day has no impact on how an athlete performs; instead, what really matters is their diurnal preference, how various periods after they woke up the competition took place, or how the measurements were evaluated [11].

However, previous studies have supported circadian factors, including chronotype and behavioral [9-13]. In addition, new measurement tools for athletes' performance assessment were introduced, including a chronometric test intended for athletes and a longitudinal sleep record that comprehensively describes circadian interruptions, influencing factors, and interior biological time [9-13]. Thus, with an increased understanding of circadian rhythms and new tools for studying the circadian chronotype, successful interventions for minimizing circadian disruptions, stabilizing circadian rhythmicity, and enhancing well-being can be developed [9-13]. A systematic review has also suggested that athletes may achieve consistent performances regardless of the time of day by recognizing the factors that affect diurnal variations in athletic performance [15]. Consequently, athletes and practitioners in sports will get valuable insights that will help to improve performance [9-13]. Likewise, the developing research science of chronotype will increase training safety and awareness about maximizing performance [9-13]. However, a lack of clarity surrounding the chronotype effect on performance studies can be attributed to several factors that may result in conflicting evidence. For example, sample sizes are small in most research studies without reporting calculations, and measurement methods vary between studies. In addition, the diurnal selected for the performance tests varied between literature, which may affect the decision about the effect of circadian rhythms on performance. Therefore, more studies regarding the chronotype effect on athletes' performance are needed with better research methodology.

INFLUENCE OF THE CIRCADIAN RHYTHMS ON RATE OF PERCEIVED EXERTION

The chronotype appears to correlate with ratings of perceived exertion (RPE) and fatigue scores, and morning types benefit in the morning since they are less exhausted in the morning [16]. During the submaximal cycle test [16], it was found that qualified male cyclists (mean age=39.8±7.7 years) classified as morning types had higher RPE scores. Although there was no time-of-day impact on total power output, speed, and cadence, these alterations in RPE were detected. According to morning-type cyclists, the equivalent relative intensity workload was more challenging in the evening than in the morning; thus, the earlier morning sessions could have motivated them more and resulted in greater intensity. However, it was also conducted research that demonstrated the influence of diurnal preference on RPE [9]. There was no difference between either type or morning-type RPE scores after warming up. Due to the intensity of the physical test, there were no alterations in RPE after the two-time trials based on chronotype. However, it was found that interactions of time between groups existed for vigor and fatigue when chronotype was tested: swimmers with morning-type profiles had lower fatigue scores before the 06:30 h time trial than before the 18:30 h time trial (4.9%±3.2% vs. 9.1%±5.9%), while swimmers with neither type profile had similar fatigue scores before each session. A higher vigor score was also observed in the morning type (06:30 h: 13.1±7.1; 18:30 h: 17.8±3.3) than in neither type (17.9±7.1) before the morning test and 15.6±5.5 before the evening test.

Nevertheless, the impact of chronotype on RPE before and after high-intensity interval exercises (HIIEs) accomplished at various times of the day has been examined [17]. Using MEQ, randomized crossover studies were conducted by [17] with 12 morning-types (morning-types; n=12; age=21±2 years; height=179±5 cm; body mass=74±12 kg) and 11 evening-types (evening-types; n=11; age=21±2 years; height=181±11 cm; body mass=76±11 kg). Morning types showed a higher RPE in the precondition than evening training (p=0.0107), while evening types presented an increased RPE value in the precondition compared to evening training (p=0.008). Furthermore, intragroup alterations indicated that evening types had a higher RPE than morning types before (p=0.002) and after 30 minutes after HIIE. The evening session did not produce any significant changes. Based on HIIE data accomplished at various times, chronotype appears to significantly influence fatigue, perceived exertion, and stamina. The evening types were more likely to struggle if they tried to complete physical tasks early in the morning. According to HIIE results, performing the procedure at times that conflict with circadian preferences can increase feelings of exhaustion and mood disturbances. Thus, the author suggests that HIIE should be scheduled based on an athlete's chronotype [17].

THE CIRCADIAN RHYTHM AND DESYNCHRONIZATION

Desynchronization of the circadian rhythm can result from changes in external factors, such as transcontinental flights or work shifts [18]. It takes several days for individuals to adapt to change and resynchronize with the new order [18]. Desynchronization of steady physiological and biological rhythms causes jet lag, a transient disturbance [18]. Generally, it occurs on flights that pass through three or more time zones before arriving at their final destination [18]. At the beginning of desynchronization, fatigue, headache, nausea, decreased concentration, or insomnia can be experienced. However, these signs gradually fade as the organism regulates the biological clock to a new time region [18]. Adapting to circadian rhythms varies from person to person, so younger people adapt more quickly than older people [18]. In order to restore regular rhythm after the passage of a time region, one day must elapse [18]. Overcoming the six-time zones can take anywhere within two weeks [18]. As the day extends and more time is available for flying west, the adaptation process is faster [18]. Physical performance may be affected by the modification period of a biological clock since the body maintains its temperature parallel to the biological clock and is not sufficiently ready for the new time region [18].

Furthermore, insomnia can negatively impact mental performance [18, 19]. A study by Lemmer and Kern [19] has reported that elite athletes travelling over six to eight-time regions showed weaker grip strength during training or several days after the trip. In order to regularize the biological rhythms as quickly as possible while the biological clock is remodelled, it is suggested to begin day-to-day routines, exposure to sunlight, rhythm activities, rest, eating, waking, and sleeping according to local times to begin constructing the biological clock [20]. Adaptation to a shifted time region also requires consideration of the food category and timing of meals [21]. Foods rich in protein boost alertness and readiness and, as a result, should be consumed for breakfast.

In contrast, foods rich in carbohydrates increase insulin release, which promotes the uptake of tryptophan, an essential amino acid, leading to drowsiness and should be consumed in the evening [21]. In addition, it is important to ensure adequate hydration to prevent fatigue associated with a jet leg [21]. Finally, planning travel in advance is important to ensure performance quality in sports events. Therefore, preparing the arrival earlier and thus sufficient adaptation is recommended, in addition to previous training (timing and intensity of exercise) in a time region aligned with the future time region [18].

However, since the light and dark cycle contributes significantly to endocrine rhythms, variations in its timing may influence physical performance [22]. In a parallel-group design, a study examined the effects of light exposure on cycling skill performance in three groups of young men exposed to light for diverse periods before a 40-minute trial. A significant dose-response association has been observed between the light introduction period and the work accomplished by the three diverse light exposure doses [22]. Another study has indicated that the amount of light integrated by the clock during each day strongly influences energy metabolism and cycling performance [23]. As a result, variations in the light/dark cycle can affect athletes' metabolic activity and circadian hormonal rhythmicity, affecting their mental performance [23]. In addition, keeping a proper sleep cycle and sleeping sufficient hours is essential to athletes [3, 24]. Sleep is a necessary synchronizer for some rhythms, including growth hormone [3, 24]. For the athlete to develop harmonically and demonstrate optimal performance during adulthood, growth hormone levels must be kept at a maximum level [18]. Throughout life, growth hormone plays a significant role in regulating intermediate metabolism, tropism, and function of numerous organs, particularly the cardiovascular, muscular, and skeletal systems, in addition to its fundamental growth-promoting activity [3, 5]. If a prepubertal secretory deficit is associated with brief stature, a deficiency in adulthood is associated with abnormalities of the heart, muscle, bone, metabolism, and mind [3]. However, it was reported that no studies have examined the impact of sleep timing during travel on sleep-wake cycles at the destination [25]. It also states that no studies specifically study sleep hygiene in athletes [25]. Participants who practice sleep hygiene are more likely to recover from travel fatigue after simulated international travel for 24 hours. However, impractical sleep habits, such as those caused by exposure to electronic equipment, can cause phase shifts in a reverse way [25]. Therefore, there is a lack of research on the sleep patterns of athletes during and after transmeridian travel and more studies are needed to address these questions [25].

INFLUENCE OF THE CIRCADIAN RHYTHMS ON AEROBIC AND ANAEROBIC EXERCISE

Exercise has been shown to enhance aerobic capacity based on the time of day [26]. Men with a 65% peak VO2 endurance exercise capacity were substantially improved in the morning than in the evening [26]. Exercise capacity was also greater at 06:45 h than at 18:45 h when carried out in the heat [26]. Additionally, it was also found that heart rate reduction after two months of aerobic exercise was observed in 35 healthy young subjects who cycled on an ergometer [27]. Despite these findings, another study found that in an evening exercise session, 12 college-age females who performed 20 high-intensity exercise training sessions had a better performance capacity after five weeks of high-intensity training [28]. Similar findings have been revealed by a study regarding the influence of aerobic exercise drills on the time of day [29]. A total of nine male athletes were recruited and were asked to ride multiple bouts of six minutes in the morning (7:00 AM) and evening (5:00 PM) using two different cycling protocols [29]. The results indicate that circadian rhythm interacts with exercise to lower blood pressure throughout training after an initial overshoot, with a superior influence in the evening, associated with increased skin blood flow [29]. As a result, various impacts may be produced based on exercise period, time, and individual.

On the other hand, morning exercise resulted in better anaerobic performance after six weeks compared to evening exercise [30]. 24 participants were randomly assigned between a morning-exercise group (07:00-08:00 h), an evening-exercise group (17:00-18:00 h), and a control group. A total of four strength and power assessments were performed on participants before and after six weeks of resistance training (one-sided isometric maximal voluntary contraction of the knee extensor muscles, squat-jump, counter-motion-jump, and wingate tests) [30]. As indicated by time-of-day-specific training, anaerobic performance increases after morning training compared to evening training [30]. However, evening exercise provided greater gains in peak muscle power than morning exercise [31]. Edwards and Pullinger [32] investigated greater grip strength, isokinetic knee flexion, peak torque, and peak power in the evening on ten healthy, active males. According to the results, raising before noon temperature to evening values through diverse methods of "warm-up" did not lead to greater muscle strength. Whereas electromyography (EMG) activity measurement was performed in Chtourou, Zarrouk [32] study and no significant differences were detected between morning and evening Wingate exercises. 22 male subjects performed the Wingate test for 30 seconds in contradiction of a continuous braking load of body mass throughout two investigational sessions, either at 07:00 or 17:00 h. The results indicated two phases of decreased power output. The initial power output reduced quickly (first 20s), and values were higher ($p=0.05$) in the evening than in the morning [32].

Time-of-day effects on repeated sprint capability have not been observed, and there was no substantial influence on measured EMG activity levels during a repeated pedalling sprint test [33]. Two repeated sprint ability tests were carried out for 12 individuals (randomized order, either at 06:00 or 18:00 h) [33]. Furthermore, neuromuscular capacity decreased significantly with repeated sprint ability testing at both times [33]. The diurnal difference in muscle power and fatigue is not caused by a change in the neural drive but rather by a rise in muscle contractile properties in the evening [33]. Nevertheless, a study reported short-duration maximal exercise performance under neutral climate conditions peaks between 16:00 and 20:00 h [34].

Additionally, morning exercise can lead to similar results if

Table 1. Summary of the impact of the chronotype on the athletes

Influence of chronotype on	Impact	Time of day
Performance	1-In evening sessions, rowers' performance (morning types) was reduced [10]. 2-Basketball performance (all chronotypes) was not affected [14]. 3-Marathon runners (morning types) perform better in morning [12]. 4-Swimmers performed (evening types) slower in morning [13].	1-6.30-18:00 h 2-18:00 h 3-Not specified 4-07:00 h
Rate of perceived exertion	1-Cyclists (morning types) have higher RPE scores in the evening [16]. 2-Swimmers (morning types) have lower RPE scores in morning while performing a 200-meter swim [9]. 3-Physically active students (morning types) showed a higher RPE score in the evening. In contrast, evening types reported higher RPE values before training commenced in the morning [17].	1-18:00-22:00 h 2-06:30 h 3-08:00 h, 20:00 h
Aerobic & anaerobic exercise	1-Recreationally active males have shown an improved peak VO2 endurance exercise capacity in the morning [27]. 2-Healthy young subjects have shown a reduction in heart rate after two months of aerobic exercise in the early morning [28]. 3-Female college students have shown a better performance capacity after five weeks of high-intensity training in the evening [29]. 4-Male athletes have shown lower blood pressure in the evening [30]. 5-In the morning, highly fit male students have shown better anaerobic performance [31]. 6-Healthy, active males have shown higher isokinetic values and right grip strength in the evening [32]. 7-Physically active students have shown higher values for the Wingate test in the evening [33]. 8-Male physical education students have shown a higher peak power in the evening during performing a repeated sprint ability test [34].	1-06:45 h 2-08:00-21:00 h 3-15:00-16:00 h 4-16:00 h 5-07:00-08:00 h 6-17:30 h 7-17:00 h 8-18:00 h

Note. RPE: Rate of perceived exertion & h: Hour

(1) warm-ups are performed after short exposures to moderately humid conditions,

(2) intermittent fasting is followed by warm-ups while listening to music, and

(3) prolonged training at specific times of the day is followed by prolonged training [34].

Nevertheless, in ten female judokas who regularly trained in judo for at least five years and competed in international competitions, Eken and Clemente [35] assessed the influence of diverse warm-up protocols on the specific judo fitness test (SJFT) at diverse periods of the day. The athletes conducted SJFTs before noon, between 9:00 and 10:00 AM, and at nightfall between 4:00 and 5:00 PM, either without warm-up or with RAMP-based protocols such as specific warm-up (SWU). The SWU protocol has been shown to alter the performance of SJFT during the evening hours. Using judo-like techniques, the SWU has incorporated the characteristic structures of the sport. Accordingly, the author proposes incorporating specific warm-ups into training plans in order to increase performance through the increase in body temperature after SWU in the evening. Thus, time-of-day-dependent fluctuations in short-duration maximal performance could be due to changes in body temperature or hormones and changes in the skeletal muscle's circadian rhythm [34]. However, research in the future may assess the major physiological alterations after resistance exercise adaptations to understand the time-of-day effects on muscle strength.

CONCLUSION

A complex system of neuronal, hormonal, and autonomous signals coordinates the master clock and peripheral clocks. The circadian clocks are synchronized through zeitgebers. Prior studies have established that chronotype and behavioural factors play an important role in circadian rhythms. Furthermore, new tools were developed, including the chronometric test designed for athletes and the sleep record that allowed a comprehensive description of circadian disruptions, influencing factors, and interior biological period. By studying the circadian chronotype and understanding circadian rhythms better, successful interventions can be developed for minimizing disruptions, stabilizing rhythmicity, and enhancing well-being. It is important to note, however, that external factors, such as transcontinental flights or shift work, can desynchronize the circadian rhythm. Nevertheless, contradictory evidence regarding the chronotype effect on performance studies can occur due to several factors. However, the chronotype effect on athletes' performance and the impact of time of day on muscle strength need further study.

Future Direction

Several aspects of athlete performance are discussed during this narrative review, including performance, perceived exertion, desynchronization, and aerobic and anaerobic exercise (**Table 1**).

Studies have shown different results of chronotype and time-of-day variation in athletes based on the type of sports, measurement methods, and gender. There are, however, limitations to the literature regarding circadian rhythms. Most research studies do not report sample size calculations, and measurement methods vary from study to study, which may limit decision-making. Moreover, the diurnal selected for each performance test differed between studies, which may affect the results. An adequate research methodology is needed to assess the chronotype effect on athletes' performance for better understanding and extending knowledge to clinical practice. Research may be conducted in the future to determine how time-of-day affects muscle strength after resistance exercise adaptations. More research is also needed on athletes' sleep patterns during and after travel.

Key Points and Take-Home Message

Understanding circadian rhythmicity and its influencing factors can minimize circadian disruptions, stabilize circadian rhythmicity, and enhance well-being, which directly impacts athletes' performance. Chronotypes may dictate how an athlete's rehabilitation, training sessions, and competitions should be scheduled.

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