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Circadian Misalignment and Social Jetlag: Consequences for Physical Performance and Injury Risk in Young Adults

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Abstract

Background. Circadian rhythms, governed by the suprachiasmatic nucleus and peripheral oscillators in skeletal muscle, regulate peak physiological performance windows. Social jetlag (SJL) - the discrepancy between biological time and social schedules - is highly prevalent in young adults due to a developmental shift toward "eveningness".

Aim. This narrative review aims to synthesize current evidence regarding the impact of SJL on physical performance metrics and musculoskeletal injury risk in the young adult demographic.

Material and method. A narrative synthesis of articles (systematic reviews, meta-analyses, and experimental studies) published between 2005 and 2026 was conducted. Analysis focused on cardiorespiratory fitness, neuromuscular power, and longitudinal injury data in tactical and athletic populations.

Results: High levels of SJL ($\geq$ 1.5-2 hours) are significantly associated with reduced cardiorespiratory fitness (VO_2 peak), particularly in males. In anaerobic domains, SJL blunts the natural diurnal rhythm of explosive power, resulting in lower vertical jump performance and reduced maximal voluntary contraction during morning training. Furthermore, prospective data from ROTC cohorts demonstrate that SJL is a robust behavioral predictor of musculoskeletal injury, with injured individuals exhibiting nearly double the SJL magnitude of their uninjured peers.

Conclusions. Chronic circadian misalignment acts as a systemic "performance inhibitor" and a significant risk factor for injury. Mitigation requires "circadian literacy" in coaching and the implementation of chronotype-adjusted training schedules to align physical demands with endogenous biological windows.

Keywords: Social Jetlag; Circadian Rhythms; Athletic Performance; Injury Prevention; Young Adults

1. Introduction

The historical harmony between human biological rhythms and the natural environment was fundamentally altered by the advent of artificial lighting [1]. Before the innovations of Thomas Edison, human activity was strictly dictated by the solar cycle - rising with the sun, working by day, and sleeping by night. The introduction of the electric light bulb and the subsequent invention of the alarm clock enabled a modern lifestyle that is often "out of sync" with the natural world, leading to profound implications for global health and athletic performance [1].

Circadian system fundamentals (SCN and peripheral oscillators).

Circadian rhythms are endogenous oscillations with a periodicity of approximately 24 hours, governed by a hierarchical system comprising the suprachiasmatic nucleus (SCN) of the hypothalamus and peripheral oscillators located in nearly all peripheral tissues, including skeletal muscle and cardiovascular structures [2–4]. This biological timing system regulates essential physiological processes, including core body temperature (CBT), heart rate, blood pressure, and the secretion of metabolic hormones such as cortisol and melatonin [1,5]. Systematic fluctuations in these parameters directly influence physical capabilities; specifically, peak values for muscle strength, anaerobic power, and aerobic capacity frequently coincide with the daily acrophase of CBT, which typically occurs between 16:00 and 20:00 [2,6]. Consequently, the temporal alignment of physical activity with these endogenous peaks is a critical determinant of maximal athletic output and metabolic efficiency [2,7]. Scientific interest in these rhythms is long-standing; for instance, NASA researchers were documenting the impact of circadian oscillations on neuromuscular, cardiovascular, and metabolic variables as early as 1985[6]

Definition of Social Jetlag (SJL) and the "eveningness" shift in young adults.

In contemporary society, a significant portion of the population - estimated at up to 70% worldwide - experiences a phenomenon known as Social Jetlag (SJL) [8]. Social jetlag represents a specific form of chronic circadian misalignment characterized by the discrepancy between an individual’s endogenous biological clock and the constraints imposed by social, academic, or professional schedules [8–10]. Quantitatively, SJL is calculated as the absolute difference between the midpoint of sleep on scheduled days (work or university days) and the midpoint of sleep on free days [10,11]. This phenomenon is particularly acute in the young adult demographic, as this population typically undergoes a biological shift toward "eveningness," resulting in an endogenous preference for delayed sleep and wake times [7,12].

When societal requirements necessitate early morning awakening, these individuals are forced to initiate physiological activity during their biological night, leading to a state of chronic desynchrony and cumulative sleep restriction [7]. High prevalence rates of SJL in adolescents and young adults suggest a systemic conflict between biological maturation and social structure, which has significant implications for cardiorespiratory fitness, metabolic health, and general physiological resilience [11,13].

Aim of this review

The objective of this narrative review is to evaluate the existing literature concerning the effects of social jetlag on physical performance and injury risk among young adults. This review aims to identify specific performance deficits associated with circadian desynchrony and propose evidence-based strategies for mitigating injury risk through chronotype-aligned training schedules.

2.1. Materials and Search Strategy

The present narrative review was conducted through a comprehensive evaluation of current scientific literature concerning the physiological, metabolic, and performance-based consequences of social jetlag (SJL) in young adults. The research corpus comprised systematic reviews, meta-analyses, and experimental studies, identified through electronic databases such as PubMed, EBSCO, and ScienceDirect. The selection process prioritized studies published between 2005 and 2026 to ensure the inclusion of contemporary evidence regarding circadian biology and sports science. Keywords utilized in the search strategy included "social jetlag," "circadian misalignment," "athletic performance," "neuromuscular power," "musculoskeletal injury risk."

3. Research results

3.1. Physiological and Metabolic Mechanisms of Social Jetlag

Social jetlag (SJL) induces systemic physiological disruption by desynchronizing the central circadian pacemaker from peripheral oscillators, leading to significant endocrine and metabolic alterations. The endogenous rhythms of melatonin and cortisol, which typically exhibit high-amplitude oscillations to facilitate the transition between sleep and wakefulness, are compromised under conditions of chronic circadian misalignment [2].

The causes of circadian rhythm disorders are divided into psychosocial and biological factors, including reduced exposure to natural sunlight, incorrect concentrations of hormones such as

melatonin and cortisol, and students putting off homework to late evening hours. In the absence of signals from the environment, the biological clock itself generates abnormal circadian rhythms, directly negatively affecting health, well-being, and professional and social life [14].

Endocrine Desynchrony: Cortisol and Melatonin Dynamics

Research indicates that individuals experiencing significant SJL often demonstrate a phase-shift in cortisol secretion, which can manifest as elevated nocturnal cortisol levels and a blunted cortisol awakening response (CAR), thereby impairing physiological readiness for physical exertion [15].

Furthermore, the suppression of nocturnal melatonin secretion due to late-night exogenous factors - prevalent in young adults with eveningness chronotypes - leads to increased systemic oxidative stress and impaired cellular recovery processes, as melatonin serves as a primary endogenous antioxidant [7].

Metabolic Homeostasis and Body Composition

At the cellular level, social jetlag (SJL) significantly impacts metabolic homeostasis and mitochondrial efficiency. Chronic circadian misalignment has been associated with impaired glucose tolerance and a reduction in insulin sensitivity, which may compromise glycogen resynthesis and metabolic substrate utilization during sustained physical exertion [8,16].

Additionally, the chronic metabolic stress associated with SJL is linked to adverse changes in body composition, including increased fat mass and body mass index (BMI), further complicating the physical performance profile of affected young adults [9].

Mitochondrial Biogenesis and Exercise-Induced Adaptations

Experimental data from animal models demonstrate that SJL alters the molecular markers of mitochondrial biogenesis and oxidative phosphorylation in cardiac and skeletal muscle tissues [8]. Specifically, exercise-induced adaptations in mitochondrial protein expression and enzymatic activity are attenuated when training occurs during periods of circadian desynchrony, thereby limiting the anticipated gains in cardiorespiratory fitness [8]. These findings suggest that the physiological adaptation to a standardized exercise stimulus is blunted in the presence of SJL, resulting in a diminished return on training investment [8,16].

3.2. Impact on Physical Performance

3.2.1. Cardiorespiratory Fitness and Aerobic Capacity

Cardiorespiratory fitness (CRF), typically quantified by maximal oxygen uptake (VO_2 max), exhibits significant sensitivity to circadian stability and the consistency of sleep timing. Empirical evidence suggests that social jetlag (SJL) is inversely correlated with aerobic capacity in young populations. Specifically, data from the EHDLA study indicated that adolescents and young adults experiencing SJL $\geq$ 1.5 hours demonstrated significantly lower levels of CRF compared to those with minimal circadian misalignment [11]. This relationship appears to be modulated by biological sex; research by Higgins et al. (2020) identified a substantial negative association between SJL and VO_2 peak in adolescents. Across the general population sample, each hour of SJL was linked to a 0.72 ml/kg/min decrease in fitness, while sex-specific models indicated a 0.93 ml/kg/min decrease specifically in males, whereas this association did not reach statistical significance in females. It is potentially due to sex-dependent differences in hormonal regulation or lifestyle-based physical activity patterns [17]. Furthermore, individuals characterized by earlier sleep-wake schedules and an earlier circadian phase - indicated by earlier acrophase and dim light melatonin onset (DLMO) - tend to possess superior cardiorespiratory profiles, although no significant association has been found between CRF and circadian amplitude [18]. The chronic variability in sleep timing inherent in SJL likely induces a state of "circadian strain," which may attenuate the physiological adaptations of the cardiovascular system to aerobic exercise [17].

Quantitative analysis from the EHDLA study involving Spanish adolescents provides a precise measure of this decline; for every one-hour increase in social jetlag (SJL), there is a significant reduction in cardiorespiratory fitness performance, represented by an unstandardized beta coefficient (B) of -1.28. This negative association persists even after adjusting for potential confounders such as age, sex, and total nocturnal sleep duration, suggesting that the timing of sleep - rather than just the volume - is a primary driver of aerobic capacity [11].

3.2.2. Neuromuscular Power and Anaerobic Performance

Neuromuscular power and anaerobic performance, characterized by short-duration maximal explosive movements, exhibit pronounced diurnal variation and are significantly compromised by social jetlag (SJL).

Research in sub-elite female volleyball players demonstrates that individuals with high levels of SJL (≥1 hour) exhibit significantly lower vertical jump height compared to those with lower

circadian misalignment [19]. Furthermore, while athletes with low SJL maintain a robust diurnal rhythm - showing significantly better jump performance in the afternoon compared to the morning - this physiological variation is blunted in athletes with high SJL, suggesting a systemic loss of synchronization between biological rhythms and social schedules. However, regarding balance as a metric, no significant association with SJL was found in this cohort, although the morning session generally yielded lower stability results than the afternoon session. [19].

These neuromuscular deficits are mirrored in anaerobic capacity assessments; data from elite athletes indicate that late-type chronotypes ("night owls") achieve significantly lower mean and peak power outputs on the Wingate Anaerobic Test compared to early-type chronotypes [20]. Additionally, subjective sleep quality is negatively correlated with Wingate performance metrics, implying that the chronic sleep debt often accompanying SJL further degrades anaerobic power [20].

Beyond explosive power, isometric muscular strength also shows a clear dependency on circadian phase and individual chronotype. Early chronotypes typically reach peak strength significantly earlier in the day compared to late chronotypes, whose performance is most severely impaired during morning hours [21]. This "morning compromise" in late chronotypes manifests as significantly lower maximal voluntary contraction (MVC) values in isometric grip strength tests when performed at 08:00 [21]. The temporal discrepancy between endogenous peak performance windows and socially required training times (e.g., early morning sessions for late chronotypes) creates a state of "circadian mismatch" that reduces maximal force production and neuromuscular efficiency [22]. Consequently, SJL serves as a negative modifier of neuromuscular readiness, potentially necessitating individualized training schedules to optimize power output and mitigate performance deficits in young adults [4].

The deleterious impact on the musculoskeletal system is further evidenced by specific deficits in lower-body muscular fitness. SJL is negatively associated with performance in lower-body muscular fitness, showing a documented unstandardized beta coefficient (B) of -2.01 for every hour of circadian misalignment. Furthermore, speed agility is a critical component of athletic performance - shows a positive association with SJL, meaning that increased misalignment leads to significantly slower times in agility shuttle run tests, potentially due to impaired motor coordination and slowed psychomotor processing speed. [11].

3.2.3. Tactical and Military Performance

In tactical populations, such as Reserve Officers' Training Corps (ROTC) cadets, social jetlag (SJL) serves as a critical behavioral predictor of physical readiness and a systemic "performance inhibitor" [15]. Cadets with high levels of SJL exhibit significantly lower scores on the Army Physical Fitness Test (APFT) compared to those with synchronized rhythms. The discrepancy between the cadets' internal "eveningness" preference and the early morning requirements of military training leads to a state of chronic desynchrony. Because peak physical tasks are performed during a circadian nadir - often as early as 06:00 - operational effectiveness is reduced and metabolic fatigue is increased [15].

3.2.4. Game Performance and Specific Sport Skills

The consequences of circadian misalignment are profoundly evident in professional team sports, where even marginal deficits can determine the outcome of a competition [23]. In the NBA, internal circadian desynchrony - often exacerbated by travel across time zones - has been shown to reduce a team's winning probability by approximately 6%, though this finding stood close to but did not reach formal statistical significance. This "circadian disadvantage" negatively impacts specific offensive metrics, including lower shooting accuracy in both 2-point and 3-point field goals, as well as a marked reduction in rebounding performance [23]

Furthermore, in synchronized sports like rowing, the alignment of chronotypes within a crew is essential for optimal collective output [12]. Crews with mismatched internal clocks demonstrate poorer technical coordination and slower race times, particularly during early morning competitions when evening-type athletes are forced to compete during their biological night [4,12].

This performance gap is also quantified in volleyball; sub-elite female players experiencing social jetlag (SJL) ≥ 1 hour exhibit significantly lower vertical jump heights in both Squat Jump (SJ) and Countermovement Jump (CMJ) tests [19]. Crucially, while athletes with low SJL maintain a robust diurnal rhythm - showing significantly better jump performance in the afternoon compared to the morning - this physiological variation is blunted in athletes with high SJL, suggesting a systemic loss of synchronization that impairs technical skill execution during peak performance windows [4,19].

3.3. Neuromuscular Control and Injury Risk

Predictive value of SJL for MSKI (musculoskeletal injury) and postural control deficits.

Circadian misalignment, specifically social jetlag (SJL), is a significant predictor of musculoskeletal injury (MSKI) due to its deleterious effects on neuromuscular coordination and cognitive vigilance. In a longitudinal evaluation of Reserve Officers' Training Corps (ROTC) cadets, SJL was identified as a critical behavioral biomarker for injury risk; cadets who sustained injuries during a training semester exhibited significantly higher levels of SJL compared to their uninjured counterparts (2:40 ± 1:03 hours vs. 1:32 ± 0:55 hours, respectively) [15].

Sleep plays a critical role in injury susceptibility and has several important roles in recovery that are essential for athletic performance and healing, including tissue regeneration, immune system function, metabolic regulation, and cognitive recovery [24]. Strong evidence has identified linking insufficient sleep to an increased risk of sports injuries in many groups of athletes. Mechanisms connecting sleep and injury include impaired cognitive function, slowed reaction time, weakened neuromuscular control, increased inflammation, and impaired tissue regeneration.[24] Prospective data indicates a dose-dependent relationship between the magnitude of circadian shift and injury frequency, with individuals experiencing ≥ 2 hours of SJL being at a substantially higher risk during time-mandated training [15]. This increased injury incidence is largely attributed to the temporal mismatch between endogenous physiological readiness and the early morning training requirements typical of tactical and collegiate environments [15].

Mechanistically, chronic circadian misalignment has been associated with impairments in postural control and balance stability, which are essential for maintaining biomechanical integrity during complex physical maneuvers [25]. Furthermore, individuals with late chronotypes - who frequently experience chronic SJL - demonstrate significant cognitive deficits during morning hours, including reduced executive function and slowed reaction times as measured by the psychomotor vigilance task (PVT) [21]. These cognitive impairments, coupled with diminished neuromuscular power during the biological night, create a physiological state characterized by increased vulnerability to traumatic and overuse injuries [15,21].

3.4. Psychological Factors and Perceived Exertion

Impact on RPE, perceived stress, and motivation.

The psychological impact of social jetlag (SJL) and circadian misalignment in young adults is characterized by an increase in perceived stress, mood disturbances, and alterations in the subjective perception of physical effort [2,26]. Empirical data indicate a significant correlation between chronotype, perceived stress levels, and sleep quality among university student-athletes, with eveningness preferences being linked to higher levels of psychological distress and daytime dysfunction [20,26]. Adolescence is a developmental period characterized by a physiologically delayed circadian phase and ongoing maturation of neural systems involved in emotional regulation and cognitive control. Emerging evidence indicates that circadian misalignment and chronic sleep restriction are consistently associated with depressive and anxiety symptoms, emotional dysregulation, and reduced cognitive performance in adolescents. Chronic circadian misalignment may interfere with the normal development of the stress axis, serotonergic and dopaminergic neurotransmission, thereby increasing long-term vulnerability to depression and anxiety disorders.[27]

Furthermore, individuals experiencing chronic circadian misalignment often report elevated scores on the Karolinska Sleepiness Scale (KSS), particularly during morning hours, which corresponds with diminished cognitive vigilance and increased subjective fatigue [10].

The ratings of perceived exertion (RPE) during physical activity are also heavily modulated by the internal biological clock [2]. Research demonstrates that morning-type athletes experience lower fatigue and higher vigor during early morning training sessions compared to evening types; however, to achieve equivalent performance levels in the late evening, morning types must exert significantly greater subjective effort (up to 5–7 times more) [2,21]. Conversely, evening types face their highest RPE and slowest performance during morning sessions, reflecting a physiological state of "circadian mismatch" [20,28]. Additionally, personality traits such as neuroticism and conscientiousness further modulate these stress appraisals, where maladaptive profiles characterized by high neuroticism are predisposed to worse sleep quality and heightened stress sensitivity in response to training loads [29]. These findings suggest that chronic SJL increases the overall allostatic load, impairing the psychological readiness of young adults for high-intensity physical tasks [26].

4.Discussion

The findings of this review underscore a significant paradox in contemporary sports science: while physical activity is generally recognized as a stabilizer of biological rhythms, the social

and academic constraints imposed on young adults often transform athletic participation into a source of circadian strain. The distribution of chronotypes within athletic populations typically reveals a leaning toward intermediate types, yet individuals characterized by "eveningness" are disproportionately affected by social jetlag (SJL) due to the rigid requirement for early morning training [30]. This chronic desynchrony is not merely a matter of subjective fatigue but acts as a systemic modifier of physiological capacity, where evening-type athletes must operate at a biological disadvantage during morning hours, characterized by lower core body temperature and reduced neuromuscular readiness [4]. Consequently, the traditional "one-size-fits-all" approach to training schedules may inadvertently penalize athletes based on their innate biological timing, leading to suboptimal performance outcomes and increased physiological stress [2]

Evidence suggests that participation in structured athletic programs may serve as a protective factor against the development of severe social jetlag (SJL) in the young adult demographic [26]. Comparative analyses indicate that the prevalence of significant circadian misalignment ($\geq$ 2 hours) is notably lower among student-athletes, reported at approximately 6%, than in the general university student population, where rates frequently range between 12% and 14% [26]. This protective effect is primarily attributed to the imposition of rigorous training schedules and institutional oversight, which restrict the variability of sleep-wake cycles and promote greater physiological consistency [26,30]. Furthermore, professional athletes often exhibit a central or slightly morning-oriented chronotype, which may facilitate a more efficient alignment with conventional early morning training requirements compared to non-athlete peers [30]. Despite these structural buffers, student-athletes remain susceptible to an increased allostatic load resulting from the dual career demands of academic and athletic excellence, which can manifest as elevated sleep effort and heightened psychological distress [26].

The metabolic consequences of social jetlag (SJL) extend beyond immediate performance deficits, significantly impacting long-term body composition and cardiometabolic health. Clinical data indicate a robust positive association between the magnitude of SJL and body mass index (BMI), identifying chronic circadian misalignment as a significant contributor to the risk of obesity in young populations [9]. This relationship is particularly evident in weight management interventions, where individuals with pronounced SJL demonstrate significantly lower reductions in both BMI and body fat percentage compared to those with stable sleep-wake cycles [31]. Mechanistically, SJL facilitates an adverse cardiometabolic profile

characterized by impaired glucose tolerance, increased glucose variability, and elevated adiposity markers [13,16]. These metabolic disruptions are likely driven by complex sleep-diet interactions, wherein circadian desynchrony alters neuroendocrine signaling related to appetite and satiety, favoring increased energy intake and metabolic suppression [13,32]

The association between social jetlag (SJL) and musculoskeletal injury (MSKI) risk is significant in populations where training schedules are incongruent with individual chronotypes. Prospective data from Reserve Officers' Training Corps (ROTC) cohorts indicates that SJL serves as a significant behavioral biomarker for MSKI, with injured individuals exhibiting markedly higher magnitudes of circadian shift than their uninjured peers [15]. Quantitatively, the difference in SJL between injured (2:40±1:03 h) and uninjured (1:32±0:55 h) cadets suggests a dose-dependent relationship between the degree of sleep-timing variability and the vulnerability to injury during time-mandated physical training [15]. Mechanistically, this vulnerability is driven by reduced neuromuscular power and impaired balance control when physical demands are imposed during the biological night, a period characterized by lower core body temperature and diminished motor unit recruitment [15,25]. Additionally, the psychomotor vigilance deficits observed in evening-type individuals during morning hours compromise the cognitive processing speed required for the safe execution of high-velocity movements [21]. Therefore, SJL represents a modifiable risk factor that must be addressed to enhance the safety and musculoskeletal health of young adults in high-demand environments.

Mitigation strategies for social jetlag (SJL) must prioritize the synchronization of training loads with individual circadian phenotypes to optimize physiological output and minimize musculoskeletal risk. The implementation of systematic screening using validated instruments, such as the Morningness-Eveningness Questionnaire (MEQ) or the Athlete Sleep Screening Questionnaire (ASSQ), is a prerequisite for identifying athletes at high risk for circadian misalignment [30]. Once chronotypes are established, training schedules should be individualized where feasible; for example, delaying high-intensity morning sessions for evening-type individuals can significantly reduce the magnitude of SJL and the associated neuromuscular deficits [4]. Behavioral interventions, including the enforcement of standardized sleep hygiene protocols - such as minimizing nocturnal exposure to short-wavelength (blue) light and stabilizing sleep-wake timing across the entire week - are critical for strengthening the amplitude of the circadian rhythm and facilitating recovery [33–35]. Additionally, the use of strategic napping (typically 20–90 minutes) during the circadian "post-lunch dip" can serve

as an effective countermeasure for cognitive fatigue and reaction time decrements in athletes with chronic sleep debt [36]. Such evidence-based adjustments facilitate the alignment of the central hypothalamic pacemaker with peripheral metabolic oscillators, thereby enhancing both aerobic capacity and explosive power [3].

4.1. Institutional and Coaching Recommendations: Systemic Chrono-Alignment

At the organizational level, the mitigation of social jetlag (SJL) requires a fundamental shift from rigid, standardized training blocks to chronotype-aware scheduling. Performance departments should implement systematic screening using validated instruments, such as the Athlete Sleep Screening Questionnaire (ASSQ), to identify "evening-type" individuals who are at the highest risk for chronic circadian misalignment [30]. For these athletes, delaying high-intensity morning training sessions by even 1–2 hours can significantly reduce the magnitude of SJL and the associated deficits in neuromuscular power and cognitive vigilance [4]. Furthermore, institutions should utilize wellness tracking tools to monitor subjective sleep quality, muscle soreness, and psychological distress, allowing strength and conditioning coaches to dynamically adjust training loads based on an athlete's current physiological readiness [26]. Such structural adjustments facilitate a more favorable alignment between the central circadian pacemaker and peripheral metabolic oscillators, potentially reducing the allostatic load that predisposes young adults to musculoskeletal injury [15].

4.2. Individual Behavioral Strategies: Optimizing Circadian Hygiene

For the individual athlete, the stabilization of the internal biological clock is predicated on rigorous adherence to circadian hygiene protocols. Athletes must be educated on the physiological necessity of maintaining consistent sleep-wake timings across both training days and free days to prevent the "rebound sleep" phase-shifts that define SJL [26]. Minimizing exposure to short-wavelength (blue) light in the 2-hour pre-sleep window is critical for preserving the natural nocturnal surge of melatonin, which serves as a primary endogenous antioxidant and facilitator of cellular recovery [33,34]. The short fraction of light waves perceived by humans as blue waves is the strongest factor that synchronizes the circadian system. Melanopsin is most sensitive to light at a wavelength of 479 nm, which corresponds to the blue light wavelength. While exposure to blue light is essential for maintaining the body's well-being and alertness during the day, chronic exposure to blue light right before bedtime can have serious consequences for sleep quality and circadian phase [37]

Additionally, the use of strategic napping - specifically "power naps" of 20 minutes or full 90-minute sleep cycles - during the post-lunch circadian dip can effectively attenuate the cognitive fatigue and reaction time decrements associated with chronic sleep debt [36]. These behavioral interventions, when combined with nutritional timing that avoids large, high-glycemic index meals close to sleep onset, enhance sleep efficiency and promote superior metabolic adaptations to exercise [32].

5. Conclusions

The evidence synthesized in this review demonstrates that social jetlag (SJL) is a critical determinant of physiological capacity and musculoskeletal safety in young adults. Circadian misalignment, resulting from the chronic discrepancy between endogenous biological timing and exogenous social or academic requirements, induces systemic disruptions that extend from cellular metabolic pathways to gross motor performance. Key findings indicate that SJL significantly impairs cardiorespiratory fitness, particularly in males, and blunts the diurnal rhythmicity of neuromuscular power, leading to diminished explosive strength during morning hours. Furthermore, the temporal mismatch between endogenous readiness and training requirements is a robust predictor of increased musculoskeletal injury risk, driven by deficits in postural control and cognitive vigilance.

From a clinical and practical perspective, addressing SJL requires a transition toward "circadian literacy" within sports medicine and athletic training. The implementation of chronotype-specific training schedules - whereby high-intensity sessions are aligned with an individual's peak biological window - represents a viable strategy for optimizing performance and mitigating injury incidence. Additionally, while participation in structured sports may act as a protective factor against the development of SJL, student-athletes remain vulnerable to high allostatic loads that necessitate comprehensive sleep hygiene and behavioral interventions. Future research should focus on the long-term metabolic consequences of chronic SJL and the efficacy of personalized circadian interventions in diverse athletic populations to further refine injury prevention protocols in the young adult demographic.

Disclosure

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