Do Long-Haul Travels and Jet Lag Affect Athletes' Physiological, Humoral and Performance Outcomes?

Academic dissertation submitted to obtain a master's degree in Sports Training, specialization in High Performance Training, organized by the Faculty of Sports - University of Porto, under Decree-Law 74/2006, of March 24th, as amended by Decree-Law 65/2018 of August 16th, and with the changes introduced by Decree-Law 27/2021, of April 16th.

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Porto, 2025

Benito, A. (2025), Do Long-Haul Travels and Jet Lag Affect Athletes' Physiological, Humoral and Performance Outcomes? Porto: A. Benito. Academic dissertation submitted pursuing the Master’s degree in Sports Training, specializing in High Performance Training at the Faculty of Sport, University of Porto, Portugal.

KEYWORDS: CIRCADIAN RHYTHMS, LONG JOURNEYS, TRAVEL FATIGUE, JET LAG, ATHLETES, PERFORMANCE, PHYSIOLOGY

Acknowledgements

Gostaria de expressar o meu sincero agradecimento à Faculdade de Desporto da Universidade do Porto. Esta Universidade, que tem sido a minha casa desde 2018, é uma referência na formação profissional e académica a nível nacional e internacional.

Ao meu orientador, Professor Doutor Rodrigo Zacca, ao qual devo um agradecimento eterno. Agradeço-lhe por iluminar os meus caminhos ao longo deste ano na redação da minha dissertação, bem como, por embelezar o meu percurso académico e científico. Desde a primeira aula de Fisiologia do Exercício, soube que gostaria que a minha dissertação fosse orientada pelo Professor. Nunca me vou esquecer do Professor, por tudo que fez por mim, pelos momentos passados no laboratório e por toda a partilha do seu vasto conhecimento.

Aos meus coorientadores, Professora Doutora Liliana Baptista, Professor Doutor Daniel Moreira-Gonçalves, por aceitarem coorientar a minha dissertação, por todo o vosso apoio ao longo deste processo, e por terem contribuído de forma ativa no meu crescimento académico. Foi um orgulho ter sido orientado por ambos.

Aos coautores do meu primeiro artigo, obrigado por terem aceite de braços abertos este projeto e pela vossa colaboração ativa na sua redação.

À minha avó, e avô, de quem herdo o nome Benito, que sempre tomaram conta de mim e que apesar de todas as suas dificuldades nunca deixaram que me faltasse nada, obrigado por fazerem esta dissertação possível.

À minha mãe, um obrigado por todas as vezes que abdicou do seu bem-estar por minha causa. Que estejas orgulhosa de mim e do meu trajeto.

À minha namorada, Joana, aos seus pais, José Carlos e Maria José, um obrigado muito especial. O vosso apoio de todas as horas, de todos os dias, foi fundamental na redação da minha dissertação. Obrigado por me fazerem sentir uma pessoa especial, e por fazerem com que eu acredite em mim.

À Professora Doutora Susana Soares, que na licenciatura me mostrou que tudo na vida tem o seu tempo, e que o trabalho é o ingrediente para o sucesso. Ensinou-me a sentir o melhor sabor do mundo, o sabor da sensação de orgulho quando realizamos algo com esforço e mérito próprio.

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Abstract

The globalized nature of modern sport requires athletes to frequently undertake long-distance travel. These trips can disrupt athletes' biological rhythms and cause travel fatigue and jet lag. This academic dissertation, in the form of a Systematic Narrative Review, aimed to explore the importance of circadian rhythms in athletes' health and performance, as well as to clearly distinguish between the terms travel fatigue and jet lag. In addition, we sought to analyze the preparation strategies of teams and athletes before, during and after long trips to competitive events, identify the readiness markers used by those responsible for assessing and monitoring athletes' training, and finally, investigate the physiological, hemodynamic and performance changes induced by long trips. The results revealed significant changes in several physiological markers, namely disturbances in sleep patterns, fluctuations in body temperature, changes in blood pressure and changes in hormone levels, namely the hormone cortisol and the enzyme alpha amylase. Physical performance is negatively affected, with this deterioration being more pronounced after trips to the East. Melatonin, caffeine, and light exposure were the most studied exogenous countermeasures and were used in practice by coaches, medical staff, and athletes during long trips. The effects of long trips are multifactorial and involve the dysregulation of the autonomic and endocrine systems. It is essential that athletes and teams implement behavioral adaptation strategies, and individualized monitoring to optimize recovery, minimize jet lag symptoms and ensure the best possible performance in competitive events after a long trip.

KEYWORDS: CIRCADIAN RHYTHMS, LONG JOURNEYS, TRAVEL FATIGUE, JET LAG, ATHLETES, PERFORMANCE, PHYSIOLOGY

Resumo

A natureza globalizada do desporto moderno exige que os atletas realizem frequentemente viagens de longo curso. Estas viagens podem desregular os ritmos biológicos dos atletas e originar quadros de fadiga de viagem e jet lag. Esta dissertação, materializada através de uma Revisão Sistemática Narrativa, teve como objetivo principal explorar a importância dos ritmos circadianos na saúde e performance dos atletas, assim como distinguir de forma clara os termos fadiga de viagem e *jet lag*. Adicionalmente, procuramos analisar as estratégias de preparação das equipas e atletas antes, durante e após viagens longas precedentes de eventos competitivos, identificar quais os marcadores de prontidão utilizados pelos responsáveis pela avaliação e controlo de treino dos atletas e por último, investigar as alterações fisiológicas, hemodinâmicas e de performance induzidas por viagens longas. Os resultados revelaram alterações significativas em vários marcadores fisiológicos, nomeadamente distúrbios nos padrões de sono, flutuações na temperatura corporal, alterações na pressão arterial e alterações nos níveis hormonais, nomeadamente a hormona cortisol e na enzima alfa amílase. No que concerne ao desempenho físico, este é negativamente afetado, sendo esta deterioração mais acentuada após viagens para Este. Melatonina, cafeína e exposição à luz foram as contramedidas exógenas mais estudas, e utilizadas na prática pelos treinadores, elementos do departamento médico e atletas aquando de uma viagem longa. Os efeitos de viagens longas são multifatoriais, e envolvem a desregulação dos sistemas autónomo e endócrino. É essencial que os atletas e equipas implementem estratégias de adaptação comportamental e que a monitorização seja de individualizadas para otimizar a recuperação, minimizar os sintomas de *jet lag* e garantir o melhor desempenho possível em eventos competitivos após uma viagem longa.

PALAVRAS-CHAVE: RITMOS CIRCADIANOS, VIAGENS-LONGAS, FADIGA DE VIAGEM, JET LAG, ATLETAS, PERFORMANCE, FISIOLOGIA

List of Abbreviations

SCN: Suprachiasmatic nucleus

WC: West Coast

EC: East Coast

NA: North America

MNF: Monday night football

TMD: Total mood disturbance

HR: Heart rate

BP: Blood pressure

GS: Grip strength

CV: Cardiovascular

NS: Not significant

SG: Specific gravity

GH: Growth hormone

MTG: Morning training group

CG: Control group

BDJ: Box drop jump

CMJ: Countermovement jump

SJ: Squat jump

EUR: Eccentric utilization ratio

SSC: Stretch shortening cycle

LG: Light group

SM: Squad members

UR: Upper respiratory

ES: Effect size

YYIR1: Yo Yo intermitent recovery level 1

sIgA: Secretory immunoglobulin A

LH: Long haul

NE: Northeast

CHO: Carbohydrates

SBP: Systolic blood pressure

SO_2: Oxygen saturation
COMP: Compression
KPI: Key performance indicator
MBB: Male basketball players
WHR: Waist to hip ratio
RHR: Resting heart rate
BMD: Bone mineral density
TIB: Time in bed
SOL: Sleep onset latency
BFR: Blood flow restriction
TD: Total distance
HI: High intensity
INT: Intervention
RCTs: Randomized control trials
CBTmin: Core body temperature minimum
WASO: Wake after sleep onset
TASO: Time of attempted sleep onset
TAW: Time of awaking
TST: Total sleep time
LDTT: Long distance transmeridian travel
EMV: Eccentric mean velocity
NOS: Newcastle Ottawa scale
LnRMSSD: Natural logarithm of the Root Mean Square of Successive Differences
CWI: Cold water immersion
ASSQ: Athlete Sleep Screening Questionnaire
TZ: Time zone
AdjTZ: Adjusted time zone
DiffActExpFSv: Difference between actual and expected Fenwick Save %
FT: Free throw
FG: Field goals
sAA: Salivary alpha amylase
$\dot{V}O_2$: Oxygen consumption

$\dot{V}E$: Ventilation

RER: Respiratory exchange ratio

HR: Heart rate

VE/VO_2: Ventilatory equivalent for oxygen

Chapter1

General Introduction

Chapter 1

1. General Introduction

1.1. Rationale and study's pertinence

The modern athlete (whether elite or recreational) spends much of the competitive season traveling, whether for competition or training(Young et al., 1998). This is a consequence of the globalized nature of sport and can involve journeys that may be long-haul trips or, more commonly, short-distance travels. Both types of travels can result in two distinct challenges: travel fatigue and jet lag (Waterhouse et al., 2002). These two conditions share certain symptoms, and due to a lack of awareness, athletes tend to mistakenly attribute all such effects solely to jet lag (Loat & Rhodes, 1989; Reilly et al., 1997; Schobersberger & Schobersberger, 2012). Travel fatigue and jet lag are distinct conditions that can co-occur when traveling east or west, but jet lag only occurs when the traveler travel across three or more time zones (Reilly et al., 2009; Samuels, 2012; Waterhouse et al., 2007).

Despite the direction and duration of flights, all travels can induce some type of fatigue (Pipe, 2011; Tsukahara et al., 2024; Waterhouse et al., 2004). These symptoms can be present in an acute way, after a single long journey or develop chronically as a cumulative result of repeated travel within a season (Reilly et al., 2009). Travel fatigue can arise regardless the number of time zones crossed, resulting from the inherent demands of travel itself. It's before the flight that travel fatigue arises, with long airport lines, flight delays and for the traveler athletes, anxiety pre-competition. During flight the challenges are cramped seating position, prolonged mild hypoxia, reduced physical activity, dehydrating effects of dry air on-board. On the arrival, the traveler can experience cultural differences that can rise the travel fatigue symptoms (Reilly et al., 1997; Reilly et al., 2009).

Jet lag results from a misalignment between the body's internal clock and the local time at the destination. Jet lag share symptoms with travel fatigue, but these are often more severe and longer lasting (Reilly et al., 2007a; Reilly et al., 2005, 2009; Samuels, 2012). Both the direction and duration of travel have direct implications for symptom manifestation, but jet lag only occurs when journeys involve crossing three or more time zones (Hartman, 1971). With respect to travel direction, it is well reported that eastward travel is associated with more severe jet lag symptoms compared to westward travel. Depending on the timing of training or competition, this circadian disruption can directly impair athletic performance (Eastman & Burgess, 2009; Samuels, 2012; Waterhouse et al., 2007).

Regular biological rhythms, also known as biological clocks, exhibit periodic oscillations ranging from milliseconds (e.g., biochemical reactions) to hours, days or years (Winget et al., 1985). Circadian rhythms, from the Latin circa diem (about a day), govern the daily rhythm of our physiology and performance (Smith et al., 1997; Winget et al., 1985). Most physiological functions exhibit circadian rhythmicity, maximum (acrophase) and minimum (nadir) that occur in specific times of day (Waterhouse et al., 2004; Winget et al., 1985). Circadian rhythms are expressed by oscillations in physiological systems (e.g., body temperature, heart rate, hormonal levels and blood cortisol levels). These variables respond to either internal (e.g., neurotransmitters, electrolytes or metabolic substrates) or external (e.g., environmental factors, drugs, food) stimuli (Jehue et al., 1993; Waterhouse et al., 2004; Winget et al., 1985). The primary synchronizer for humans is light-dark cycle (Eichner, 1994; Reilly et al., 1997; Waterhouse et al., 2004; Winget et al., 1985).

The circadian rhythm is defined by the suprachiasmatic nucleus (SCN), located in the hypothalamus, and considered the master biological clock. It regulates, among others, the production of melatonin by the pineal gland ad interacts with neurotransmitters such as serotonin, which participates indirectly in sleep and serves as precursor of melatonin. Through these substances, our body is able to change from daytime alertness to night-time drowsiness (Reilly et al., 1997). The SCN signals different regions of the hypothalamus, influencing processes such as temperature regulation, hormone release, feeding and sleep, which shows the SCN central role in the coordination of all organism (Waterhouse et al., 2004).

External timing cues, known as zeitgebers (German for “time-givers”), synchronize the body’s internal clock network with the external environment. The most powerful zeitgeber in humans’ circadian system is light. The SCN receives photic input from the retina and uses it to reset subordinate clocks in other brain regions and peripheral tissues, either through direct neural connections, humoral signals, or by regulating behavioral rhythms such as the sleep/wake and feeding/fasting cycles (Heyde & Oster, 2019). Limiting food intake to the normal rest phase (nighttime in humans, daytime in nocturnal rodents) can cause peripheral tissue clocks to become uncoupled from the SCN pacemaker, with glucocorticoids playing a role in this process. This internal desynchronization is a characteristic of shift work and may contribute to the development of shift work-related health problems, including obesity, type 2 diabetes, cardiovascular disease, and mood disorders (Damiola et al., 2000; Heyde & Oster, 2019).

Humans typically exhibit individual differences in the timing of their behaviors, such as social activities, daytime routines, and sleep patterns (Lastella et al., 2016; Roenneberg et al., 2003). This is evident in their preferred timing of sleep and wakefulness. At one end of the scale there are morning types and at the other end there are evening types, while in the middle there are intermediate types (Adan et al., 2012; Lastella et al., 2016). Morning types are phase advanced demonstrating clear preferences in waking up and performing activities in the early morning and find it difficult to remain awake beyond their usual bedtime (Adan et al., 2012; Lastella et al., 2016). In contrast, evening types are phase delayed such that they prefer going to bed later and find it difficult to wake up early (Adan et al., 2012; Lastella et al., 2016). Research on the chronotype distribution in the general adult population (ages 19–31) shows that the majority are intermediate types (70%), while smaller portions are morning types (14%) and evening types (16%) (Rosenthal et al., 2001).

Defining a predominant chronotype among elite athletes remains challenging, as existing studies yield conflicting results. In the study conducted by Samuels, S. et al. most athletes were classified as morning types (51%), followed by intermediate types (40%), with only a small proportion identified as evening types (9%) (Samuels, 2008). However, it is important to note that these findings were based on school and Paralympic athletes participating in individual sports (e.g., bobsleigh, skeleton, track and field), which may limit their generalizability to the broader elite athlete population. Similarly, Silva et al. reported that 83% of athletes experienced daytime sleepiness, with 71% of these individuals classified as morning types (Silva et al., 2012). In East Asia, investigations conducted in Japan and Korea have examined the chronotypes of elite athletes, revealing distinct patterns: the majority of Japanese athletes exhibited intermediate chronotypes, whereas most Korean athletes demonstrated a tendency toward eveningness (Tan et al., 2023).

In elite sports, athletes' sleep–wake patterns are largely shaped by the demands of their training schedules (Lastella et al., 2015). Optimal training and performance require alignment between an athlete's chronotype and their training timetable (Drust et al., 2005). Athletes participating in morning sports will be predominantly morning types and athletes participating in evening sports will be evening types (Lastella et al., 2016).

The American Academy of Sleep Medicine defines jet lag as a syndrome that may occur following travel across at least two time zone (Medicine, 2014). This condition can adversely affect both physical and mental performance, leading to symptoms such as insomnia and/or excessive daytime sleepiness, fatigue, reduced muscular strength and psychomotor coordination, impaired cognition and memory, anxiety, depression, and somatic complaints including constipation and loss of appetite (Challet, 2013; Cho et al., 2000; Coutinho et al., 2015; Forbes-Robertson et al., 2012; Horsey et al., 2019; Katz et al., 2002; Takahashi et al., 2002; Waterhouse et al., 2007; Zhang et al., 2020). These manifestations arise because the body continues to function according to the circadian rhythm of the departure time zone (Glinski & Chandy, 2022). Over time, the circadian system gradually aligns with the day–night cycle of the new location, and these physical and psychological effects progressively resolve (Herxheimer, 2014).

One important aspect to consider regarding jet lag is the direction of travel. When traveling west, we are effectively lengthening our day, which delays our biological clock, whereas traveling east shortens our day, advancing our biological clock

(Lee & Galvez, 2012). Consequently, the time required to resynchronize our internal clock with the local time varies. Traveling west generally requires about half a day to adjust for each hour of time difference, while traveling east typically requires approximately one and a half days per hour of difference (Forbes-Robertson et al., 2012; Lee & Galvez, 2012; Reilly et al., 2007a). It is also important to note that eastward travel tends to produce more pronounced jet lag symptoms, as the human circadian system is naturally better adapted to extending the day rather than shortening it (Lee & Galvez, 2012; Winget et al., 1985).

1.2. Research Aims

The primary aim of this academic dissertation was to explore the importance of circadian rhythms for athlete's health and performance. Another purpose of this academic dissertation was to distinguish the terms jet lag and travel fatigue. This academic dissertation also aimed to examine how athletes and teams prepare for long-haul travel preceding competitive events, to identify the markers used to assess athletes' readiness and to investigate whether long-haul travel induces physiological, hemodynamic, or performance related changes.

1.3. Academic dissertation overview

This academic dissertation was organized as follows. The current chapter (Chapter 1) provides a general introduction with the rationale and study's pertinence with definitions of concepts regarding Circadian Rhythms, Chronotypes and Jet Lag. The purposes of this academic dissertation are also outlined on Chapter 1.

Chapter 2 presents an original article, a Systematic Narrative Review regarding the effects of long-haul travels and jet lag in athletes' physiological systems, humoral and performance outcomes as well. In this article we aimed to explore the importance of circadian rhythms for athlete's health and performance, to examine how athletes and teams prepare for long-haul travel preceding competitive events, to identify the markers used to assess athletes' readiness and to investigate whether long-haul travel induces physiological, hemodynamic, or performance related changes.

Chapter 3 of this academic dissertation aimed to discuss the conclusions obtained in the article, to present limitations, to present practical applications and future perspectives to develop the investigation regarding long-haul travels and jet lag in sports.

The Chapter 4 presents and summarizes the overall conclusions of this academic dissertation.

Ultimately, the Chapter 5 provides references for Chapters 1, 3 and 4.

Chapter 2

Do Long-Haul Travels and Jet Lag Affect Athletes' Physiological, Humoral and Performance Outcomes? A Systematic Narrative Review

Chapter 2

Title: **Do Long-Haul Travels and Jet Lag Affect Athletes' Physiological, Humoral and Performance Outcomes? A Systematic Narrative Review**

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Abstract

The modern athlete spends much of the competitive season traveling. Long-haul travels or short-distance travels can result in two distinct challenges: travel fatigue and jet lag. This Systematic Narrative Review aimed i) to explore the effect of circadian rhythms for athlete's health and performance, ii) to distinguish the terms jet lag and travel fatigue, iii) to examine how athletes and teams prepare for long-haul travel preceding competitive events, iv) to identify the markers used to assess athletes' readiness and v) to investigate whether long-haul travel induces physiological, hemodynamic, or performance-related changes. **Methods:** Electronic databases searches of PubMed, Scopus and Web of Science were conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines (PRISMA). Studies were eligible for inclusion if the study had a long-haul travel and used an outcome measure for performance or hemodynamic markers after the travel. **Results:** A total of 284 records were identified. Of the 100 studies retained for full-text screening, 11 did not meet inclusion criteria and were removed. 89 studies were therefore deemed eligible for inclusion in the review. 72 did not report any intervention to mitigate travel effects. The use of melatonin was the most frequently common intervention, followed by caffeine and light exposure. Thirty-six studies reported changes in sleep, 18 reported alterations in body temperature, 9 (n=9) reported changes in blood pressure, nine (n=9) reported hormonal changes, four (n=4) reported heart rate variability alterations, and four (n=4) reported effects on the immune system. The most cited physical performance metric was related to anaerobic power and capacity, being cited in 18 studies. Strength was the next most common, reported in 14 studies, followed by velocity in 12 studies, aerobic power and capacity in ten (n=10), and coordination in eight (n=8). Lastly, reaction time was reported in seven (n=7) studies. Coordination was cited in 8 studies. Lastly, in 7 studies, reaction time. **Conclusion:** In terms of hemodynamic and physiological markers, changes in blood pressure, body temperature, and sleep patterns were observed, with direct impacts on recovery and athletes' readiness to compete. In general, physical performance is negatively affected, especially after eastward travel. In summary, the effects of long-haul travel are multifactorial and link physical performance with autonomic and endocrine regulation, making personalized monitoring fundamental to mitigating the effects of long-haul travel and jet lag in athletes at all levels.

Introduction

The modern athlete (whether elite or recreational) spends much of the competitive season traveling, whether for competition or training (Young et al., 1998). This is a consequence of the globalized nature of sport and can involve journeys that may be long-haul trips or, more commonly, short-distance travels. Both types of travels can result in two distinct challenges: travel fatigue and jet lag(Waterhouse et al., 2002). These two conditions share certain symptoms, and due to a lack of awareness, often leads the athletes to mistakenly attribute all such effects solely to jet lag (Loat & Rhodes, 1989; Reilly et al., 1997; Schobersberger & Schobersberger, 2012). Travel fatigue and jet lag are distinct conditions that can co-occur when traveling east or west, but jet lag only occurs when the traveler across three or more time zones (Reilly et al., 2009; Samuels, 2012; Waterhouse et al., 2007).

Despite the direction and duration of flights, all travels can induce some type of fatigue (Pipe, 2011; Tsukahara et al., 2024; Waterhouse et al., 2004). These symptoms can be present in an acute way, after a single long journey or develop chronically as a cumulative result of repeated travel within a season (Reilly et al., 2009). Travel fatigue can arise regardless the number of time zones crossed, resulting from the inherent demands of travel itself. It's before the flight that travel fatigue arises, with long airport lines, flight delays and for the traveler athletes, anxiety pre-competition. During flight the challenges are cramped seating position, prolonged mild hypoxia, reduced physical activity, dehydrating effects of dry air on-board. On the arrival, the traveler can experience cultural differences that can rise the travel fatigue symptoms (Reilly et al., 1997; Reilly et al., 2009).

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The circadian rhythm is defined by the suprachiasmatic nucleus (SCN), located in the hypothalamus, is considered the master biological clock. It regulates, among others, the production of melatonin by the pineal gland ad interacts with neurotransmitters such as serotonin, which participates indirectly in sleep and serves as precursor of melatonin. Through these substances, our body is able to change from daytime alertness to night-time drowsiness (Reilly et al., 1997). The SCN signals different regions of the hypothalamus, influencing processes such as temperature regulation, hormone release, feeding and sleep, which shows the SCN central role in the coordination of all organism (Waterhouse et al., 2004).

External timing cues, known as zeitgebers (German for “time-givers”), synchronize the body’s internal clock network with the external environment. The most powerful zeitgeber in humans’ circadian system is light. The SCN receives photic input from the retina and uses it to reset subordinate clocks in other brain regions and peripheral tissues, either through direct neural connections, humoral signals, or by regulating behavioral rhythms such as the sleep/wake and feeding/fasting cycles (Heyde & Oster, 2019). Limiting food intake to the normal rest phase (nighttime in humans, daytime in nocturnal rodents) can cause peripheral tissue clocks to become uncoupled from the SCN pacemaker, with glucocorticoids playing a role in this process. This internal desynchronization is a characteristic feature of shift work and may contribute to the development of shift work-related health problems, including obesity, type 2 diabetes, cardiovascular disease, and mood disorders (Damiola et al., 2000; Heyde & Oster, 2019).

Humans typically exhibit significant individual differences in the timing of their behaviors, such as social activities, daytime routines, and sleep patterns (Lastella et al., 2016; Roenneberg et al., 2003). This is evident in their preferred timing of sleep and wakefulness. At one end of the scale there are morning types and at the other end there are evening types, while in the middle there are intermediate types (Adan et al., 2012; Lastella et al., 2016). Morning types are phase advanced demonstrating clear preferences in waking up and performing activities in the early morning and find it difficult to remain awake beyond their usual bedtime (Adan et al., 2012; Lastella et al., 2016). In contrast, evening types are phase delayed such that they prefer going to bed later and find it difficult to wake up early (Adan et al., 2012; Lastella et al., 2016). Research on the chronotype distribution in the general adult population (ages 19–31) shows that the majority are intermediate types (70%), while smaller portions are morning types (14%) and evening types (16%) (Rosenthal et al., 2001).

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In elite sports, athletes' sleep–wake patterns are largely shaped by the demands of their training schedules (Lastella et al., 2015). Optimal training and performance require alignment between an athlete's chronotype and their training timetable (Drust et al., 2005). Athletes participating in morning sports will be predominantly morning types and athletes participating in evening sports will be evening types (Lastella et al., 2016).

The American Academy of Sleep Medicine defines jet lag as a syndrome that may occur following travel across at least two time zones (Medicine, 2014). This condition can adversely affect both physical and mental performance, leading to symptoms such as insomnia and/or excessive daytime sleepiness, fatigue, reduced muscular strength and psychomotor coordination, impaired cognition and memory, anxiety, depression, and somatic complaints including constipation and loss of appetite (Challet, 2013; Cho et al., 2000; Coutinho et al., 2015; Forbes-Robertson et al., 2012; Horsey et al., 2019; Katz et al., 2002; Takahashi et al., 2002; Waterhouse et al., 2007; Zhang et al., 2020). These manifestations arise because the body continues to function according to the circadian rhythm of the departure time zone(Glinski & Chandy, 2022). Over time, the circadian system gradually aligns with the day–night cycle of the new location, and these physical and psychological effects progressively resolve(Herxheimer, 2014).

One important aspect to consider regarding jet lag is the direction of travel. When traveling west, we are effectively lengthening our day, which delays our biological clock, whereas traveling east shortens our day, advancing our biological clock (Lee & Galvez, 2012). Consequently, the time required to resynchronize our internal clock with the local time varies. Traveling west generally requires about half a day to adjust for each hour of time difference, while traveling east typically requires approximately one and a half days per hour of difference (Forbes-Robertson et al., 2012; Lee & Galvez, 2012; Reilly et al., 2007a). It is also important to note that eastward travel tends to produce more pronounced jet lag symptoms, as the human circadian system is naturally better adapted to extending the day rather than shortening it (Lee & Galvez, 2012; Winget et al., 1985).

Thus, the main aims of this systematic narrative review were i) to explore the importance of circadian rhythms for athlete's health and performance, ii) to distinguish the terms jet lag and travel fatigue, iii) to examine how athletes and teams prepare for long-haul travel preceding competitive events, iv) to identify the markers used to assess athletes' readiness and v) to investigate whether long-haul travel induces physiological, hemodynamic, or performance-related changes. We hypothesized that 1) circadian rhythms have impact on athlete's and performance, 2) the available literature will be capable to distinguish the terms travel fatigue and jet lag, 3) teams and athletes are better prepared for travels preceding competitive events, with more science based practices, 4) teams and athletes use objective sleep parameters, physiological markers (e.g salivary cortisol, body temperature and heart rate variability) and performance markers (e.g countermovement jump height, sprint time and aerobic power and capacity) and our last hypothesis is 5) that long haul travels have negative impacts on athlete's physiological systems and performance markers.

Methods

Eligibility

This study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). We used three databases: PubMed, Scopus and Web of Science. The search string and Boolean operators used were: ((“jet lag”) OR (“travel fatigue”) OR (“long travel”) OR (“transmeridian travel”) AND (“performance”) AND (“athletes”). Participants, interventions, comparators, outcomes, and study design (PICOS) were defined as follows:

- **(i)** **Participants –** Athletes of all levels, ages, and both sexes (male and female);
- **(ii)** **Interventions –** Jet lag and long-haul travel. Long-haul travel refers to journeys that typically exceed 4,000 km and often involve crossing multiple time zones or continental boundaries. While long-haul travel offers significant economic and cultural benefits, it may also pose specific challenges, including health and performance-related impacts;
- **(iii)** **Comparators –** Athletes who are frequently exposed to long-haul travel for training and/or competition;
- **(iv)** **Outcomes –** The primary outcomes in this review include humoral alterations, gastrointestinal disturbances, circadian rhythm disruptions, psychophysiological responses, hemodynamic changes, and variations in blood biomarkers. Additionally, secondary outcomes encompass physical fitness and performance-related indicators such as cardiorespiratory fitness, body composition, bone health, and various measures of muscular strength (isometric, dynamic, explosive, and reactive), as well as flexibility, agility and speed;
- **(v)** **Study Design -** The review did not impose restrictions on study design, and all types of studies were deemed eligible for inclusion.

This review has been registered with the International Prospective Register of Systematic Reviews (PROSPERO; registration number: CRD42025630974)

Study Selection

After defining the Boolean operators and keywords for the literature search, all retrieved references were imported into an EndNote database (version 21.5; (https://endnote.com, London, United Kingdom. Automatic duplicate removal tool was performed, followed by manual verification to identify and remove any remaining duplicates. Subsequently, two authors independently screened the titles and abstracts to determine eligibility for full-text review or exclusion. Disagreements between the two reviewers were resolved by consultation with a third author, who made the final decision. Full-text articles selected for inclusion were then read in detail, and a third stage of selection was applied: studies whose topic was not related to the aim of the review were excluded at this stage.

Data Extraction

From the eligible studies that were included in this review, data that was extracted from the studies were: publication details (first author, study tittle, year of publication), study design, participants (sex, sample size, competitive level), travel details (direction, number of time zones crossed), supplementation (exogenous strategies to mitigate travel effects), main results and conclusions.
Table 1 shows the 89 studies included in the review.

Risk of bias assessment

The methodological quality of the included studies was assessed independently by two reviewers using the appropriate Joanna Briggs Institute (JBI) Critical Appraisal Tools, according to the specific study design. Each criterion within the tool was rated as “yes,” “no,” “unclear,” or “not applicable.” The results of the risk of bias assessment were used to inform the interpretation of findings but did not serve as exclusion criteria for studies (Table 2).

Table 1. Study characteristics

Reference	Study Design	Participants	Sport modalitie	Travel Details	Supplementation	Main Results	Conclusions
(Winget et al., 1985)	Review	n/a	n/a	n/a	n/a	n/a	Athletic performance undergoes significantly daily oscillations under the control of the circadian system. The window for optimal performance is between 12:00 and 21:00.
(Loat & Rhodes, 1989)	Review	n/a	n/a	n/a	n/a	n/a	Circadian rhythm disruptions negatively affect performance and require consideration in competition
(Hill et al., 1993)	Review	USA Women's National Soccer team (n=7); Healthy individuals (n=19)	Soccer	WC NA to Taiwan; NA to West Europe; Europe to NA	n/a	Mood disturbances (↑ fatigue/confusion; ↓ vigor) in first 1-2 days; grip strength <; anaerobic power and work capacity <; mainly Days 1-2 post-travel	Rapid travel across 6-8 time zones temporarily disrupts mood, sleep and anaerobic performance with recovery occurring within a few days
(Jehue et al., 1993)	Observational design	All 28 NFL Teams	American Football	All in America (west to east; east to west)	n/a	Day games: home 56.6%, away 43.8%; night games: home 61.9%, away -23.8% change. Away teams lost more in East/Central; WC teams kept high home win %	Home field advantage is strong, but West-to-East travel impairs performance, whereas East/Central teams are less affected. Adaptation appears faster after westbound travel
(Eichner, 1994)	Review	college swimmers (22 men, 18 women); 27 National Football League teams	Swimming; American Football	Wisconsin to Hawaii and back (four time zones)	n/a	Travel across 4 time zones had minimal impact on mood, soreness or perceived effort in swimming. WC teams lose more in day games when traveling east but win night games regardless location	Circadian rhythms significantly influence health and performance and should guide training and daily activity timing
(Smith et al., 1997)	Observational design	NFL teams from 1970-1994 seasons	American Football	n/a	n/a	WC teams won more overall (63.5%) and on MNF (59-71%). EC MNF home wins (43.8%) but increases vs non-WC opponents (67.5%)	Circadian timing can affect performance as much as home/away status; competing near peak time may be more beneficial than full time zone acclimation
(Reilly et al., 1997)	Review	Swimmers; Rugby players; Military personnel; British; Olympic squad members; American footballers	Swimming; Rugby; American Football	England to Australia (eastward, 6 time zones); London to Tallahassee (westward, 5 time zones)	Melatonin Hypnotics	Muscle strength affected more by time-of-day than short sleep; performance drops lasted ~5 days. Simpler tasks adapted within 3 days; eastward travel caused greater performance decline than westward	Fatigue from travel is worsened by jet lag and environmental stress; athletes benefit from behavioral, not pharmacological strategies
(Manfredini et al., 2000)	Quasi-Experimental design	elite athletes of the Italian National Biathlon Team (n=8 men, mean age 25.9 years; n=4 women, mean age 22.5 years)	Biathlon	Milan to Japan (eastward, 8 time zones)	Melatonin	Men with delayed body temperature peaks showed little change after flight; melatonin advanced peaks afternoon. Women showed an 8-h shift after flight; melatonin had no effect. No adverse effects or sleep disturbances were reported	Standardized melatonin intake may variably affect biological rhythms, with incomplete resynchronization influenced by inter-individual variability
(Straub et al., 2001)	Experimental	(n = 15) were male (n = 12) and female (n = 3) Finnish junior elite track and field athletes	track and field	Helsinki to Marietta (westward, 7 time zones)	n/a	No significant effects of treatment or group were observed on TMD, HR or jet lag ratings. Total jet lag scores: westward 160, eastward 126.5	No significant effects observed; emphasizing sleep is important, particularly alongside jet lag
(Cardinali et al., 2002)	Case report	Male professional soccer players and their coaches from Boca Juniors Club (n=22)	soccer	Buenos Aires – Tokyo (westward, 12 time zones)	Melatonin	Sleep largely unchanged; awakenings↑ (days 1 and 3), sleep latency ↓ (days 2,6,8). Mean resynchronization 2.13±0.88 days vs expected 6 days (significant)	Melatonin plus timed light and exercise accelerates resynchronization; individualized dosing improves jet lag outcomes
(Waterhouse et al., 2002)	Observational Study	Athletes (n=51) Trainers (n=18) Academics (n=16)	n/a	UK to Australia (eastward, 10 time zones)	n/a	Jet lag symptoms decreased over days in Australia. Older subjects experienced less fatigue, men slept later and had less early fatigue. Fitter/repeat travelers reported worse jet lag. Later arrivals experienced less jet lag and better appetite. Phase-advance ↑ jet lag on final days	Flexibility in sleep, time of arrival, age, and adjustment direction affect jet lag and fatigue; phase-advance adjustments may worsen symptoms, especially early in the day
(Lemmer et al., 2002)	Observational Study	Members of the German Olympic gymnastics team (n=15)	Athletics	Frankfurt to Atlanta (westward, 6 time zones) Munich to Osaka (eastward, 7 time zones)	n/a	Jet lag peaked first 3 days; eastward flights worse initially; training less affected than westward. West: BP, HR, cortisol, melatonin, temperature, GS, disrupted up to 11 days. East: HR stable; cortisol, melatonin, temperature, GS disrupted; melatonin peak delayed ~4h	Time zone changes disrupt cardiovascular rhythms and performance; ≥2 weeks needed post westward flight; individual differences must be considered
(Waterhouse et al., 2004)	Review	n/a	n/a	n/a	n/a	Travel stressors impair health and cognition; frequent travelers at higher risk. Stress management, sleep hygiene, hydration, nutrition and activity reduce effects	Jet lag impairs mood, training and performance; preparation, sleep, melatonin and light exposure are key countermeasures, especially in endurance sports
(Reilly et al., 2005)	Review	Elite athletes, sedentary controls, and military personnel and airline crew members	Soccer; rugby; swimming; cycling; tennis; badminton; golf; American football	UK to Florida (westward,5 time zones); UK to Australia (eastward, 10 time zones)	Melatonin; caffeine; hypnotic agents and other banned stimulants (amphetamines, modafinil)	Jet lag disrupts sleep, cognition and performance (worse eastward, 5-7 d). Circadian misalignment impairs strength/power; light and sleep shifts help; melatonin inconsistent	Jet lag hinders performance; behavioral strategies > drugs; athlete/staff education is essential
(Postolache et al., 2005)	Review	American footballers; Olympic athletes; Sedentary subjects; Swimmers; Female soccer players; Rugby League players	American Football; Swimming; Soccer; Rugby	n/a	stimulants (amphetamines, methylphenidate, ephedrine, cocaine); caffeine; pseudoephedrine; melatonin	Adjustment matched zones crossed; eastward worse. Pre-shift training helped. Symptoms: appetite loss, constipation. Women distinct, staff at higher CV risk. Body temperature readapted before BP	Jet lag is transient, training continues, but with reduced quality of performance. Behavioral strategies + rehydration is effective; drugs are limited. Educate athletes and staff to optimize adaptation
(Armstrong, 2006)	Review	n/a	Soccer	Transmeridian travel	n/a	Performance peaks: 14-18h (physical), 12-15h (mental). Jet lag often causes sleep loss, slight thermoregulation	When athletes experience jet lag, caffeine consumption and adjustments of meal size/composition may be helpful

						impairment. Food timing affects sleep; pre-travel training shifts help. Melatonin ± caffeine ↓ symptoms	
(Milne & Fuard, 2007)	Case report	Rugby Player (n=1)	Rugby	Great Britain to New Zealand (eastward, 12 time zones); Great Britain to New Zealand (westward, 12 time zones)	Melatonin; Triazolam	Performance in the final was up to its usual high standard, directing play effectively, plus he kicked a conversion and three penalty goals	Appropriate advice and selective use of medications, travel across many time zones don't need to be associated with a detriment in performance in the sporting arena
(Bullock et al., 2007)	Observational Study	Elite Australian skeleton athletes (n=5) Elite Canadian skeleton athletes(n=7)	Skeleton	Canberra, Australia to Calgary, Canada (eastward, 4 time zones)	n/a	Cortisol↓ 67% day 1, 47% day 2 (NS). Sprint and urine SG unchanged. Jet lag↑ days 1-4, 7; improved on day 11. Hunger, motivation, concentration, tiredness remained stable	Eastward travel: cortisol rhythm disrupted, jet lag ↑ 7 days; sprint performance unaffected. Circadian resynchronization ~1 day/time zones (varies individually)
(Reilly et al., 2007b)	Narrative review	n/a	n/a	n/a	Melatonin; caffeine; probiotics	Jet lag↓ sleep, mood, digestion, performance. Nutrition strategies ↓ symptoms, ↑ hydration levels. Travel risks: limited food, hygiene, culture, buffet temptations, diarrhea (up to 60% of travelers)	Plan & educate athletes. Key: meals, hydration, light, hygiene. Behavioral strategies are the macronutrients. Drugs/supplements → cautions. Adaptation leads to optimal performance
(Reilly et al., 2007a)	Position statement	n/a	n/a	n/a	n/a	n/a	Education → informed travel choices. Behavioral adjustments preferred over drugs for time-zone adaptation
(Meijer et al., 2008)	Narrative review	Elite athletes; Healthy volunteers; General population	Track and field; Swimming; Cycling; Soccer; Tennis; Badminton; High Jump/Long Jump	eastward to Beijing (≥6 time zones)	Melatonin	Performance peaks early evening, lowest morning. Eastward jet lag ↓ performance; disrupts BP, body temperature, strength rhythms. Sleep loss → impaired hormonal balance (↑cortisol, ↓ GH), glucose metabolism and tissue recovery	Circadian misalignment ↓ performance; adjust clocks ≥ 2 weeks pre-event. Light, sleep, local meals, no alcohol/caffeine → jet lag ↓; competitive readiness ↑
(Dranitsin, 2008)	Experimental	(12 males and 1 female); age 17.7 years, s = 0.8; height 1.89 m, s = 0.06; body mass 88.9 kg, s= 13.1; training history 4.0 years, s=0.9	Row	Kiev, Ukraine to Beijing, China (eastward, 5 time zones)	n/a	Beijing ↑ temperature/humidity vs Kiev. HRV stable days 1-3, ↓ standing position days 4-5, partial recovery day6, ↓ again days 8-10, baseline day 13. Competition→ no HRV change. Standing HRV was strongly related to humidity. Supine HRV unaffected	Standing HRV adapts first 5 days post 5 time zone shift; supine HRV correlates with prior training load
(Montaruli et al., 2009)	Case study	Amateur level marathon runners (n=18 males)	Athletics	Milan to New York (westward, 5 time zones)	n/a	Sleep parameters & efficiency→ no group differences post-flight. Cosine peak: day 1 differences persist; day 2→ CG/ETG 20-30 minutes delay, MTG 2.5h delay. Questionnaire→ no worsening; CG vs marathon groups NS	Evening physical activity ↑ sleep quality; shifts circadian rhythms → faster westward adaptation. Scheduled exercise ↓ jet lag sleep disturbances
(Pipe, 2011)	Review	n/a	n/a	n/a	n/a	n/a	Travel planning + sleep/light/activity → restore sleep-wake cycles. Training timing/intensity ↓ injury, ↑ circadian reset
(Chapman et al., 2012)	pre–post intervention comparison with a control group	national team skeleton athletes (World Cup athletes and America's Cup athletes) (n=12)	Skeleton	Canberra, Australia to Canada (eastward, 4 time zones)	n/a	Contact time unchanged. Flight time ↓6% day 9; BDJ ↓4.2% day 5. CMJ height ↓1-2 days; CMJ velocity/power stable. SJ velocity/power ↓ post-flight; EUR power ↑ days 2,4,7	Long-haul travel ↓ acyclic power; velocity/power EUR disrupted 48h. Slow SSC more affected; BDJ minor changes. Arrive ≥5 days pre-competition
(Schobersberger & Schobersberger, 2012)	Report	n/a	n/a	n/a	Melatonin	Travel related thrombosis is rare but should be considered. Crossing 1-2 time zones → minimal jet lag. Eastward→harder sleep. Adjustment: west 1 day/zone, east 1-5 days/zone	Prioritize sleep and recovery before flight. East→sleep/wake 1h earlier; West→1h later. Hydrate, avoid alcohol/caffeine, light exercise. Align sleep and meals to local time. Pretreatment or melatonin if ≥5-8 time zones
(Samuels, 2012)	Review	n/a	n/a	n/a	Melatonin	n/a	Jet lag and travel fatigue→major disturbances. Structured travel program + monitoring→symptoms ↓, performance ↑
(Lee & Galvez, 2012)	Descriptive review	n/a	n/a	n/a	n/a	Behavioral > pharmacological strategies. Sleep, light timing, ± melatonin→adaptation	Travel→physical and cognitive function↓; mood, cognition, performance are impaired by jet lag
(Forbes-Robertson et al., 2012)	Review	Elite and sub-elite athletes from various sports, plus data from general population and shift workers	Soccer; rugby; swimming; cycling; tennis; American football; endurance skill-based sports	Eastward and westward intercontinental travel crossing multiple time zones	Caffeine; melatonin; prescribed hypnotics (zopiclone, temazepam)	Circadian misalignment ↓ performance, reaction skill, cognition. East travel slower. Light→strongest cue; melatonin aids sleep; caffeine ↑ alertness, may ↓ recovery. Macronutrient timing has limited effect	Circadian disruption ↓ performance/recovery. Behavioral strategies primary; drugs selective. Education + individualized plans are essential to performance
(Leatherwood & Dragoo, 2013)	Review	n/a	n/a	n/a	n/a	n/a	Air travel effects are hard to study; small samples, variable measures, limited generalizability

(Thompson et al., 2013)	parallel group randomized controlled trial	elite female soccer players from a national team (n=22; 26±4 years; 65.1 ± 5.9 kg; height of 1.71 ± 0.05 m)	Soccer	East coast of USA to Lisbon, Portugal (westward, 5 time zones)	Bright Light	LG: jet lag ↑ first 24h→over 4 days ↓; function worst 8-12h, best improvement on day 2. Sleep night 1 was best. Temperature ↑ day 1. GS differed, unclear pattern	Light ↑ body temperature acutely; no jet lag relief in elite female footballers (west 5-8 time zones). Effects mainly acute, not chronobiological
(Stellingwerff et al., 2014)	Review	aquatic athletes	Swimming	n/a	n/a	Melatonin ↓ sleep onset ~7 min; well tolerated; unclear impact on performance/recovery	Adequate hydration, carbs, iron, fluid management, hygiene→mitigate environmental stress during travel
(Fuller et al., 2015)	cohort study	All players from nine core teams competing in the Sevens World Series from 2008/2009 to 2013/2014	Rugby	n/a	n/a	Injury incidence is similar across travel categories; Category C ↓ injuries. No differences in type, cause, timing or activity. One country showed potential performance effect	4 days recovery are generally sufficient to recover; long-distance travel→no ↑ in overall, muscle or forwards' injury risk
(Fowler et al., 2015)	Observational Study	Professional Australian football (soccer) players (n=16)	Soccer	Australia to Japan (northbound, 1 time zone)	n/a	Away travel ↓ training load/intensity/speed; ↓ sleep and wellness; ↑ jet lag; ↑ fatigue and soreness; stress/mood were unaffected. High jet lag in fewer first-team appearances	Minimal time-zone travel→little effect; sleep disruption and competition fatigue→larger impact; experience athletes ↓ impact; avoid early/late travel
(Simmons et al., 2015)	Review	n/a	n/a	n/a	n/a	n/a	Short trips→naps/caffeine/limited use of sedatives; long trips→rapid sleep-wake synchronization, timed melatonin/light; medications may be helpful but carry side effects
(Silva et al., 2016)	cross-sectional survey	male kite surfers (34.3 ± 8.8 years) n=94	kite surf	n/a	n/a	SM→farther travel, earlier arrival, ↑ fluids/fruit, broader jet-lag strategies; NoSM→mainly eating/drinking. No meds. More training/sleep/water→fewer travel effects	Travel effects→distance, sleep, hydration, nutrition education needed. Mitigate jet lag: early arrival, ↓ training, sleep hygiene. Eastward travel→worse symptoms, ↓ performance
(Fowler et al., 2016)	Observational Study	male professional rugby league players (n=18)	Rugby	Sydney, Australia, to London, UK (westward, 11 time zones)	Melatonin	Jet lag↑ post-2, 6, 8; sleep/fatigue improved post-8; UR symptoms ↑ post-6; wellness stable; strength/soreness unchanged; training load ↓ post-travel	Strength and ROM recover in 24h; training preserves wellness; jet lag, sleep, UR symptoms ↑ ≤8 days, use sleep hygiene for recovery
(Fullagar et al., 2016)	Observational study	Elite male football players (n=15)	Soccer	London, United Kingdom to Montevideo, Uruguay (westward, 4 time zones)	n/a	NS changes from baseline in perceptual measures; jet lag ES large on day 2, moderate on day; sleep restfulness ES moderate on day 6	LH travel ↓ sleep, minimal recovery impact; rebound ↑ sleep on first night
(Fowler et al., 2017b)	Case study	male professional football players from the Australian national football (n= 22; Mean±SD; age 26±4 y, height 180±6cm, body mass 75.8 ± 6.5 kg)	Soccer	Sydney, Australia to Vitoria, Brazil (eastward, 11 time zones)	Melatonin	Jet lag ↑ post 1-4; sleep ↓ during travel/arrival; wellness ↓ post-travel week	Eastward travel→sleep disruption, jet lag ↓ wellness and readiness
(Williams et al., 2017)	Review	n/a	n/a	n/a	n/a	n/a	Sleep, light, nutrition, exercise, hygiene and travel planning mitigate travel effects
(Fowler et al., 2017a)	Observational Study	healthy, physically trained men (n=10)	n/a	Sydney, Australia to Doha, Qatar (westward, 8 time zones)	n/a	Eastward travel impaired peak force, sprint speed, YYIR1 performance, sleep, motivation and hydration more than westward; most effects recovered by day 4	Lower-body power recovers within ~96h after long-haul travel, but eastward flights disrupt sleep, jet lag, fatigue and sprit performance more than westward, especially in the first 48-72h
(Kölling et al., 2017)	Observational Study	Rowers (male n=30, 190.6 ± 7.5 cm, 86.3 ± 10.9 kg ; female n=25, 176.8 ± 6.3 cm, 71.3 ± 6.3 kg; mean age 17.8 ± 0.5 years)	Row	Germany to Brazil (westward, 5 time zones)	n/a	Fatigue peaked on the first evening post-travel; general and sport-specific recovery improved in Brazil, with most jet-lag symptoms decreasing over subsequent evenings	Jet lag peaked on arrival and persisted through day 6; early sleep times and reduced daylight delayed adaptation. Recovery ↑ by day 6
(Song et al., 2017)	Observational Study	Major League Baseball teams	Baseball	n/a	n/a	Winning%: Home teams +3.9%; eastward travel worse than westward; Offense: eastward travel ↓ doubles, triples, stolen bases; ↑ double plays; westward ↓ stolen base attempts; Defense: eastward travel ↓ performance; westward ↑ triples allowed; Away-team slugging: NS effects of travel direction	Jet-lag effects on winning percentage and runs scored were generally stronger after eastward travel.
(Roy & Forest, 2018)	Observational Study	Athletes of al teams competing in NBA, NHL and NFL	Basketball; American football; Ice Hockey	n/a	n/a	NBA: Westward evening ↓ win%, eastward evening ↑ win%; time zones explain 18.5%; no afternoon effect. NHL: Westward ↓ win%, eastward no advantage; time zones explain 23.2%; no afternoon effect. NFL: No travel direction effect; time zones explain 11.3%; no afternoon effect	Evening away games show a significant link between winning % and number of time zones travelled in NBA, NHL and NFL. Westward travel in the evening is disadvantageous, with greater effects as time zones increase. Teams performing closer to their circadian peak have an advantage, highlighting the role of circadian rhythms in sports performance

(Stevens et al., 2018)	Prospective cohort study	Masters level triathletes (age: 48 ± 14 years, height: 172 ± 11 cm, body mass: 72 ± 11 kg) (n=12)	Triathlon	Australia to Hawaii (eastward, 21 time zones)	n/a	Sleep duration: ↓ during flight, ↑ Night 1, returned to baseline, ↓ night before competition; sleep quality and efficiency unchanged; 25% of athletes developed mild to severe illness 3-5 days post-arrival; sIgA and cortisol unchanged from day 2 onward	LH NE travel ↑ sleep disruption and fatigue, but immunity and stress markers remain stable; recovery occurs within 48h
(Thornton et al., 2018)	Longitudinal research	National wheelchair basketball athletes (n=11)	Wheelchair basketball	USA (eastward travel) and Australia (westward travel) crossed up to 7 time zones to Manchester, UK; Europe crossed at least one but no more than 2 time zones to Manchester, UK	n/a	Long trips ↑ early bedtime/get-up and naps; ↓ vigor, ↑ jet lag/fatigue; Short trips ↑ vigor post 1-5	LH trips ↑ subjective jet lag, ↓ vigor and ↑ fatigue vs short trips; subjective effects exceed objective sleep changes; adequate recovery time is needed before competition; circadian adjustment rates for Paralympic athletes may require re-evaluation
(Silva et al., 2019)	Narrative review of the literature	International team soccer players	Soccer	n/a	n/a	n/a	Jet lag arises after >3 time zones crossing; resynchronization depends on direction, cues and individual factors. Usually benign but may harm health and performance
(Halson et al., 2019)	Review	n/a	n/a	n/a	Melatonin; caffeine	Melatonin ↓ jet lag but had side effects; caffeine ↓ fatigue, mixed sleep effects; Argonne diet ↓ symptoms (1 study)	Pre-sleep diet (CHO, caffeine, alcohol, fluids) influence sleep; probiotics ↓ illness; antibiotic use is unclear; nutrition issues = scarcity or overeating
(Broatch et al., 2019)	Quasi-experimental	elite Australian female volleyball athletes (mean 6 SD: age, 25 6 2 years and range 22–27 years; body mass, 78.9 6 4.5 kg; and years competing at the international level, 5 6 2 years) n=12	Volleyball	Canberra, Australia to Manila, Philippines (westward,2 time zones)	n/a	COMP vs CG→CMJ ↑ (24-48h), ↓ calf girth, altered SBP, HR, SO_2; jet lag ↑ (+12h); no major effects on mood, fatigue, soreness or coagulation markers	Compression socks→ ↑ performance, wellness ↑, ↓ swelling, ↓ CV strain, stabilize SO_2; no coagulation issues
(Fullagar et al., 2019)	Observational Study	American Football College Teams (NCAA)	American Football	n/a	n/a	Home→+5.3 points advantage; Penalty yards→no clear differences; Away<483kms→minimal effect; Away>484kms→moderate disadvantage; Crossing≥1 time zone→ -5 points disadvantage; East travel→no clear disadvantage; West travel→ -7.5 points disadvantage	Playing at home in NCAA football is worth +5 points. Away travel >483km imposes a – point disadvantage, further exacerbated (-7.5 points) by westward time-zone travel. No clear disadvantage with short travel (<483km) or eastward travel.
(Lo et al., 2019a)	Observational Study	Super Rugby Teams from 2006-2017 season	Super Rugby	n/a	n/a	Travel effects trivial-moderate; East ↓ overall; West mixed (↑ tries, ↓ carries); small KPI differences after East	East LH travel ↓ performance/KPIs; Westward was unchanged or slight ↑. LH travel ↓ players and team KPIs; Eastward more detrimental than Westward
(Atalag et al., 2019)	Quasi-experimental	Division II university men basketball players (MBB) (age = 21.32 y ± 1.7 y; body weight 98.99 kg ± 16.15, total body fat = 16.81% (n=36); age-matched men full-time university students (CT) (age = 22.67 y ± 1.2 y; body weight = 79.51 kg ± 17.1, total body fat = 20.37% ± 6.1 (n=37)	Basketball	Hawaii to the mainland United States (eastward, 2 to 5 time zones)	n/a	MBB ↑ fat, waist/WHR, ↓ knee flexion, ↓ vertical jump, ↑ RHR and BP, ↑ cortisol; CG NS changes in body composition, performance, CV markers; ↑ vertical jump; BMD unchanged in both groups	East travel ↑ cortisol and trunk fat; ↓ knee strength in student athletes due to circadian disruption, cabin environment, limited movement and combined travel, academic and competitive stressors
(Lo et al., 2019b)	Observational Study	Super Rugby Teams from 1996-2017 season	Super Rugby	n/a	n/a	Over 21 years: Wins ↑ east > west; away disadvantage ↓; points ↑; travel effect trivial-positive (east), unclear (west)	Continuous LH travel ↓ individual/team performance; over time, teams improved travel management, ↓ travel effects
(Lastella et al., 2019)	Case study	male professional soccer players (mean ± SD: age 25.2 ± 3.2 years, height 182.8 ± 5.2 cm, body mass 84.6 ± 7.4 kg; n=7)	Soccer	Adelaide, Australia to Hiroshima, Japan (eastward, 1.5 time zones)	n/a	Location type affected bedtime, time in bed and total sleep time. Bedtime was later during flights vs Adelaide and Hiroshima. No differences in get-up time, sleep latency, sleep efficiency, fatigue, movement, or subjective sleep quality	Flights disrupted sleep time and duration in professional soccer players. Sleep onset was later (+3.5h), total sleep reduced (-3.h), quality poorer vs home/away. Likely due to congested schedules and multiple flights, not minor time zone changes
(Roach & Sargent, 2019)	Experimental	International-level athletes n=11 (men from a wrestling team n=6; mean age 5 20.2	Wrestling	Tokyo, Japan to Rio de Janeiro, Brazil	8 mg of ramelton	Rio: TIB ↑, Experimental group sleep efficiency ↑ 1^{st} to 3^{rd} nights; SOL ↓; morning tiredness ↑ 1^{st} night	Light + sleep + ramelteon→better sleep, less strain post LH travel

		6 0.8 years [age range: 19-21 years]; height5 176.1 6 7.6 cm; mass 86.3 6 17.9 kg, and women from the national fencing team n=5; mean age5 23.6 6 2.7 years [age range: 21-28 years]; height5 169.4 6 4.0 cm; mass 59.1 6 5.4 kg)		(westward, 12 time zones)			
(van Rensburg et al., 2020)	Systematic review	Athletes	n/a	n/a	n/a	Little high-quality evidence exists for interventions managing travel fatigue or jet lag; exercise can induce circadian phase shifts, but timing is critical; sleep hygiene is essential; nutrition may help reducing jet lag symptoms; evidence for exogenous melatonin is weak; benzodiazepines may improve sleep quality and accelerate circadian readjustments (in some cases)	Caffeine ↑ alertness but delays circadian rhythms; tasimelteon dose-dependent sleep/alertness effects, memory ↓; glucocorticoids realign circadian rhythms; antihistamines not advised; evidence in athletes is limited
Zubac, D. et al. (2020)(Zubac et al., 2020)	Narrative Review	Athletes (e.g., kite surfers, endurance athletes, rugby players, gymnasts); Healthy volunteers; Military aviators	Marathon; triathlon; volleyball; skeleton; rugby; gymnastics; combat sports; sailing	Europe to Middle East; Australia to Canada/UK/USA; crossing multiple time zones (up to 12 hours difference)	Electrolyte; caffeine	Flight ↑ water loss; fluid intake often ↓; plasma volume sometimes ↓; impact on performance is unclear	LH travel→probable dehydration; combined effects with jet lag are unclear; hydration advice largely anecdotal
Nikolaidi, M. K. et al. (2021)(Nikolaidi et al., 2021)	Commentary	Athletes	Athletics	n/a	n/a	BFR ↑ mTOR, corticomotor excitability, cortical activation→faster reactions	BFR is safe; can ↓ jet lag via physiological adaptations
Augusto, D. et al. (2021)(Augusto et al., 2021)	Observational design	male players from one club participating in the 1st Division of the Brazilian soccer championship (n=20; aged, 27 ± 5 years; height, 180.5 ± 6.9 cm; body mass, 74.8 ± 7.8 kg)	Soccer	All in Brazil (short travel games with travel <520km; long-travel games with travel >520 km)	n/a	TD ↑ in losses; sprint ↑ in draws; coach change ↓ running, HI sprint distance, HI actions, deaccelerations; long travel ↓ HI sprint distance; short travel NS	Long trips ↓ recovery and intense actions; travel factors also affect performance; running performance ↓ with long travel
Charest, J. et al. (2021)(Charest et al., 2021)	Observational design	NBA Players from season 2013 to 2020	Basketball	n/a	n/a	Home-Away = Away-Away; win%: Away-Home 54.4%, Away-Away 39.2%, Home-Away 36.8%; travel ↓ impact except Away-Home; sequences ending home: travel ↓ results; eastward travel ↑ wins vs west/no time zone change	Time zone travel ↓ recovery/mindset; home return ↑ wins (15-18%); distance effects vary by sequence; Away-Home ↑ sleep/circadian risk; long flights + inactivity ↓ O_2→wins ↓; eastward travel ↑ win% vs west; fatigue/circadian disruption depend on distance
Fowler, P. M. et al. (2021)(Fowler et al., 2021)	randomized, matched-pairs design	healthy, physically trained males (n=20)	n/a	Doha, Qatar to Sydney, Australia (eastward, 8 time zones)	n/a	INT ↑ CMJ peak/height, ↑ 5/20-m sprint (at 17:00h); T-test/Yo-Yo NS; travel/post travel ↑ sleep duration/efficiency, earlier sleep; motivation/mood ↑; CG worse day 3; jet lag NS	Light + sleep hygiene ↓ sleep disruption, ↑ mood/motivation, ↑ CMJ; baseline recovery 72h (INT) vs 96h (CG); sleep timing ↑ duration (2.5h); jet lag NS
Janse van Rensburg, D. C. et al. (2021)(Janse van Rensburg et al., 2021)	Review	Professional and elite athletes	Basketball; football; rugby; track and field	Short (<3h) and long (>3h) travel; trans meridian (east-west or west-east) and trans latitudinal (north-south)	Melatonin	Travel fatigue: no high-quality evidence; strategies→sleep, planning, hydration/nutrition, illness, prevention; Jet lag: limited evidence; strategies→light, melatonin, sleep/exercise adjustment, nutrition	Travel fatigue/jet lag ↓ performance/health; expert consensus guides management; future studies→validated tools, RCTs, individualized strategies, physiological markers (melatonin, CBTmin)
Lalor, B. J. et al. (2021)(Lalor et al., 2021)	Observational Study	Elite female cricketers from the national team (n=11)	Cricket	Melbourne, Australia to Chennai, India (westward, 5.5 time zones)	n/a	AM jet lag ↑ days 1-3; PM jet lag ↑ day 2; in-flight ↑ sleep efficiency→ ↓ fatigue; stress ↑ total average wake; soreness→ ↑ wake and ↓ efficiency; well-being→longer wake bouts; higher AM jet lag ratings→ ↓ sleep efficiency and ↑ total wake	In-flight sleep ↑; during competition→↓sleep; planning departure→better recovery, ↓ jet lag; stress/soreness ↓ efficiency, ↑ wake; sleep fragmentation possible despite low stress; avoid early AM activity to optimize sleep
Leduc, C. et al. (2021)(Leduc et al., 2021)	Observational Study	male international rugby sevens players from an international team based in Europe (n=17)	Rugby	eastward and westward	n/a	Pre-tour→TST ↓; WASO ↓ pre-tour; sleep quality ↓ tourn. 1-2 + relocation; eastward→earlier sleep onset; westward→earlier wake; tourn.1 westward→sleep ↓; eastward pre-competition→quality/efficiency ↑; westward pre-competition→WASO ↑	LH travel did not negatively affect short-term sleep; tourn/relocation→biggest sleep ↓; pre comp > pre-tourn sleep; east vs west→sleep differences; direction unclear, westward ↓ quality
Lo, M. et al. (2021)(Lo et al., 2021)	Qualitative description	(S&C) Coaches (n=3) or Medical Doctors (n=5) from Super Rugby Teams from 2016 season (n=8)	Super Rugby	n/a	n/a	Main issues: fatigue + sleep disruption; all teams use strategies→same choices, different implementation; some rely on sleep meds; naps variably allowed; flight planning	Travel ↓ performance; teams use mixed strategies (experience>literature); gap science-practice; travel management = space for innovation→ ↑ performance and cohesion

						common; practice>literature; one clinical/individualized vs one humanistic	
(Smithies et al., 2021)	Longitudinal Observational Study	male professional rugby players (n=37)	Super Rugby	Westward	n/a	6% ↑ sleepiness, 39% ↓ sleep quality; chronotype: 50% intermediate, 43% morning, 7% evening; Day 7: TASO ↑ 143 min, TST ↓, TAW ↑ (day 4-5)	LDTT→sleep timing shifts, TST stable; avoid AM activities/flights post-match; westward AM flights ↓ adaptations; TST ↓ short term, normalizes in 2d
(Everett et al., 2022)	Prospective single-group observational pre-post measures	Highly trained male rowers (n = 21, 23.7 ± 1.4 years, 190.9 ± 7.5 cm, 86.9 ± 9.9 kg)	Row	Canberra, Australia to Milan, Italy (westward, 9 time zones)	n/a	Westbound travel→JH ↑10.3% (NS), Mean Velocity ↑ 4.6%, EMV ↑, Dip ↑7.4%, JH:Dip ↑5.9%, Power ↑5.5%	Westbound travel→concentric/eccentric velocity ↑, mean power ↑, eccentric displacement ↑; CMJ ↓
(Rossiter et al., 2022b)	Systematic review	elite athletes	n/a	n/a	n/a	14 studies (197 athletes); NOS 6±1. Jet lag ↑ post LH, less severe westward. Temperature, BP, cortisol disturbed ≤11 days, sometimes recover at day 3. Jump and sprint performance: ↓ skeleton, ↑ rowers	Perceived jet lag ↑, sleep/psychometrics minimally affected; recovery→1 day/time zone; performance effects unclear: GS ↓ , complex tasks =); symptom/recovery variability→sex, age, chronotype; mechanisms poorly understood
(Flatt & Howells, 2022)	Observational study	Great Britain athletes selected for Olympic Summer Games (n = 12 men; height = 185 [7] cm; weight = 91 [7] kg; maximum aerobic speed = 4.60 [0.15] m·s−1)	Rugby	Grain Britain to Brazil (westward, 4 time zones)	Caffeine supplementation (100– 200 mg)	LnRMSSD average ↓ days 4-7; LnRMSSD ↑ day ; sleep/soreness/recovery/energy significant ↓, mood NS; recovery ↓ day 1, ↑ day 13; energy ↑ day 13	Tournament/travel→HRV ↓, returns ↑; AM activity westward→circadian resynchronization; low-intensity>high-intensity for HRV recovery; CWI→parasympathetic ↑; elite athletes: HRV ↑ and stable; less experienced players = more vulnerable
(Lever et al., 2022)	Case study	junior national level netball players (n=11)	netball	Johannesburg to Sydney (eastward, 11 time zones); Sydney to Johannesburg (westward, 11 time zones)	n/a	TIB ↑ on match and pre-travel vs travel and training days; sleep rating ↑ on pre-travel vs match days; nº of awakenings ↑ on pre-travel, training days and matches vs travel days; jet lag ↑ match vs pre-travel; sleep ↓ pre-travel, travel and match vs post-travel; NS for ASSQ	LDTT ↓ sleep vs pre-travel and tournament days; travel and competition disrupted routines and sleep
(Biggins et al., 2022)	Observational, longitudinal, repeated measures	elite soccer athletes (n=41)	Soccer	Ireland to Taiwan (eastward, 7 time zones)	n/a	Jet lag ↑ pre-competition vs competitions; Symptoms lasted up to ≤10d on females, ≤13d on males; no association was found between chronotype and jet lag; 76% were intermediate type	Jet lag may persist; young athletes cope better; sleep hygiene is insufficient; females ↑ pre-sleep anxiety; eastward 7 time zones → ↓ sleep, ↓ quality, up to ≤13d
(Charest et al., 2022)	Longitudinal Observational Study	All NHL teams from seasons 2013 - 2020	Ice Hockey	n/a	n/a	NS associations between circadian change or travel distance and most hockey performance outcomes; GameDistance was strongly associated with GoalDifferential when controlling for TZ, but not for AdjTZ_B; quadratic AdjTZ_B was associated with GoalDifferential when controlling for GameDistance; Interections were observed between GameDistance and circadian change; GameDistance was also associated with DiffActExpFSv%	↑ Distance and circadian change→ ↓ skill performance; +900 km→ -0.04 GoalDifferential; ability/location > travel; circadian misalignment + long travel = worst impact
(Glinski & Chandy, 2022)	Longitudinal observational Study	NBA Players from season 1999 to 2000	Basketball	n/a	n/a	Jet lag→↓teams FT%; main shooters NS; others ↓; effect only on eastward travel	Jet lag ↓ FT; Eastward travel worsens FT; performance declines are mainly due to circadian disruption; repeated exposure mitigates effects
(Jasper et al., 2022)	Original research	elite and professional athletes; general populations; military personnel; occupational shift workers	Athletics	n/a	n/a	Time zone changes→↓medal; eastward travel is worse for gold, silver, bronze and total medals	↑TZ→ ↓ performance; eastward travel is worse; ↑ TZs→larger decline; amateurs and unsupported teams are more affected
(Leota et al., 2022)	Longitudinal Observational Study	NBA teams from season 2011/2012 to the 2020/ 2021	Basketball	n/a	n/a	Eastward jet lag→↓ wins, points, rebounds, FG%; westward jet lag = no effect on wins, points, rebounds, FG%; + eastward jet lag→↓worse points	Eastward jet lag→↓ shooting, rebounds, points, wins (home only); westward jet lag no effect; circadian disruption from eastward travel harms performance
(Read et al., 2022)	Descriptive longitudinal design	NRL teams from seasons 2007-2019	Rugby	n/a	n/a	Per 1.000km→ -2.7% win, -1.1 pts; away team Odds Ratio 0.5, -6 pts; +1 day turnaround→ Odds Ratio 0.98, -0.1 pts	Travel ↓ performance; travel impact has been reduced over time (fatigue management, recovery strategies); no inter-state differences
(Rossiter et al., 2022a)	Observational study	Olympic team support staff (n=9)	n/a	Ireland to Japan (eastward, 8 time zones)	n/a	Jet lag ↑ am day 1 to day 6, pm day 1 to day 4 and day 6; appetite/bowel disturbances on days 1, 3, 5 and 6; cortisol am was ↓ 66% on day 1 to day 5, returns to baseline on day 6; cortisol pm = baseline; sAA ↑ evening on day 3 only; mood am: confusion ↓, depression ↓, vigor ↑; mood pm:	Eastward travel crossing 8 TZ→manage first 7 days for jet lag/fatigue; sleep and mood strategies recommended on pre/post LH travel for Olympic staff

						confusion ↑, depression ↑, fatigue ↑, vigor ↓; tension ↓ am and pm	
(Cullen et al., 2023)	Observational study	referees n=65; (47 males and 18 females; mean age 35 ± 5 years; height 180.3 ± 8.6 cm, weight 79.1 ± 10.5 kgs; BMI 24.2 ± 1.8)	Basketball	n/a	n/a	Poor sleep: early wake (16.4%), jet lag (14.9%), late/evening game (14.9%); jet lag-related poor sleep occurred in the 1st half of the tournament, with 70% on the 1st day	Jet lag→acute early sleep disruption (70% day 1, 3 days post-flight); earlier bedtimes on day 1 to day 2; sleep likely worse immediately post-travel; jet lag main early factor
(Doherty et al., 2023)	Case report	elite international track cycling squad (n = 7; n = 3 males and n = 4 females)	cycling	Maiorca to Hong Kong (eastward, 7 time zones)	n/a	TIB ↓ 213 minutes on travel day and ↓ 257 minutes on arrival; TST ↓ 140 minutes 4 days before travel, 268 minutes on travel day, 197 minutes on arrival, ↑ 87 minutes on 4th day of arrival; SOL ↑ on travel day; SE ↓ 22.63% o travel day, 13.12% on arrival, ↑ 10.27% on 4th of arrival; effects were observed for TIB x day, TST x day, SE x day and fatigue at bedtime x day	LHT ↓ TIB, TST, SE; LHT ↑ fatigue; jet lag impacts 48 h; travel 5-6 days pre competition; individualized sleep, jet lag strategies are recommended; early post-travel sleep loss harms health and performance
(Clements et al., 2023a)	Case-study	male senior Australian national football (soccer) team (n=58)	Soccer	n/a	n/a	Trips: ≤3h TZ %, >3h 34%, ≥8h 17%; westward direction 50%, eastward 43%, none 7%; travel ≥10h 51%, ≥24h 8%; flight ≥10h 41%, ≥20h 7%; overnight 64% none, 33% one night, 3% two nights; arrival at evenings 39%, early morning 23%, day (09:00-18:00) 39%; location→significant TZ change, travel and flight time	Most trips are unlikely to impair performance or wellbeing; travel strategies→location-specific; interventions: sleep, naps, schedule; European based face greater challenges arriving at camp, Australian based players are at higher risk post-return
(Clements et al., 2023b)	Observational Study	professional footballers (n=68)	Soccer	n/a	n/a	Asia→Europe & Europe→Australia→highest jet lag; Australia→Asia<Asia→Asia; transition travel ↑ jet lag; older players ↑ jet lag, experience players ↓; flight path→wellness, fatigue, sleep, soreness (Europe→Australia, Asia→Europe worst); return travel is worse; night arrivals ↑ stress	Jet lag ratings > wellness for travel effects; older players ↑ jet lag, experience players ↓; post-national team return→recovery challenge; individualized travel, recovery strategies; midday-late afternoon arrival preferred
(Clements et al., 2023c)	Observational Study	elite senior male national footballers (n=62)	Soccer	n/a	n/a	TZ difference→wellness, fatigue, sleep, soreness; direction→sleep, stress; ≥9h→worse wellness, fatigue, sleep, improves on day 1 and day 2; soreness was worse after 6-9h compared with <3h; stress ↑ after ≥9h on day 2 compared with 3-6 h	Large TZ changes→↑ fatigue, soreness ↓ sleep, wellness; eastward→worse sleep, ↑ stress; <6h minimal effect; first 48h post eastward travel→sleep interventions
Garbellotto, L. et al. (2023)(Garbellotto et al., 2023)	Observational design	elite mountain bikers of the French national team [(5 men (age: 28.2 ± 4.5 years; height: 178.6 ± 4.1 cm; body mass: 66.5 6 3.6 kg) 1 woman (age: 19 years; height: 166 cm; mass: 56.1 kg)]	Mountain Bike	France to Japan (eastward, 8 time zones)	Melatonin; light therapy	Sleep metrics (TST, TIB, WASO; REM) = baseline; SOL ↑ day11; bedtime and wake were earlier on days 9-11; Body temperature recovered to baseline in 3 days; Wingate and ME5 tests showed no differences in Pmean, Pmax, Pmin, fatigue index or cardiorespiratory parameters ($\dot{V}O_2$, $\dot{V}E$, RER, HR, VE/VO_2) at different times of day or after phase advances/adjustments	3h sleep-wake advance + melatonin + morning light→minimized eastward travel disruption; anaerobic/aerobic performance maintained; partial circadian resynchronization pre-arrival; high melatonin→initial sleep; nonstop flight and early sunrise→faster body temperature adjustment; peak power, fatigue→unchanged
(Paule-Koba et al., 2024)	Qualitative	NCAA Division I football and hockey players from the Big Ten, Big 12, WCHA, and Hockey East conferences (n=133)	Hockey; Football	n/a	n/a	Travel enjoyed for new places; away games→long travel, missed classes, routine disruption; 52% report ↓ athletic performance; legs and sleep affected; academic impact mixed; less time with non-team individuals	Circadian disruption→jet lag, fatigue; early classes post travel→↓ academic performance; reduced travel supports university engagement and overall development
(Anderson et al., 2024)	Invited commentary	Visually Impaired Paralympic Athletes	n/a	n/a	n/a	n/a	Paralympic athletes pre, intra, post-flight strategies: bedtime shifting, light exposure, sleep hygiene and melatonin; visual impaired athletes: non-photic cues (meals, exercise, social), maintain habitual sleep-wake; some residual light sensitivity; melatonin; non-photic cues <light circadian entrainment
(Varesco et al., 2024)	prospective observational design with non-invasive procedures	elite short-track speed skaters from the Canadian National Team (11 females, age: 24 ± 4 years; height: 169 ± 0.06 m; body mass: 64.4 ± 7.3 kg);	speed skaters	Montréal to Asia (eastward, 10 time zones)	n/a	Sleep ↑ SIA > Baseline, travel, race; Travel, Race ↓ vs Baseline; SIA +9 minutes/night, breakpoint on day 5; SE ↑ SIA, slight ↓ over time: bedtime, wake later Race, ↑ linearly SIA; MESOR ↓; CMJ ↑ SIA, Race; RPE ↑ baseline	Sleep debt, jet lag resolved ≤5 days; ensure sleep and activity as zeitgeber; informs long-haul travel planning for coaches, staff
(Tsukahara et al., 2024)	Observational Study	athletes (26 men and 20 women) who competed in	athletics	Tokyo to Helsinki (westward, 7 time zones)	n/a	Performance and agility = AD vs GD; flexibility ↓ GD; sleep onset ↑, quality ↓, duration ↓, awakenings ↓ GD; hunger,	Prior international travel ↑ adaptation; sophomores ↑ sleep difficulty 4 days post-travel; travel→digestive circadian shift, ↓ flexibility and sleep quality; scheduling

		the 2018 World U20 Athletics Championships				fullness ↓ GD; travel experience ↑ sleep, alertness; males ↑ awakenings; sophomores ↑ sleep difficulty	critical; educate young athletes to manage jet lag for performance
(Özdalyan et al., 2024)	Case report	NBA Teams from 2000-2001 season to 2020-2021 season	Basketball	n/a	n/a	Home win 59.3%, away 40.7%; LB<P and FGM groups; LA>LB, ↑FGA, ↓ W/L and FG%; LS PD/FGM>LA; OA>OS; OA TR>OB	Forward westward circadian shift ↑ performance; backward eastward ↓ performance; full local adaptation→best away performance; home eastward shift→↓ performance; away circadian rhythm shift negative, forward worse; consider in game planning
(Rossiter et al., 2024)	Original research	Irish HP athletes, coaches, and support staff, >18 years and competing or working with athletes at an elite level (professional, Olympic/Paralympic, international, and national); n=144	Athletics; Boxing; clay target shooting; cricket; cycling; diving; golf; gymnastics; hockey; rugby; sailing; skeleton; swimming; triathlon	n/a	n/a	LH travel→↓ physical (86.4%) and mental (72.7%) performance, ↑ illness, injury risk (86.4%), 93.2% symptoms ≤3 days, fatigue most common; females ↑ fatigue and appetite; age, chronotype, experience, TZ affect symptoms; recovery ≤7 fays, longer with more TZs; travel strategies widely used (sleep, meals, movement, stretching, fluids); ≥9 TZs→sleep schedule adjusted in-flight	More TZs→longer recovery; all recovered ≤7d (most ≤3d); early waking, fatigue ↑ with TZs; ≤3 TZ also experienced sleep, fatigue issues; strategies; schedule, naps, sleep hygiene, movement; females and evening chronotypes ↑ symptoms; athletes, younger↑ sleep adjustment

→ (leads to); ↓ (decreased); ↑ (increased); n/a (not applicable); < (less than); > (greater than); ≤ (less than or equal to); ≥ (greater than or equal to); n/a (not applicable)

Table 2. Joanna Briggs Institute (JBI) Checklist

Reference	Type of study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Evaluation	Tool *
(Winget et al., 1985)	Narrative Review	Yes	No	No	No	No	Yes	No							Include	4
(Loat & Rhodes, 1989)	Narrative Review	Yes	No	No	Yes	No	Yes	No							Include	4
(Hill et al., 1993)	Narrative Review	Yes	No	No	No	No	No	No							Include	4
(Eichner, 1994)	Narrative Review	Yes	Yes	No	No	No	No	No							Include	4
(Reilly et al., 1997)	Narrative Review	No	No	No	No	No	Yes	No							Include	4
(Waterhouse et al., 2004)	Narrative Review	Yes	No	No	No	No	Yes	No							Include	4
(Postolache et al., 2005)	Narrative Review	No	No	No	No	No	Yes	No							Include	4
(Reilly et al., 2005)	Critical Review	Yes	No	No	No	No	Yes	No	No	No	Yes	Yes			Include	4
(Armstrong, 2006)	Critical Review	Yes	No	No	No	No	No	No	No	No	No	Yes			Include	4
(Reilly et al., 2007b)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Meijer et al., 2008)	Narrative Review	Yes	Yes	Yes	No	Yes	Yes								Include	4
(Pipe, 2011)	Narrative Review	Yes	No	No	No	No	No								Include	4
(Samuels, 2012)	Narrative Review	Yes	No	No	No	No	No								Include	4
(Lee & Galvez, 2012)	Narrative Review	Yes	No	Yes	Yes	No	Yes								Include	4
(Forbes-Robertson et al., 2012)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Leatherwood & Dragoo, 2013)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Stellingwerff et al., 2014)	Narrative Review	No	No	No	No	No	Yes								Include	4
(Simmons et al., 2015)	Narrative Review	No	No	No	No	No	Yes								Include	4
(Williams et al., 2017)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Silva et al., 2019)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Halson et al., 2019)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Zubac et al., 2020)	Narrative Review	Yes	No	No	No	No	Yes								Include	4
(Janse van Rensburg et al., 2021)	Narrative Review	Yes	Yes	No	Yes	No	Yes								Include	4
(van Rensburg et al., 2020)	Systematic Review	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes			Include	4
(Rossiter et al., 2022b)	Systematic Review	Yes	No	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes			Include	4
(Jehue et al., 1993)	Observational	Yes	No	No	Yes	No	Yes	Yes	Yes	No	No	Yes			Include	5
(Smith et al., 1997)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes			Include	5
(Waterhouse et al., 2002)	Observational	No	No	No	Yes	Yes	Yes	No	Yes	No	No	Yes			Include	5
(Lemmer et al., 2002)	Observational	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes			Include	5
(Bullock et al., 2007)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes			Include	5
(Fowler et al., 2015)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes			Include	5
(Fowler et al., 2016)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes			Include	5
(Fullagar et al., 2016)	Observational	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes			Include	5
(Silva et al., 2016)	Observational	Yes	No	No	No	No	Yes	No	Yes	Yes	No	Yes			Include	5
(Fowler et al., 2017a)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes			Include	5
(Fowler et al., 2017b)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes			Include	5

(Kölling et al., 2017)	Observational	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Song et al., 2017)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Include	5
(Roy & Forest, 2018)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Include	5
(Thornton et al., 2018)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Lo et al., 2019a)	Observational	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Fullagar et al., 2019)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Lo et al., 2019b)	Observational	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Augusto et al., 2021)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Leduc et al., 2021)	Observational	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Include	5
(Lalor et al., 2021)	Observational	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Charest et al., 2021)	Observational	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Smithies et al., 2021)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Charest et al., 2022)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Glinski & Chandy, 2022)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Leota et al., 2022)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Flatt & Howells, 2022)	Observational	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Read et al., 2022)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Biggins et al., 2022)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Everett et al., 2022)	Observational	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	No	Yes	Include	5
(Rossiter et al., 2022b)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Clements et al., 2023b)	Observational	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Clements et al., 2023c)	Observational	Yes	No	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Cullen et al., 2023)	Observational	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Garbellotto et al., 2023)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Tsukahara et al., 2024)	Observational	Yes	Yes	No	No	No	Yes	No	Yes	Yes	No	No	Include	5
(Varesco et al., 2024)	Observational	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Fuller et al., 2015)	Cohort study	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Stevens et al., 2018)	Cohort study	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Yes	Include	5
(Jasper et al., 2022)	Cohort study	No	No	No	No	No	Yes	No	Yes	Yes	No	Yes	Include	5
(Milne & Fuard, 2007)	Case report	No	Yes	No	Yes	No	No	No	Yes				Include	2
(Cardinali et al., 2002)	Case study	Yes	Yes	No	Yes	Yes	Yes	No	Yes	No	Yes		Include	1
(Montaruli et al., 2009)	Case study	No	Yes	Yes	No	No	No	No	Yes	No	Yes		Include	1
(Lastella et al., 2019)	Case study	No	Yes	No	No	No	Yes	No	Yes	No	Yes		Include	1
(Lever et al., 2022)	Case study	No	No	No	No	No	No	No	Yes	No	Yes		Include	1
(Doherty et al., 2023)	Case study	No	No	No	No	No	Yes	Yes	Yes	No	Yes		Include	1
(Clements et al., 2023a)	Case study	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes		Include	1
(Özdalyan et al., 2024)	Case study	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes		Include	1
(Manfredini et al., 2000)	Quasi-experimental study	Yes	No	No	Yes	Yes	No	No	Yes	Yes			Include	3
(Chapman et al., 2012)	Quasi-experimental study	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes			Include	3
(Broatch et al., 2019)	Quasi-experimental study	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes			Include	3

(Atalag et al., 2019)	Quasi-experimental study	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes					Include	3
(Straub et al., 2001)	Experimental	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes					Include	3
(Dranitsin, 2008)	Experimental	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes					Include	3
(Hoshikawa et al., 2020)	Experimental	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes					Include	3
(Thompson et al., 2013)	Parallel-group RCT	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Include	6
(Fowler et al., 2021)	RCT	No	No	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Include	6
(Lo et al., 2021)	Qualitative description	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes				Include	7
(Paule-Koba et al., 2024)	Qualitative description	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes				Include	7
(Schobersberger & Schobersberger, 2012)	Commentary	Yes	No	No	Yes	Yes	Yes								Include	8
(Nikolaidi et al., 2021)	Commentary	Yes	Yes	Yes	Yes	Yes	Yes								Include	8
(Anderson et al., 2024)	Commentary	No	Yes	Yes	Yes	Yes	No								Include	8
(Reilly et al., 2007a)	Position statement	Yes	Yes	Yes	Yes	Yes	Yes								Include	8
(Rossiter et al., 2024)	Cross-sectional survey	Yes	No	No	No	No	No	No	Yes						Include	9

* 1. Checklist JBI for case series; 2. Checklist JBI for case reports; 3. Checklist JBI for Quasi-experimental studies; 4. Checklist JBI for systematic reviews and research syntheses; 5. Checklist JBI for cohort studies; 6. Checklist JBI for Randomized Controlled Trials; 7. Checklist JBI for qualitative research; 8. Checklist JBI for expert opinion; 9. Checklist JBI for analytical cross sectional studies. "Yes" (low risk of bias); "No" No (high risk of bias); Source: https://jbi.global/critical-appraisal-tools

Results

Overall, a total of 284 records were identified using the search strategy as described above. Of the 100 studies retained for full-text screening, 11 did not meet inclusion criteria and were removed. 89 studies were therefore deemed eligible for inclusion in the review (Figure 1). The 89 studies were published between 1985 and 2024 and included the sports of soccer (n=21); Rugby (n=12); American Football (n=8); Basketball (n=8); Swimming (n=7); Athletics (n=7); Cycling (n=6); Skeleton (n=4); Super Rugby (n=4); Tennis (n=3); Track and field (n=3); Row (n=3); Triathlon (n=3); Badminton (n=2); Golf (n=2); Ice Hockey (n=2); Volleyball (n=2); Gymnastics (n=2); Boxing (n=2); Sailing (n=2); Cricket (n=2); Hockey (n=2); High Jump/Long Jump (n=1); Baseball (n=1); Wheelchair basketball (n=1); Netball (n=1); Speed skaters (n=1); Biathlon (n=1); Kite surfers (n=1); Wrestling (n=1); Clay target and shooting (n=1); Diving (n=1) (See Table 1).

Travel Details

Of the 89 studies included in this review, approximately 33 did not report any travel details (e.g., duration, direction, time zones crossed). Forty-nine studies reported the direction of travel, with eastward and westward journeys occurring equally (twenty-three each), followed by northeast (two studies). One study reported travels across all North America. Regarding time zones, 31 studies reported the number of time zones crossed. Overall, participants crossed between 1 and 12 time zones. The most frequently crossed time zones were: 8 time zones (n = 6), 5 time zones (n = 5), 7 time zones (n = 4), 12 time zones (n=3), 9 time zones (n = 3), 4 time zones (n=2), 10 time zones (n = 2), 1 time zone (n=1), 2 time zones (n=1), 3 time zones (n=1), 6 time zones (n=1) and 11 time zones (n = 1) (See Table 1).

Interventions to mitigate travel effects

Of the 89 studies included in this review, seventy-two did not report any intervention to mitigate travel effects. Among those that did, melatonin was the most frequently used intervention, being cited in sixteen studies, followed by caffeine with six studies and light exposure with three studies. Other reported interventions included physical exercise, probiotics and ramelteon being cited in one study (See Table 1).

Physiological and Hemodynamic markers

In terms of physiological and hemodynamic changes, thirty-six studies cited sleep changes. Alongside sleep disturbances, other physiological markers were consistently reported. These included alterations in body temperature (n=18), blood pressure, hormonal changes (n=9), heart rate variability (n=4), and immune system (n=4) (See Table 1).

Travel effects

Regarding the effects imposed by travel, the most cited was fatigue (n=25), followed by sleep changes (e.g. insomnia, bad sleep quality) (n=21), decreased physical performance (e.g. strength, power, coordination, velocity) (n=18), mood changes (e.g. irritability, confusion, demotivation) (n=15), cognitive problems (e.g. attention, reaction time, concentration) (n=9) (See Table 1).

Physical Performance markers

In the 89 studies included, 69 reported physical performance outcomes. The most physical performance cited was in relation to anaerobic power and capacity (e.g. sprints, jumps) being cited in 18 studies. Being reported in 14 studies, follows strength (e.g. grip, isometric). Velocity was the third more cited, in 12 studies. Aerobic power and capacity were studied in 10 studies. Coordination was cited in 8 studies. Lastly, in 7 studies, reaction time.

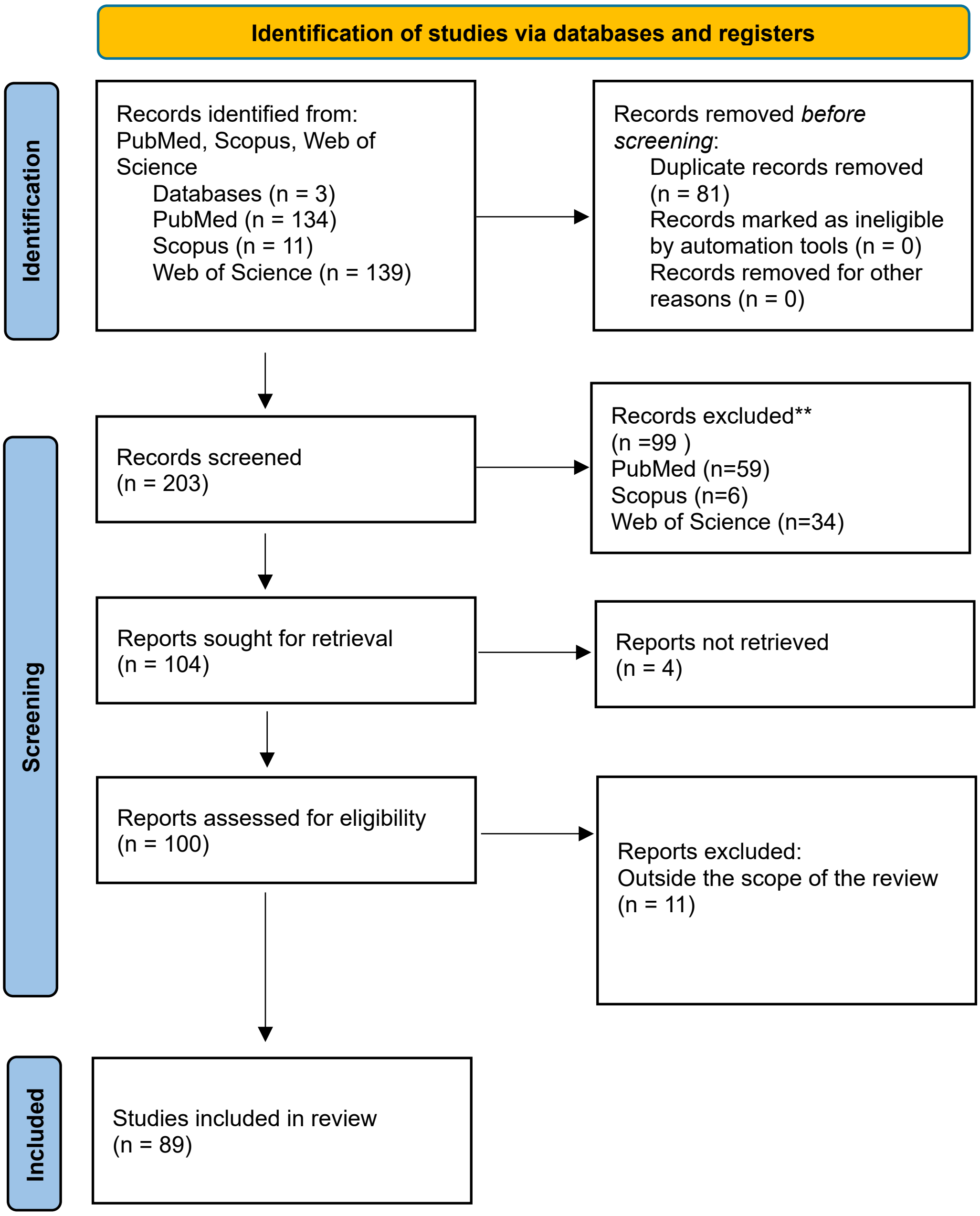

Figure 1: Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram of the systematic review

Discussion

The main aims of this systematic narrative review were i) to explore the importance of circadian rhythms for athlete's health and performance, ii) to distinguish the terms jet lag and travel fatigue, iii) to examine how athletes and teams prepare for long-haul travel preceding competitive events, iv) to identify the markers used to assess athletes' readiness and v) to investigate whether long-haul travel induces physiological, hemodynamic, or performance-related changes. The results revealed significant changes in several physiological markers, namely disturbances in sleep patterns, fluctuations in body temperature, changes in blood pressure and changes in hormone levels, namely the hormone cortisol and the enzyme alpha amylase. Physical performance is negatively affected, with this deterioration being more pronounced after trips to the East. The effects of long trips are undeniably multifactorial and involve the dysregulation of the autonomic and endocrine systems.

Physiological and hemodynamic markers

Circadian rhythms that persist under constant conditions originate from within the body, meaning they have an endogenous component (Winget et al., 1985). When body temperature is measured under normal conditions, including sleep and activity, environmental and lifestyle influences are also present, as indicated by the increased amplitude of the rhythm (Winget et al., 1985). This influence is referred to as the exogenous component. During the day, body temperature is elevated due to the combined effect of the internal clock and the alerting influence of environmental factors and physical or mental activity. At night, the internal clock, environmental cues, and inactivity all contribute to lowering body temperature. This interaction between endogenous and exogenous components occurs in all physiological variables (Waterhouse et al., 2004).

Body temperature: In relation to alterations in body temperature, 1 study (Lemmer et al., 2002) reported that irrespective of travel direction (westward or eastward), the rhythmic patterns in body temperature were greatly disturbed on day 1, however, when travelling to east, these rhythmicity suffered a phase-delay, while travelling west, a phase advance. In 2 studies (Armstrong, 2006; Postolache et al., 2005), body temperature was associated with sleep-wake cycle, and only after this cycle was regulated the body's ability to regulate core body temperature. About the duration of the disruption of core body temperature, 2 studies (Meijer et al., 2008; Rossiter et al., 2022b) concluded that takes up to 11 days to recover. However, in some cases, recovered by day 3 (See Table 1). In an observational study by Lemmer et al.(Lemmer et al., 2002) it was found that after travel, independently of direction, body temperature was disturbed but normalized within a week. Reilly et al.(Reilly et al., 1997) highlighted in his review that sleep privacy has detrimental effects on body temperature regulation. Core body temperature rhythm is disrupted by transmeridian travel regardless of flight direction, with eastward travel causing phase delays and westward travel causing phase advances. Recovery may occur within a few days, but typically requires up to one week.

Blood pressure: When blood pressure values were assessed, we can see in a study conducted by Lemmer et al.(Lemmer et al., 2002) in German Olympic gymnasts that blood pressure after westward travel revealed subtle changes in the 24h profiles, with peak value of systolic and diastolic blood pressure increasing. Conversely, after eastward travel, the same values showed a decrease. Waterhouse et al.(Waterhouse et al., 2004) in a review concluded that changes in altitude, pressure, vibration and fatigue can negatively impact physiological health of individuals, and long travels are associated with rhythm disturbances in blood pressure and heart rate. Westward flights increased systolic and diastolic blood pressure, while eastward flights tended to decrease them. Such alterations, compounded by factors like cabin pressure, vibration and fatigue, contribute to broader cardiovascular rhythm disturbances during and after long-haul flights.

Sleep: Regarding sleep, a case report conducted by Cardinali et al.(Cardinali et al., 2002) in male professional soccer players, found no significant changes (except for the number of awakenings and sleep latency) after a westward travel crossing twelve time zones. The number of awakenings augmented on days one and three. With respect to sleep latency, it was observed a decrease on days two, six and eight. The study (Cardinali et al., 2002) showed that exposure to outdoor light combined with physical exercise and melatonin administration did accelerate the resynchronization of the sleep cycle. In a case study conducted by Montaruli et al. (Montaruli et al., 2009) in amateur level marathon runners found no statistically significant differences in the sleep parameters for the first and second nights. As in the study conducted by Cardinali et al.(Cardinali et al., 2002), Montaruli et al.(Montaruli et al., 2009) showed in his case study that physical exercise planned at specific times of the day, before and after travel, can help the organism to adapt better in terms of a more rapid synchronization, with improvements in disorders linked to sleep. In an experimental design study by Roach and Sargent (Roach & Sargent, 2019) in international level athletes, it was observed that bright light exposure, shifting sleep schedules and ramelteon had positive effects after a twelve time zones transition. Roach and Sargent (Roach & Sargent, 2019) showed that time in bed was longer and sleep onset latency shorter for the control group in comparison with experimental group. On the other hand, Tsukahara et al.(Tsukahara et al., 2024), in an observational study conducted at the World U20 Athletics Championships, reported that after westward travel, athletes experienced greater difficulty falling asleep, and their sleep quality decreased significantly. After transmeridian travel sleep was consistently disrupted. Increased number of awakenings altered sleep latency and reduced sleep quality were reported, however interventions such as physical exercise, light exposure and melatonin administration can accelerate resynchronization of sleep-wake cycle and mitigate these disturbances.

Cortisol: Cortisol is one of the most important stress hormones, and a fundamental marker of the hypothalamic–pituitary–adrenal (HPA) axis (Andreadi et al., 2025; Born & Fehm, 2000). However, the literature was not all in accordance with the travel effects on cortisol secretion profile. When a disruption was found, not all studies reported the same. Some studies reported an increase in cortisol levels, and some studies reported a decrease in cortisol levels. When a disruption was found, Lemmer et al. (Lemmer et al., 2002); Bullock et al. (Bullock et al., 2007) and Rossiter et al. (Rossiter et al., 2022b) showed that it is needed 7 to 11 days to cortisol levels return to baseline. Meijer et al. (Meijer et al., 2008) in a narrative review reported an increase in cortisol levels. The same results were found by Atalag et al. (Atalag et al., 2019) in a quasi-experimental study with basketball players. On the other hand, in a observational study conducted by Bullock et al. (Bullock et al., 2007) reported a decrease on cortisol levels in skeleton athletes. In contrast to results reported by Meijer et al. (Meijer et al., 2008) and Atalag et al. (Atalag et al., 2019), Stevens et al. (Stevens et al., 2018) found no statistical significative differences in long travel, when cortisol levels were quantified. Bullock et al. (Bullock et al., 2007) identified a reduction on salivary cortisol levels one day after travel, with reduced values on the second day. Similar results were described by Lemmer et al. (Lemmer et al., 2002) with a disturbed cortisol rhythm observed in both westward and eastward travel, until eleven days. These changes can compromise physiological processes regarding performance likewise recovery and immune system. However, Reilly et al. (Reilly et al., 2007b) showed that this endocrine response is not uniform, highlighting the need for a personalized strategies to mitigate these travel effects on cortisol and endocrine system.

Heart rate variability (HRV): HRV is known as a robust indicator of autonomic function and the balance between sympathetic and parasympathetic activity (Perini et al., 2006). It’s the sensitivity to physiological changes that make heart rate variability a relevant marker in long haul travel impacts (Dranitsin, 2008). The results of all articles included in this review were not all in accordance with regard to the HRV behavior. Heart rate variability measures worsened after a transmeridian travel crossing more than 3 time zones (Dranitsin, 2008; Flatt & Howells, 2022; Straub et al., 2001). However, one study reported that these values returned to baseline 1 day per time zone change (Dranitsin, 2008). In a study conducted by Dranitsin et al. (Dranitsin, 2008) after crossing five time zones, HRV values were impaired on the days four and five, with progressive recovery until the thirteenth day, suggesting that the autonomic system requires several days to reestablish stability after a circadian disruption. The same study showed that HRV values were associated with training loads of the day before, which indicates an interaction between environmental factors such as temperature, humidity and physiological factors related to training volumes. More recently, Flatt & Howells (Flatt & Howells, 2022) showed a temporary decrease after a long travel on LnRMSSD, being more evident in non-starters, suggesting that exposure to competition and game loads can modulate the autonomic response to jet lag. Thus, these data suggest that HRV is a practical tool and non-invasive to monitor cardiovascular adaptations to exercise and long travels, and to optimize training loads and athletes' recovery, not just in an international travel context.

Physical Performance markers

The higher the performance caliber, the smaller the differences between competing athletes, and the narrower the gap between winners and losers. In elite competitions, success is often determined by the smallest details. Since professional athletes are constantly seeking a competitive edge, manipulating circadian rhythms may provide such an advantage (Jehue et al., 1993). Most parameters that influence athletic performance, such as grip strength, anaerobic power and capacity, aerobic power and capacity, hormonal secretion and self-chosen work rate are closely related to the body temperature curve, which peaks in the late afternoon (at about 18:00) (Jehue et al., 1993; Waterhouse et al., 2004). In fact, a disproportionally large number of world records have been broken in the late afternoon (Eichner, 1994; Jehue et al., 1993).

Anaerobic power and capacity: The literature was not in agreement with the results found. There were studies that found a decreased in power capacity (Augusto et al., 2021; Chapman et al., 2012; Fowler et al., 2017a; Hill et al., 1993; Reilly et al., 1997; Rossiter et al., 2022b) and some studies did not found any detrimental effect of travel in power capacity (Bullock et al., 2007; Rossiter et al., 2022b). In some cases, there was an increased after travel (Everett et al., 2022;

Rossiter et al., 2022b; Varesco et al., 2024). In a review conducted by Hill et al. (Hill et al., 1993) in women's national soccer team and healthy individuals, peak power and work capacity were significantly affected, but returned quickly to pre travel levels. In another review, conducted by Reilly et al. (Reilly et al., 1997) in swimmers, rugby players, military personal, Olympic squad members and American footballers travelling eastward crossing six time zones also found decreases in muscle performance, but simple tasks adjusted at a faster rate. Chapman et al. (Chapman et al., 2012), in a pre-post intervention in national team of skeleton found that vertical jump performance was also impacted by eastward travel crossing four time zones. This study reported that maximal acyclic tests of power were affected by the long-haul travel. Fowler et al. (Fowler et al., 2017a), in an observational study conducted in healthy physical trained man traveling in a westward direction crossing eight time zones found performance deficits in lower body power assessed by maximal and intermittent sprint performance until up to 96 hours after travel. In another observational study conducted by Augusto et al. (Augusto et al., 2021) in male professional soccer players from Brazilian 1st division championship, intense actions such as sprint distance covered and high intensity running distance in games after travel were negatively impacted. In a systematic review conducted by Rossiter et al. (Rossiter et al., 2022b) including elite athletes found that there were detrimental effects on jump performance after westward travels. However, in an observational study conducted by Bullock et al. (Bullock et al., 2007) in skeleton athletes after an eastward travel crossing four time zones, there were no statistically significative differences found in post travel 30 m sprint time. On the other hand, there were studies reported an increase in anaerobic power tasks after travel. Everet et al. (Everett et al., 2022) in highly trained rowers traveling in a westward direction crossing nine time zones found increases in the propulsive phase and eccentric velocity during loaded countermovement jumps, resulting in an increase in mean power. Varesco et al. (Varesco et al., 2024) in speed skaters also found an increase in jump high after an eastward travel crossing ten time zones. The effects of long-haul travel on anaerobic power were inconsistent. In this review, there were studies that reported decreases, other studies reported no changes, and other studies reported improvements, depending on sport modality and direction of travel. Power performance often shows transient impairments (particularly after eastward travel); however, some athletes experience enhanced outputs in certain anaerobic tasks.

Strength: In terms of strength, results followed the same tendency as power, some studies found detrimental effects (Atalag et al., 2019; Hill et al., 1993; Meijer et al., 2008; Reilly et al., 1997; Rossiter et al., 2022b; Tsukahara et al., 2024), one study did not find any statistical significative differences (Fowler et al., 2016) and some studies actually found increases in strength after travel (Everett et al., 2022; Rossiter et al., 2022b; Varesco et al., 2024). Hill et al. (Hill et al., 1993) in a review with the national women's soccer team travelling in a westward direction found that press-pull strength at slow velocity and fast velocity were both decreased. In a narrative review conducted by Meijer et al. (Meijer et al., 2008) in elite athletes from Track and field, Swimming, Cycling, Soccer, Tennis, Badminton and general population travelling in an eastward travel crossing 6 time zones or more, showed that muscle strength was decreased for several days, showing a circadian rhythm in performance, being lowest in the morning and high at the early evening. Atalag et al. (Atalag et al., 2019) in a quasi-experimental study with basketball players playing in second division on American college basketball, the strength of players on knee flexion was showed after one season travelling from Hawaii to mainland of America, and consequently, vertical jump height also decreased. However, Fowler et al. (Fowler et al., 2016) in an observational study with rugby players showed that after a westward travel crossing eleven time zones, muscle strength and range of motion values were not statistically significative different from pre travel values. As for anaerobic power and capacity, there were studies showing an increase on strength capacity even after travel. Everet et al. (Everett et al., 2022) in a sample with highly trained male rowers found that eccentric velocity and jump high after a westward travel had increased. The same was concluded by Varesco et al. (Varesco et al., 2024) in speed skaters' athletes, with athletes jumping higher after an eastward travel crossing ten time zones. The effects of transmeridian travel on muscle strength were inconsistent. Some studies reported decreases, others did not find any significant changes and some studies reported improvements. These variations suggest that strength responses depend on travel direction, sport modality and the timing of performance assessments relative to circadian rhythms.

Velocity: With respect to velocity, two studies did not found any statistical significative difference after long haul travel (Bullock et al., 2007; Varesco et al., 2024), one study found detrimental effects (Rossiter et al., 2022b) and two studies did found increases after travel (Everett et al., 2022; Rossiter et al., 2022b). Bullock et al. (Bullock et al., 2007) in an observational study with skeleton athletes traveling in an eastward direction crossing four time zones, data indicated that there were no detrimental effects on maximal 30m sprinting. The same results were observed in an observational design study conducted by Varesco et al. (Varesco et al., 2024) with speed skaters travelling in the same direction, crossing ten time zones, with the results showing no differences on athletes' race times after the eastward travel. In another observational study by Everett et al. (Everett et al., 2022) the athletes' overall performance showed a small increase after a westward travel crossing nine time zones, with an increase in mean velocity during loaded countermovement jumps. These results are in accordance with a systematic review conducted by Rossiter et al. (Rossiter et al., 2022b) with elite athletes showing improved sprint performance after westward travel. However, the same study found negative impacts in another group of athletes on sprint performance after a westward travel. Evidence of the impacts on velocity after transmeridian travel is mixed. Some studies found no changes, other reported either impairments or improvements, in particular following westward flights. These findings suggest that the effect of jet lag on velocity depend on direction of travel and the type of sport.

Aerobic power and capacity: Studies consistently reported that aerobic power and capacity are negatively affected by long-haul travels. Eichner et al. (Eichner, 1994) found that college swimmers traveling westward experienced a measurable decrease in endurance performance. The same reductions were found by Fowler et al. (Fowler et al., 2017a) in male professional soccer players after an eastward travel crossing eleven time zones. In addition, sleep disturbances and accumulated travel fatigue further compromise aerobic performance, reducing maximal oxygen consumption. These effects can persist for several days post-travel, although the rate of recovery appears to be influenced by individual differences, the direction of travel, and the scheduling of subsequent training or competition sessions. Aerobic power and capacity are particularly vulnerable to the combined stressors of time zone changes, sleep disruption and travel related fatigue, highlighting the need for targeted strategies to mitigate performance decrements in endurance sports.

Coordination and reaction time: Travel also had a negative effect in coordination (Forbes-Robertson et al., 2012), but it was less affected after eastward travel (Lemmer et al., 2002). In an observational study with German Olympic gymnastics members crossing six time zones in a westward direction, Lemmer et al. (Lemmer et al., 2002) found that coordination was negatively impacted, however, the same group of athletes had their training performance and coordination in an eastward travel less affected when comparing with westward travel. In the same line of results, Forbes-Robertson et al. (Forbes-Robertson et al., 2012) in a review including elite and sub-elite athletes from various sports (e.g. soccer, rugby, swimming, tennis) also traveling in a westward and eastward direction had coordination and reaction time impaired after both travel directions. Coordination and reaction time were particularly vulnerable to the effects of long-haul travel, with studies reporting impairments regardless of direction. However, evidence suggests that in comparison with eastward travels, westward travels have a more pronounced negative impact. These disturbances are likely linked to circadian misalignment and fatigue, which can compromise fine motor control and responsiveness. These factors have critical importance for technical performance in sports requiring precision and rapid decision making.

Sport specific tasks: However, the physical performance tasks chosen to understand the effects of long haul travels in the majority of studies were not sporting specific activities, and some studies, the majority in the USA (n=10) and in Australia (n=1), did some longitudinal researches in the travel effect on the actual game performance and specific sports statistics and movements (e.g. number of free throws made, number of home runs, final match result). In total there were 11 studies reporting these travel effects. From these 11 studies, 5 studies were in basketball (NBA), 4 studies were in American football (NFL and NCAA), 2 studies were in hockey (NHL),1study was in baseball (MBL) and 1study was in Rugby (NRL).

In the NBA, all studies reported that travel before a game has negative impacts on team performance (e.g. win percentage, free throws made, field goals percentage, number of rebound). The direction of travel was highly correlated with the team's performance, where travelling westward was related to poor performance (Charest et al., 2021; Glinski & Chandy, 2022; Roy & Forest, 2018), however in two studies was the travel direction eastward correlated with poor performance (Leota et al., 2022; Özdalyan et al., 2024). In American football (NFL and NCAA) modality, two studies found that travel in the east direction had negative impacts on the team's ability to win (Jehue et al., 1993; Smith et al., 1997). One the other hand, one study found that travel in the west direction had a negative impact on team's overall performance (Fullagar et al., 2019). However, one study reported that neither westward nor eastward travel had influence on team's ability to win matches (Roy & Forest, 2018). In the NHL, one study found that westward travel had a significant disadvantage for the teams travelling (Roy & Forest, 2018), and one study found that travel impacts in a negative way teams overall performance independently the direction (Charest et al., 2022). In baseball modality (MLB), one study reported that travel had negative influence on the team's performance, but eastward travel when compared with westward was worst (Song et al., 2017). Away from North America, in rugby (NRL, Australia national rugby league), one study found that travel negatively affect performance, independently the direction (Read et al., 2022). Long-haul travel negatively affects sport-specific taks, with effects being evident in game statistics and team outcomes across multiple professional leagues. In contrast to what has been observed in the literature, that eastward travels are related with severe jet lag symptoms, when analyzing game statistics, westward travels were frequently associated with poorer performance (e.g decreased win%). Circadian rhythm disruption, fatigue and travel-related stress translate directly into measurable decrements in competitive performance, highlighting the importance of travel management strategies in professional sport.

Limitations

The included research involved heterogeneous populations, including athletes from different sports, competitive levels, and ages, as well as variations in travel direction, number of time zones crossed, and performance assessments, making direct comparisons challenging. Methodological differences across studies, small sample sizes, ad reliance on observational designs further limit the generalizability of the findings. Additionally, contextual factors such as competition schedules, and geographic origin or destination were not consistently controlled, which may influence the observed effects of long-haul travel on athletic performance.

Practical Applications

The results of this narrative review showed that long-haul travels and consequent jet lag have relevant and multifactorial impacts on physical performance, physiologic markers and athletes' well-being. In this way, it recommended that coaches, medical staff and sports managers adopt preventive strategies and individualized monitoring to mitigate these effects. It is fundamental to:

1. Plan the trip to allow for gradual adaptation to the new time zone (when possible)
2. Monitor physiological variables (HRV, cortisol, body temperature)
3. Implement behavioral interventions (sleep hygiene, strategic light exposure, hydration, nutrition)

4. Educate athletes and technical staff to recognize early signs of travel fatigue and jet lag

Conclusion

In conclusion, this narrative systematic review showed that long-haul travels and consequently jet lag significative but variable impacts on physical performance and physiological markers on athletes. In terms of performance, anaerobic power and capacity, strength and velocity seemed to be affected in a heterogeneous way, depending on the direction of the travel and the number of time zones crossed, the sport modality and the specificity of the task required to do. In general, physical performance is negatively impacted, especially after eastward travels, however some studies reported some increases in power and strength in some athletes and tasks. Aerobic power and capacity and coordination seemed to be the most consistently negatively impacted, particularly in eastward travels and complex tasks. In terms of hemodynamic and physiological markers, it was observed changes in blood pressure, body temperature and sleep patterns, with direct impacts on recovery and athletes' readiness to compete. Heart rate variability revealed as a sensitive tool to monitor autonomic response, showing that autonomic nervous system can take several days to stabilize after a circadian dysrhythmia. Lastly, cortisol secretion is variably affected, potentially compromising recovery processes and immune function, highlighting the need for personalized strategies to mitigate the effects of jet lag in athletes. In summary, long-haul travels effects are multifactorial and link physical performance, autonomic and endocrine regulation, being fundamental to a personalized monitoring to mitigate long-haul travels and jet lag in all level athletes.

Funding

Nothing to declare.

Competing interests

Nothing to declare.

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Chapter 3

General Discussion

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Circadian rhythms that persist under constant conditions originate from within the body, meaning they have an endogenous component[(Winget et al., 1985)]. When body temperature is measured under normal conditions, including sleep and activity, environmental and lifestyle influences are also present, as indicated by the increased amplitude of the rhythm[(Winget et al., 1985)]. This influence is referred to as the exogenous component. During the day, body temperature is elevated due to the combined effect of the internal clock and the alerting influence of environmental factors and physical or mental activity. At night, the internal clock, environmental cues, and inactivity all contribute to lowering body temperature. This interaction between endogenous and exogenous components occurs in all physiological variables.[(Waterhouse et al., 2004)]

3.1. Physiological and hemodynamic markers

3.1.1. Body Temperature

Regardless travel direction, westward or eastward, the rhythmic patterns in body temperature are greatly disturbed on day 1 (Lemmer et al., 2002). When travelling to east, this rhythmicity suffers a phase-delay, while travelling west, a phase advance. Body temperature is associated with sleep-wake cycle, and only after this cycle is regulated the body’s ability to regulate core body temperature (Armstrong, 2006; Postolache et al., 2005). About the duration of the disruption of core body temperature, it takes up to 11 days to recover (Meijer et al., 2008; Rossiter et al., 2022b). However, in some cases, independently of direction, body temperature was disturbed but normalized within a week (Lemmer et al., 2002). Reilly et al. (Reilly et al., 1997) highlighted in his review that sleep privacy has detrimental effects on body temperature regulation. Core body temperature rhythm is disrupted by transmeridian travel regardless of flight direction, with eastward travel causing phase delays and westward travel causing phase advances. Recovery may occur within a few days, but typically requires up to one week.

3.1.2. Blood Pressure

In a study conducted by Lemmer et al. (Lemmer et al., 2002) in German Olympic gymnasts, blood pressure after westward travel revealed subtle changes in the 24h profiles, with peak value of systolic and diastolic blood pressure increasing. Conversely, after eastward travel, the same values showed a decrease. Waterhouse et al. (Waterhouse et al., 2004) concluded that changes in altitude, pressure, vibration and fatigue can negatively impact physiological health of individuals, and long travels are associated with rhythm disturbances in blood pressure and heart rate. Westward flights increased systolic and diastolic blood pressure, while eastward flights tended to decrease them. Such alterations, compounded by factors like cabin pressure, vibration and fatigue, contribute to broader cardiovascular rhythm disturbances during and after long-haul flights.

3.1.3. Sleep

A case report conducted by Cardinali et al. (Cardinali et al., 2002) in male professional soccer players, found no significant changes (except for the number of awakenings and sleep latency) after a westward travel crossing twelve time zones. The number of awakenings augmented on days one and three. With respect to sleep latency, it was observed a decrease on days two, six and eight. The study (Cardinali et al., 2002) showed that exposure to outdoor light combined with physical exercise and melatonin administration did accelerate the resynchronization of the sleep cycle. In a case study conducted by Montaruli et al. (Montaruli et al., 2009) in amateur level marathon runners found no statistically significant differences in the sleep parameters for the first and second nights. As in the study conducted by Cardinali et al. (Cardinali et al., 2002), Montaruli et al. (Montaruli et al., 2009) showed in his case study that physical exercise planned at specific times of the day, before and after travel, can help the organism to adapt better in terms of a more rapid synchronization, with improvements in disorders linked to sleep. In an experimental design study by Roach and Sargent (Roach & Sargent, 2019) in international level athletes, it was observed that bright light exposure, shifting sleep schedules and ramelteon had positive effects after a twelve time zones transition. Roach and Sargent (Roach & Sargent, 2019) showed that time in bed was longer and sleep onset latency shorter for the control group in comparison with experimental group. On the other hand, Tsukahara et al. (Tsukahara et al., 2024), in an observational study conducted at the World U20 Athletics Championships, reported that after westward travel, athletes experienced greater difficulty falling asleep, and their sleep quality decreased significantly. After transmeridian travel sleep was consistently disrupted. Increased number of awakenings altered sleep latency and reduced sleep quality are reported after LH travels, however interventions such as physical exercise, light exposure and melatonin administration can accelerate resynchronization of sleep-wake cycle and mitigate these disturbances.

3.1.4. Cortisol

Cortisol is one of the most important stress hormones, and a fundamental marker of the hypothalamic–pituitary–adrenal (HPA) axis (Andreadi et al., 2025; Born & Fehm, 2000). However, the literature is not all in accordance with the travel effects on cortisol secretion profile. Some authors report an increase in cortisol levels and some authors report a decrease in cortisol levels. Lemmer, B. et al. (Lemmer et al., 2002); Bullock, N. et al. (Bullock et al., 2007) and Rossiter, A. et al. (Rossiter et al., 2022b) showed that it is need 7 to 11 days to cortisol levels return to baseline. Meijer, J. H. et al. (Meijer et al., 2008) reported an increase in cortisol levels. The same results were found by Atalag, O. et al. (Atalag et al., 2019). On the other hand Bullock, N. et al. (Bullock et al., 2007) reported a decrease on cortisol levels in skeleton athletes. In contrast to results reported by Meijer, J.H. et al. (Meijer et al., 2008) and Atalag, O. et al. (Atalag et al., 2019), Stevens, C. J. et al. (Stevens et al., 2018) found no statistical significative differences after a long travel in cortisol levels. Bullock et al. (Bullock et al., 2007) identified a reduction on salivary cortisol levels one day after travel, with reduced values on the second day. Similar results were described by Lemmer et al. (Lemmer et al., 2002) with a disturbed cortisol rhythm observed in both westward and eastward travel, until eleven days. These changes can compromise physiological processes regarding performance likewise recovery and immune system. However, Reilly et al. (Reilly et al., 2007b) showed that this endocrine response is not uniform, highlighting the need for a personalized strategies to mitigate these travel effects on cortisol and endocrine system.

3.1.5. Heart rate variability

HRV is known as a robust indicator of autonomic function and the balance between sympathetic and parasympathetic activity. (Perini et al., 2006). It's the sensitivity to physiological changes that make heart rate variability a relevant marker in long haul travel impacts (Dranitsin, 2008). We can found in the literature that HRV measures worsened after a transmeridian travel crossing more than 3 time zones (Dranitsin, 2008; Flatt & Howells, 2022; Straub et al., 2001). However, one study reported that these values returned to baseline 1 day per time zone change (Dranitsin, 2008). In a study conducted by Dranitsin et al. (Dranitsin, 2008) after crossing five time zones, HRV values were impaired on the days four and five, with progressive recovery until the thirteenth day, suggesting that the autonomic system requires several days to reestablish stability after a circadian disruption. The same study showed that HRV values were associated with training loads of the day before, which indicates an interaction between environmental factors such as temperature, humidity and physiological factors related to training volumes. More recently, Flatt & Howells (Flatt & Howells, 2022) showed a temporary decrease after a long travel on LnRMSSD, being more evident in non-starters, suggesting that exposure to competition and game loads can modulate the autonomic response to jet lag. Thus, HRV can be a practical tool and non-invasive to monitor cardiovascular adaptations to exercise and long travels, and to optimize training loads and athletes' recovery, not just in an international travel context.

3.2. Physical Performance markers

The higher the performance caliber, the smaller the differences between competing athletes, and the narrower the gap between winners and losers. In elite competitions, success is often determined by the smallest details. Since professional athletes are constantly seeking a competitive edge, manipulating circadian rhythms may provide such an advantage (Jehue et al., 1993). Most parameters that influence athletic performance, such as grip strength, anaerobic power and capacity, aerobic power and capacity, hormonal secretion and self-chosen work rate are closely related to the body temperature curve, which peaks in the late afternoon (at about 18:00) (Jehue et al., 1993; Waterhouse et al., 2004). In fact, a disproportionally large number of world records have been broken in the late afternoon (Eichner, 1994; Jehue et al., 1993).

3.2.1. Anaerobic power and capacity

The literature was not in agreement with the results found. We can find studies that report a decreased in power capacity (Augusto et al., 2021; Chapman et al., 2012; Fowler et al., 2017a; Hill et al., 1993; Reilly et al., 1997; Rossiter et al., 2022b) and some studies did not found any detrimental effect of travel in power capacity (Bullock et al., 2007; Rossiter et al., 2022b). In some cases, there was an increased after travel (Everett et al., 2022; Rossiter et al., 2022b; Varesco et al., 2024). Hill et al. (Hill et al., 1993) showed that in women's national soccer team and healthy individuals, peak power and work capacity were significantly affected, but returned quickly to pre travel levels. Reilly et al. (Reilly et al., 1997) found in swimmers, rugby players, military personal, Olympic squad members and American footballers travelling eastward crossing six time zones resulted in decreases in muscle performance, but simple tasks adjusted at a faster rate. Chapman et al. (Chapman et al., 2012) in national team of skeleton found that vertical jump performance was also impacted by eastward travel crossing four time zones. This study reported that maximal acyclic tests of power were affected by the long-haul travel. Fowler et al. (Fowler et al., 2017a), in healthy physical trained man traveling in a westward direction crossing eight time zones found performance deficits in lower body power assessed by maximal and intermittent sprint performance until up to 96 hours after travel. Augusto et al. (Augusto et al., 2021) in male professional soccer players from Brazilian 1st division championship, intense actions such as sprint distance covered and high intensity running distance in games after travel were negatively impacted. Rossiter et al. (Rossiter et al., 2022b) in elite athletes found that there were detrimental effects on jump performance after westward travels. However, Bullock et al. (Bullock et al., 2007) in skeleton athletes after an eastward travel crossing four time zones, reported no statistically significative differences in post travel 30m sprint time. On the other hand, there were studies reported an increase in anaerobic power tasks after travel. Everet et al. (Everett et al., 2022) in highly trained rowers traveling in a westward direction crossing nine time zones found increases in the propulsive phase and eccentric velocity during loaded countermovement jumps, resulting in an increase in mean power. Varesco et al. (Varesco et al., 2024) in speed skaters also found an increase in jump high after an eastward travel crossing ten time zones. The effects of long-haul travel on anaerobic power and capacity are inconsistent. In the literature, there are studies that report decreases, other studies report no changes, and other studies report improvements, depending on sport modality and direction of travel. Power performance often shows transient impairments (particularly after eastward travel); however, some athletes experience enhanced outputs in certain anaerobic tasks.

3.2.2. Strength

In terms of strength, results follow the same tendency as power, some studies report detrimental effects (Atalag et al., 2019; Hill et al., 1993; Meijer et al., 2008; Reilly et al., 1997; Rossiter et al., 2022b; Tsukahara et al., 2024), one study did not find any statistical significative differences (Fowler et al., 2016) and some studies actually report increases in strength after travel (Everett et al., 2022; Rossiter et al., 2022b; Varesco et al., 2024). Hill et al. (Hill et al., 1993) in a review with the national women's soccer team travelling in a westward direction found that press-pull strength at slow velocity and fast velocity were both decreased. In a narrative review conducted by Meijer et al. (Meijer et al., 2008) in elite athletes from Track and field, Swimming, Cycling, Soccer, Tennis, Badminton and general population travelling in an eastward travel crossing 6 time zones or more, showed that muscle strength was decreased for several days, showing a circadian rhythm in performance, being lowest in the morning and high at the early evening. Atalag et al. (Atalag et al., 2019) in a quasi-experimental study with basketball players playing in second division on American college basketball, the strength of players on knee flexion was showed after one season travelling from Hawaii to mainland of America, and consequently, vertical jump height also decreased. However, Fowler et al. (Fowler et al., 2016) in an observational study with rugby players showed that after a westward travel crossing eleven time zones, muscle strength and range of motion values were not statistically significative different from pre travel values. As for anaerobic power and capacity, there were studies showing an increase on strength capacity even after travel. Everet et al. (Everett et al., 2022) in a sample with highly trained male rowers found that eccentric velocity and jump high after a westward travel had increased. The same was concluded by Varesco et al. (Varesco et al., 2024) in speed skaters' athletes, with athletes jumping higher after an eastward travel crossing ten time zones. The effects of transmeridian travel on muscle strength were inconsistent. Some studies reported decreases, others did not find any significant changes and some studies reported improvements. These variations suggest that strength responses depend on travel direction, sport modality and the timing of performance assessments relative to circadian rhythms.

3.2.3. Velocity

Bullock et al. (Bullock et al., 2007) in an observational study with skeleton athletes traveling in an eastward direction crossing four time zones, data indicated that there were no detrimental effects on maximal 30m sprinting. The same results were observed in an observational design study conducted by Varesco et al. (Varesco et al., 2024) with speed skaters travelling in the same direction, crossing ten time zones, with the results showing no differences on athletes' race times after the eastward travel. In another observational study by Everett et al. (Everett et al., 2022) the athletes' overall performance showed a small increase after a westward travel crossing nine time zones, with an increase in mean velocity during loaded countermovement jumps. These results are in accordance with a systematic review conducted by Rossiter et al. (Rossiter et al., 2022b) with elite athletes showing improved sprint performance after westward travel. However, the same study found negative impacts in another group of athletes on sprint performance after a westward travel. Evidence of the impacts on velocity after transmeridian travel is mixed. Some studies found no changes, other reported either impairments or improvements, in particular following westward flights. These findings suggest that the effect of jet lag on velocity depend on direction of travel and the type of sport.

3.2.4. Aerobic power and capacity

Studies consistently reported that aerobic power and capacity are negatively affected by long-haul travels. Eichner et al. (Eichner, 1994) found that college swimmers traveling westward experienced a measurable decrease in endurance performance. The same reductions were found by Fowler et al. (Fowler et al., 2017a) in male professional soccer players after an eastward travel crossing eleven time zones. In addition, sleep disturbances and accumulated travel fatigue further compromise aerobic performance, reducing maximal oxygen consumption. These effects can persist for several days post-travel, although the rate of recovery appears to be influenced by individual differences, the direction of travel, and the scheduling of subsequent training or competition sessions. Aerobic power and capacity are particularly vulnerable to the combined stressors of time zone changes, sleep disruption and travel related fatigue, highlighting the need for targeted strategies to mitigate performance decrements in endurance sports.

3.2.5. Sport specific tasks

Nevertheless, the physical performance tasks chosen to understand the effects of long haul travels in the majority of studies were not sporting specific activities, and some studies, the majority in the USA (n=10) and in Australia (n=1), did some longitudinal researches in the travel effect on the actual game performance and specific sports statistics and movements (e.g. number of free throws made, number of home runs, final match result).

In the NBA, all studies reported that travel before a game has negative impacts on team performance (e.g. win percentage, free throws made, field goals percentage, number of rebound). The direction of travel was highly correlated with the team's performance, where travelling westward was related to poor performance (Charest et al., 2021; Glinski & Chandy, 2022; Roy & Forest, 2018), however in two studies was the travel direction eastward correlated with poor performance (Leota et al., 2022; Özdalyan et al., 2024).

In American football (NFL and NCAA) modality, two studies found that travel in the east direction had negative impacts on the team's ability to win (Jehue et al., 1993; Smith et al., 1997). One the other hand, one study found that travel in the west direction had a negative impact on team's overall performance (Fullagar et al., 2019). However, one study reported that neither westward nor eastward travel had influence on team's ability to win matches (Roy & Forest, 2018).

In the NHL, one study found that westward travel had a significant disadvantage for the teams travelling (Roy & Forest, 2018), and one study found that travel impacts in a negative way teams overall performance independently the direction (Charest et al., 2022). In baseball modality (MLB), one study reported that travel had negative influence on the team's performance, but eastward travel when compared with westward was worst (Song et al., 2017). Away from North America, in rugby (NRL, Australia national rugby league), one study found that travel negatively affect performance, independently the direction (Read et al., 2022).

Long-haul travel negatively affects sport-specific tasks, with effects being evident in game statistics and team outcomes across multiple professional leagues. In contrast to what has been observed in the literature, that eastward travels are related with severe jet lag symptoms, when analyzing game statistics, westward travels were frequently associated with poorer performance (e.g. decreased win%, decreased free throws made, field goals% , number of rebound). Circadian rhythm disruption, fatigue and travel-related stress translate directly into measurable decrements in competitive performance, highlighting the importance of travel management strategies in professional sport.

3.3. Practical Applications

This academic dissertation carries important implications for applied sports practice. First, the findings emphasize the need for individualized monitoring of athletes before, during and after long-haul travel. Since physiological and performance responses to jet lag are highly variable, the systematic use of tools such as heart rate variability, salivary cortisol and sleep quality assessments may help practitioners detect early maladaptations and adjust training loads accordingly.

The results highlight the importance of adopting preventive strategies to minimize circadian disruptions. Pre-travel plans (e.g. gradual adjustments to the destination time zone, tailored sleep-wake schedules, and controlled exposure to light) should be systematically implemented, particularly in sports where competitions are scheduled within a short time frame after arrival.

Third, these findings provide useful guidance for the design of recovery protocols after long-haul travels. Behavioral interventions, including proper hydration, nutrition, sleep hygiene, and the judicious use of ergogenic aids such as melatonin or caffeine, can accelerate resynchronization and reduce travel related fatigue.

Finally, this academic dissertation reinforces the strategic role of coaches, medical staff and performance managers in integrating based science evidence into daily practices. Effective travel planning and science-based countermeasures should not be considered optional, but rather fundamental elements of high-performance management.

3.4. Future Perspectives

While this academic dissertation contributes to the understanding of the multifactorial effects of long-haul travels and jet lag on athletes, several avenues for future research remain open. First, more high-quality longitudinal studies are needed to assess the cumulative effects of repeated travel across competitive seasons, particularly in team sports with congested schedules.

Second, future research should prioritize sport-specific performance assessments, rather than relying primarily on general physical fitness markers. This would allow more precise conclusions about the impact of long-haul travels on actual in-game performance. There is a need for experimental studies testing the effectiveness of different countermeasures, such as light therapy, nutritional interventions, pharmacological strategies, and training schedule adjustments, under real competitive conditions. Future investigations should consider individual variability, including chronotype, gender, age, and prior travel experience, as potential moderators of physiological and performance responses. Personalized approaches may prove more effective than generalized recommendations.

Finally, greater collaboration between researchers and professional sports organization is essential. Applied research in real-world competitive contexts will help bridge the gap between theory and practice, ensuring that scientific knowledge is translated into effective strategies to protect athlete health and optimize performance during international competition.

Chapter 4

References

Chapter 4

4. References

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Appended Work

Article Supplements: Do Long-Haul Travels and Jet Lag Affect Athletes' Physiological, Humoral and Performance Outcomes? A Systematic Narrative Review

Appendix A: Prisma 2020 Checklist

Supplementary Table 1. PRISMA 2020 Checklist - Do Long-Haul Travels and Jet Lag Affect Athletes' Physiological, Humoral and Performance Outcomes? A Narrative Systematic Review

Section and Topic	**Item #**	**Checklist item**	**Location where item is reported**
		TITLE	
Title	1	Identify the report as a systematic review.	11
		ABSTRACT	
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	11
		INTRODUCTION	
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	12, 13, 14
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	15, 16
		METHODS	
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	16
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	16
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	16
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	16
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or	17

		confirming data from study investigators, and if applicable, details of automation tools used in the process.	
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	15, 16
	10b	List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	17
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	17
Effect measures	12	Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.	n/a
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	17
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n/a
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	17
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	n/a
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).	n/a
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n/a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	n/a

Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	n/a
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	29, 31
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	n/a
Study characteristics	17	Cite each included study and present its characteristics.	18 - 25
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	26-28
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	n/a
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	n/a
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	29,30
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	n/a
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n/a
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n/a
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n/a
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	32
	23b	Discuss any limitations of the evidence included in the review.	40

	23c	Discuss any limitations of the review processes used.	40
	23d	Discuss implications of the results for practice, policy, and future research.	40
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	16
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	16
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	16
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	41
Competing interests	26	Declare any competing interests of review authors.	41
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	n/a