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Human Kinetics
INVITED COMMENTARY

Addressing Circadian Disruptions in Visually Impaired Paralympic Athletes

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Purpose: Transmeridian travel is common for elite athletes participating in competitions and training. However, this travel can lead to circadian misalignment wherein the internal biological clock becomes desynchronized with the light–dark cycle of the new environment, resulting in performance decrement and potential negative health consequences. Existing literature extensively discusses recommendations for managing jet lag, predominantly emphasizing light-based interventions to synchronize the internal clock with the anticipated time at the destination. Nevertheless, visually impaired (VI) athletes may lack photoreceptiveness, diminishing or nullifying the effectiveness of this therapy. Consequently, this invited commentary explores alternative strategies for addressing jet lag in VI athletes. ***Conclusions:*** VI athletes with light perception but reduced visual acuity or visual fields may still benefit from light interventions in managing jet lag. However, VI athletes lacking a conscious perception of light should rely on gradual shifts in behavioral factors, such as meal timing and exercise, to facilitate the entrainment of circadian rhythms to the destination time. Furthermore, interventions like melatonin supplementation may prove useful during and after travel. In addition, it is recommended that athlete guides adopt phase-forward or phase-back approaches to synchronize with the athlete, aiding in jet-lag management and optimizing performance.

Keywords: jet lag, entrainment, phase shift

Transmeridian travel (ie, travel across various time zones) has been shown to have deleterious effects on sleep, recovery, fatigue, and athletic performance.[1–4] The degradation of performance and other health or well-being outcomes is due to a disruption of one's circadian clock wherein the desynchronization of an individual's circadian rhythm compared with the 24-hour light and dark cycle results in jet lag. This is of particular importance for athletes competing in international competitions where travel may take them to time zones that are greater than 3 zones from their location of origin. Extensive work has been conducted to develop effective mitigation strategies to combat the jet lag-mediated declines in both human health and performance.

Although a variety of jet lag mitigation strategies have been developed, continued efforts toward developing and implementing effective strategies to attenuate the detrimental effects of jet lag in specific athlete populations, such as those with visual impairment, are needed. Individuals with impaired vision, particularly where light perception is absent, often have an impaired ability to reset their circadian clock, which not only affects their day-to-day function but also may impact sport performance.[5–8] This has implications for the transmeridian travel of the visually impaired (VI) athlete as the external time cues associated with travel may inadvertently impact the athlete's preparedness to perform optimally. Although previous strategies such as light therapy, chronobiotics (eg, melatonin), exercise, diet, and meal timing have been shown to be effective in eliciting a phase response in an individual's circadian rhythm in sighted athletes for combating jet lag,[9–16] there is a paucity of evidence specific to the VI athlete from which practitioners can glean data-informed recommendations.

Purpose

The purpose of this invited commentary is to (1) briefly discuss interventions for managing jet lag in the elite athlete, (2) describe the physiological underpinnings of light therapy on the circadian rhythm and the effectiveness of this therapy among VI athletes, and (3) provide practitioners with recommendations to adapt jet lag mitigation strategies for the VI athlete.

Jet-Lag Interventions in Elite Athletes

A variety of interventions have been explored to mitigate jet lag, including both pharmacological (melatonin supplementation, melatonin analogues, sedatives, and stimulants) and nonpharmacological (exercise, nutrition, sleep preservation, and light exposure) options.[15,17] However, it is important to note that the literature on management strategies primarily consists of opinions, collective experience manuscripts, and laboratory research studies, with limited research in athletic or elite athlete populations.[15,17]

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Pharmacological interventions, such as melatonin and melatonin analogues, sedatives, and stimulants, have all been explored to varying degrees. Studies investigating melatonin administration and melatonin analogues have reported a reduction in the time required for circadian system resynchronization following long-haul travel.[16,18–22] However, the evidence is limited by small sample sizes and the absence of control groups, emphasizing the need for more extensive studies with robust methodologies.[15] Present guidelines concerning the management of jet lag through melatonin supplementation propose that, although 0.5 mg can be efficacious,[23] individuals may begin with an initial dosage of 2 to 3 mg and consider a gradual increase up to 5 mg as necessary.[24] Moreover, it appears that there is little additional benefit beyond 5 mg[25] and that slow-release supplements have reduced efficacy compared with faster-acting counterparts.[23] The use of sedatives and stimulants in the athlete population remains limited and requires more comprehensive studies to determine their efficacy and safety.[15,26–28]

Nonpharmacological interventions may also play an important role in mitigating jet lag symptoms in elite athletes. Exercise has been suggested to aid in resynchronizing the circadian system, but the timing and intensity of exercise sessions need to be carefully considered.[18,29–31] Similarly, appropriate meal timing and composition may play a role in reducing jet lag symptoms, although research specific to athletes is needed to establish precise recommendations.[32,33] Nutritional strategies primarily target peripheral clocks as opposed to central circadian regulators.[34] Although the specific micronutrient and macronutrient composition of the meal that is ideal for managing jet lag and resynchronizing circadian rhythms is not presently well evidenced,[35] current guidelines for athletes suggest that carbohydrate-rich meals can promote sleep prior to travel while attempting to shift biological rhythms, and high daily fat intake may inhibit total sleep time.[17] Other dietary considerations, such as consuming nutrients that act as precursors to neurotransmitters that, in turn, modulate the sleep–wake cycle, may also be effective[35] and should be considered in consultation with health care professionals and sports dietitians.

Preserving sleep is another nonpharmacological intervention that has been investigated with the goal of minimizing jet lag's impact on athletic performance.[36,37] By ensuring that athletes maintain their regular sleep patterns as much as possible during travel and adjusting sleep schedules accordingly, it is believed that the disruption caused by jet lag can be minimized.[36,37] However, like other nonpharmacological interventions, current evidence on sleep interventions is extremely limited within athlete populations.[15]

Finally, research on light exposure as an intervention for recovering from jet lag within athlete populations has found conflicting results, making it challenging to draw definitive conclusions.[11,18] Although one study reported a positive effect of light treatment on minimizing the effects of jet lag, the intervention in that study also included exercise and melatonin administration.[18] Further research is necessary to understand the specific effects of light interventions in reducing jet lag. However, the physiology underlying light exposure as a stimulus for altering circadian rhythms indicates that light exposure may play a critical role as an intervention for jet lag recovery in elite athletes.

Circadian Rhythm Physiology and Light Entrainment

Nearly all organisms exhibit varying degrees of circadian regulation to anticipate environmental changes, denoting a physiological rhythm that spans approximately 1 day ("about a day"; circa—about, dies—a day). In human beings, this circadian rhythm governs numerous vital processes, including the sleep–wake cycle, endocrine secretion patterns, body temperature, and various physiological and psychological functions. These intricate regulatory mechanisms are orchestrated by a complex interplay of proteins within the suprachiasmatic nucleus (SCN), colloquially known as the "biological clock" or "master pacemaker," which can transmit circadian information downstream. Located within the hypothalamus, the SCN contains an endogenous self-oscillating transcriptional loop that includes the circadian locomotor output cycle kaput and brain muscle arnt-like protein 1. Together, these proteins form a heterodimeric complex that subsequently binds to specific segments of deoxyribonucleic acid E-box response elements.[38] This binding event promotes the translation of period (Per1/Per2/Per3) and cryptochrome (Cry1/Cry2) proteins, which form the negative arm of the loop and are typically most abundant during the night.[39] Per and Cry proteins inhibit the transcriptional activity of the circadian locomotor output cycle kaput–brain muscle arnt-like protein 1 dimer, thus downregulating their own expression before ubiquitylation and proteasomal degradation.[40] Additional regulatory proteins (eg, Rev-erb and retinoic-acid-related orphan receptors) contribute to the stability of this loop and modulate its duration to approximately a 24-hour cycle. Readers are directed to excellent reviews on the topic for further detail regarding the molecular regulation of the biological clock.[41]

Anatomically positioned in close proximity to the optic nerve, the SCN possesses the capacity to modulate the circadian protein feedback loop in response to external light cues.[42] In fact, light acts as a potent zeitgeber capable of entraining the transcriptional loop to the prevailing light–dark cycle. Upon exposure to light, particularly light in the blue spectrum ($\lambda \approx 480$ nm),[43] the photopigment melanopsin is activated in retinal ganglion cells, which then transmit the electrochemical signal through the retinal tract to the optic nerve. Current understanding posits that this light-induced signal alters cAMP response element-binding protein signaling in the SCN[44] and regulates the activity of the Per proteins.[45] Through this intricate mechanism, light exposure can create either circadian phase advances or delays, contingent upon the timing of the light exposure.[46] The duration of light exposure will also impact circadian modulation in a nonlinear and dose-dependent manner,[47] with durations as short as 12 minutes inducing phase delays,[47] and 30 minutes of exposure demonstrating significant melatonin suppression.[48] However, the effect of exposure duration also varies nonlinearly with light intensity and the specific wavelength employed, and phase shifts will be dependent on the timing within the circadian rhythm that the exposure occurs.[49]

Light Exposure Efficacy in Managing Jet Lag in VI Athletes

Light exposure is a pillar of jet lag management in sighted athletes due to its etiological roots in the disruption of the habitual light–dark cycle.[17,50] However, it will have diverging degrees of utility in VI athletes as this population includes individuals with a broad range of photic sensitivities. The International Blind Sports Federation maintains 3 sport class profiles (labeled B1, B2, and B3) for athletes with VI (see Table 1 for details), which is a typical structure of VI classification in Paralympic sport,[51] with some sport-specific variation.[52] These classes range from complete blindness with no conscious perception of light (NPL) to athletes with perception of light but reduced visual acuity and/or reduced visual fields (PL).

Table 1 Sport Classes as Defined by the International Blind Sports Federation

Sport class	Visual acuity	Visual field	Description
B1	LogMAR > 2.60		No light perception in either eye up to inability to recognize shape of hand
B2	LogMAR 1.50–2.60 (inclusive)	<10° diameter	Ability to recognize shape of hand up to set field and acuity guidelines with best corrected vision
B3	LogMAR 1.00–1.50 (inclusive)	<40° diameter	Stated acuity and/or field characteristics with best corrected vision

Abbreviation: LogMAR, logarithm of the minimum angle of resolution. Note: For B2 and B3 classes, either the visual acuity or the visual field criteria may be met.

VI individuals with NPL (ie, some B1 athletes) often have abnormal circadian rhythms[53] and may not be able to use light to entrain circadian rhythmicity and manage jet lag.[8] Within this population, individuals completely lacking eyes—either congenitally or due to enucleation—are unable to entrain their SCN to a 24-hour light–dark cycle.[53] Of the NPL VI individuals with intact eyes, approximately 50% will still typically exhibit non-24-hour circadian rhythms as well, suggesting that light will be an ineffective zeitgeber in their management of jet lag.[8,54] Some NPL VI individuals with intact eyes do exhibit circadian phase shifting in response to light exposure, likely due to functioning nonimage-forming pathways of the visual system.[55] These individuals may respond to traditional recommendations for light exposure in the management of jet lag.

VI individuals with PL (all B2 and B3 athletes, some B1 athletes) will likely have normally entrained circadian rhythms (ie, 24-h light–dark rhythmicity in pineal melatonin secretion).[53] Consequently, they will likely experience jet lag and require its management similar to fully sighted individuals.[17]

Practical Applications and Conclusions

Given the dichotomy in photic sensitivity and corresponding capacity for circadian entrainment in VI populations, the strategies for managing jet lag in VI athletes will fall into 2 sets of recommendations: 1 for PL VI athletes and 1 for NPL VI athletes. For the PL athletes, their recommendations and interventions to manage jet lag will be consistent with other sighted athletes.[17] With respect to light exposure, preflight recommendations include moving bedtimes toward the destination time zone and maximizing/minimizing morning/evening light toward the destination (eg, maximizing morning light exposure and minimizing evening light exposure for eastward travel). Within-flight recommendations include maximizing and minimizing light exposure before or after an expected minimum in core body temperature (CBTmin), which would typically occur 5 hours after bedtime (eg, for eastward travel, minimizing light exposure 0–3 h before CBTmin and maximizing light exposure 0–3 h after expected CBTmin). Postflight recommendations would include similar strategies around light exposure relative to CBTmin (anticipating that it will move by 1 h/d in eastward travel and 2 h/d in westward travel), proactive sleep hygiene strategies, and the consideration of a melatonin supplement 11.5 hours before anticipated CBTmin following eastward travel and 4 hours after anticipated CBTmin following westward travel.[17]

The recommendations for NPL VI athletes will typically rely on nonphotic cues. These include timing of exercise, meals, and social interactions.[53] These athletes may generally benefit from strict schedules around meals and training to best entrain their native clock in their daily living, and the use of these cues in and around long travel may serve to advance or delay their biological clock to the destination clock. Pretravel, they may consider shifting their meals and training times in a similar fashion described earlier for PL athletes and light exposure (eg, meals and training 30–60 min earlier/later per day for 3–4 d ahead of eastward/westward travel, respectively, see Figure 1). It is also prudent to consider evidence suggesting that even in NPL VI athletes, some photosensitivity geared toward circadian regulation may persist,[55,56] illustrated by the suppression of melatonin following light exposure in animal[57] and human[58] models. Consequently, it could be beneficial to incorporate some light exposure and protection schedules for specific NPL VI individuals, especially those who do not report sleep disorders and exhibit age-appropriate sleep–wake activity patterns.[59] NPL VI individuals may even consider trialing the effect of light exposure on their subjective sleep quality ahead of travel to assess the possible efficacy or lack thereof of this management strategy. This personalized approach to address these variations ensures the optimal opportunity for achieving circadian synchronization and reducing jet lag's impact.

Within travel, they may consider eating breakfast and dinner before or after a CBTmin, which would typically occur 5 hours after bedtime (eg, for eastward travel, eating dinner and doing light stretching or movement 0–3 h before CBTmin and eating breakfast and doing light stretching or movement 0–3 h after expected CBTmin). Postflight, using meals and exercise in the same fashion will likely be beneficial as well. These athletes may also benefit from a melatonin supplement 11.5 hours before anticipated CBTmin after eastward travel and 4 hours after anticipated CBTmin during westward travel.[17] Of note, although the aforementioned melatonin dose recommendations may be adhered to, lower and more physiological doses (~0.3 mg) have been demonstrated to assist in synchronizing a 24-hour circadian rhythm in persons with visual impairment.[60] However, in our own practice, some NPL VI athletes have reported positive experiences in response to a larger, albeit tapered, dosing regimen wherein doses start large (eg, an initial 7–8 mg dose) then reduce (eg, 5 mg for days 1–3). Thus, the precise melatonin dose for NPL VI athletes to alleviate the effects of jet lag is currently unknown, and it is advised that athletes, in conjunction with health care professionals and dietitians, ascertain individual dosages that optimally support their physiological requirements.

Another consideration with NPL VI athletes is the influence of a guide athlete (typical of para athletics, cycling, rowing, triathlon, Nordic skiing, and Alpine skiing competition) or their PL VI teammates (such as in goalball, football, or judo team settings) and their own jet lag management and behavior. For the NPL VI athlete, their guide or PL VI teammates may have the ability to assist entrainment via the nonphotic cues described earlier, and they may be especially effective with the timing of social interaction to promote entrainment. The guide themselves should follow the recommendations for jet lag management in sighted athletes[17] as failure to manage jet lag may have a negative impact both on the VI athlete's jet lag management and on the guide's own athletic

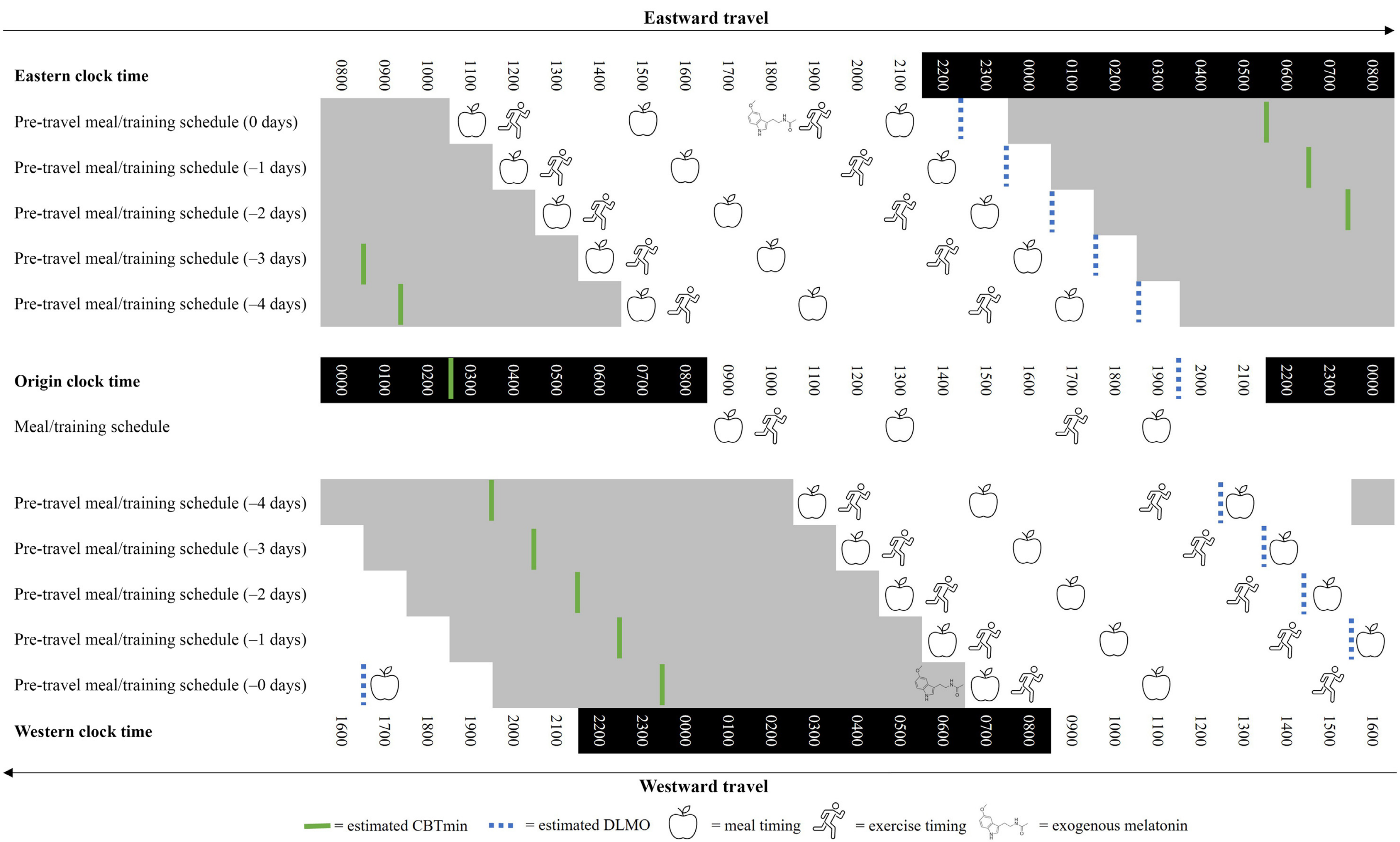

Figure 1 — An example of phase shifting forward and backward in preparation for eastward (+8 h) and westward (–8 h) travel using nonphotic cues for visually impaired athletes. Black regions represent estimated sleep time in origin and destination. Gray regions represent a shift in sleep schedule in preparation for travel. CBTmin indicates minimum core body temperature; DLMO, dim-light melatonin onset.

performance. In any case, all VI athletes should be encouraged to advocate to team staff for the needed components of travel (eg, roommate selection and daily routine) that will best facilitate their management and adaptation to the new environment.

In some contexts, NPL VI athletes may benefit from not attempting to advance or delay their biological clocks. Given their insensitivity to the strongest zeitgeber, light, and that nonphotic cues are much weaker than photic cues in advancing or delaying the biological clock,[53,61] they may facilitate their best competition performance in the new time zone by maintaining a habitual sleep–wake cycle. This would only be recommended under circumstances wherein the athlete would be able to train safely, eat in a timely fashion, and be able to manage logistics around the competition. This may be feasible in some team sports (eg, goalball or football) where there may be several NPL VI athletes without guides and where team staff could facilitate this strategy without compromising PL VI athlete jet lag management or in guided sports where this strategy would not affect the capabilities of the guide.

Finally, it should be noted that nonphotic cues are much less effective than light in entraining circadian rhythms.[61] Strict adherence to scheduled activity and meals is required for effective entrainment in NPL VI individuals,[54,62] and many NPL VI individuals still struggle to maintain 24-hour clock entrainment despite many 24-hour cues in daily living.[8] NPL VI athletes with biological clocks that are far from 24 hours may struggle to respond to any form of jet lag management and, thus, may not benefit from the strategy described earlier.

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