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Managing Midnight Miles: A Qualitative Descriptive Single-Case Study on Sleep Strategies Among United States Ultra-Marathon Runners

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Abstract

Sleep plays a vital role in athletic performance, yet ultra-marathon runners often face inadequate sleep due to the intense demands of their sport. The negative effects of insufficient sleep on the physical health, psychological health, and social well-being of ultra-marathon athletes are considerable; however, tailored sleep interventions for this group are still not well understood. This qualitative descriptive single-case study explored how ultra-marathon runners in the United States perceive the role of sleep in relation to their physical health, psychological health, and social factors during endurance events. Guided by the biopsychosocial model, the study explored sleep management from biological, psychological, and social perspectives. A purposive sample of 15 ultra-marathon runners from across the United States participated in semi-structured virtual interviews. Data analysis followed Braun and Clarke's reflexive thematic analysis framework, resulting in nine major themes. Key themes included strategic sleep optimization, bidirectional sleep negotiation, psychological adaptation, identity and community belonging, and sleep disruption consequences. Athletes described using intentional sleep practices, such as sleep tracking technology, behavioral sleep hygiene, and recovery strategies, aimed at enhancing performance, while acknowledging the challenges posed by external factors, including work and family responsibilities. The findings highlighted significant psychological disruptions caused by sleep deprivation, including emotional instability, motivational issues, and cognitive impairments during critical race moments. Recommendations suggest targeted interventions that combine technology, behavioral approaches, and social support. Future research should explore larger, more diverse samples and assess the effectiveness of specific sleep interventions. These findings offer valuable guidance for improving sleep in ultra-endurance sports, benefiting athletes, coaches, and sports health professionals.

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Chapter 1: Introduction

Sleep, an integral component of human health, is increasingly recognized for its critical role in enhancing athletic performance, particularly within sports science (Byrne et al., 2024; Fullagar et al., 2015). Adequate sleep is essential for athletes to achieve optimal performance levels, yet many athletes, especially those engaged in ultra-endurance sports, frequently encounter sleep insufficiency (Brace et al., 2023; Miller et al., 2022). This issue is acutely observed among ultra-marathon runners, who grapple with the compounded effects of extreme physical exertion and inadequate sleep (Benchetrit et al., 2023; Miller et al., 2022).

Ultra-marathons pose significant physiological and psychological strains on participants (Roberts et al., 2022). The demanding nature of ultra-marathon events and the extensive training required can lead to disrupted sleep patterns and inadequate rest, intensifying fatigue and impairing cognitive and physical performance (Bianchi et al., 2023; Fullagar et al., 2015; Riegler et al., 2023). Ultra-marathon athletes often engage in months-long, intense training regimens, leaving little time for the recovery essential for maintaining cognitive sharpness and psychological resilience—factors critical for succeeding in ultra-endurance challenges (Bender & Lambing, 2024; Roberts et al., 2022).

The prominence of sleep studies within sports science has grown, with research highlighting the profound impact of sleep on athletes' performance, injury prevention, and recovery (Fox et al., 2020; Fullagar et al., 2015). However, most existing research has concentrated on team or individual sports with shorter event durations. The unique demands of ultra-marathons, which include extreme environmental conditions like high altitudes and harsh weather, necessitate specialized sleep management understanding (Brace et al., 2023; Miller et al., 2022). The global surge in ultra-marathon popularity underscores the importance of

developing robust sleep management strategies for participants who often confront additional challenges, such as adjusting to different time zones and unfamiliar sleeping environments (Byrne et al., 2024; Riegler et al., 2023).

Despite the increasing recognition of sleep management issues, there remains a notable deficiency in research specifically addressing sleep strategies tailored for ultra-marathon runners, resulting in a significant knowledge gap for coaches, athletes, and sports scientists (Brace et al., 2023; Roberts et al., 2022). There is an emphasis on the need for studies concentrated on devising effective interventions and management practices designed to meet the unique requirements of ultra-marathon runners. By exploring how ultra-marathon athletes sleep under severe conditions, targeted strategies can be developed to improve sleep quality, thus enhancing athletic performance and ensuring their long-term health (Bender & Lambing, 2024; Miller et al., 2022).

Inadequate sleep, affecting approximately 27.7% of adults, has profound implications for health and functional performance (CDC, 2023). Urbanization and modern lifestyles, such as increased exposure to artificial lighting and electronic devices, have disrupted natural sleep cycles across society, compounded by the demands of long working hours and shift work (Tähkämö et al., 2019; Vetter, 2018). Economically, sleep insufficiency carries substantial costs, including reduced productivity, increased absenteeism, and elevated healthcare expenditures (Hafner et al., 2017). For ultra-marathon runners, the stakes are higher due to the sport's extreme physical demands, which affect muscle recovery, mental alertness, and decision-making essential for prolonged physical exertion (Miller et al., 2022; Roberts et al., 2022). Training schedules, competitive anxiety, and frequent travel disrupt sleep patterns, exacerbating stress and impairing cognitive functions essential for athlete performance in endurance sports (Charest & Grandner,

2020; Gattoni et al., 2022; Montero et al., 2022). The growing popularity of ultra-marathons underlines the need for targeted sleep management strategies in environments that may vary dramatically (Walsh et al., 2020). Recent studies emphasize developing personalized interventions to address sleep-related challenges faced by ultra-marathon runners, whose performance and well-being are critically dependent on effective sleep management (Fox et al., 2020; Roberts et al., 2022).

Exploring sleep strategies in ultra-marathon athletes is relevant to current psychological performance research because sleep quality profoundly impacts cognitive function, emotional regulation, and overall mental well-being (Fox et al., 2020). Sleep management research is gaining attention in sports science due to the apparent relationship between athletic performance and overall health (Fox et al., 2020; Roberts et al., 2022). Ultra-marathon runners are a distinctive subgroup of athletes who endure extreme physical and psychological demands surrounding ultra-marathon events, making effective sleep management vital for maintaining their health and enhancing performance (Miller et al., 2022; Walsh et al., 2020). Furthermore, exploring sleep strategies in ultra-marathon runners is warranted as a doctoral research study in psychological performance research due to the need for more comprehensive exploration into the sleep dynamics of this population surrounding ultra-marathon events (Miller et al., 2022). With the increasing recognition of the critical role of sleep in cognitive and emotional functioning, understanding and addressing the specific sleep challenges faced by ultra-marathon runners is essential for optimizing their psychological performance and overall well-being (Fox et al., 2020; Gattoni et al., 2022).

Previous research has established a foundational understanding of the critical role of sleep in enhancing performance and health among ultra-marathon athletes, demonstrating how

inadequate sleep detrimentally impacts both physical and cognitive functions (Fox et al., 2020; Fullagar et al., 2015). Ultra-marathon athletes, characterized by prolonged exertion and extreme demands, require tailored sleep strategies to combat the adverse effects of sleep deprivation and support recovery during and after races (Miller et al., 2022; Riegler et al., 2023). Sleep strategies, ranging from sleep hygiene practices to napping protocols and environmental modifications, are essential for optimizing sleep and improving performance outcomes, accounting for individual differences and specific race demands (Bender & Lambing, 2024; Fox et al., 2020).

The practical significance lies in the direct application to the daily lives of athletes, informing training, race preparation, and recovery protocols to enhance well-being and performance during rigorous competitions (Bender & Lambing, 2024; Miller et al., 2022). Empirically, exploring sleep strategies in ultra-marathon athletes addresses an underexplored area within performance psychology, highlighting the need for further research to provide robust empirical evidence (Charest & Grandner, 2020; de Blasiis et al., 2021; Hausswirth et al., 2014). Theoretically, exploring sleep strategies in ultra-marathon athletes prompts the development of novel theoretical frameworks to elucidate the intricate relationships between sleep, endurance performance, and recovery (Engel, 1977; Flyvbjerg, 2001). While previous studies offered insights into the physiological and psychological impacts of sleep deprivation, a deeper theoretical exploration of the mechanisms involved is warranted, thus opening avenues for innovative approaches to optimize sleep and enhance athletic performance in ultra-marathon athletes (Engel, 1980).

The negative impact of inadequate sleep on athletes' health, performance, and well-being, particularly in ultra-endurance sports, is well-documented. The demands of training and competition exacerbate sleep insufficiency, highlighting the need to explore how ultra-marathon

runners manage sleep to sustain performance and recovery (Fullagar et al., 2015; Miller et al., 2022). Addressing gaps in the literature advances theoretical knowledge and facilitates the development of supportive strategies that broadly enhance the health and performance of ultra-marathon runners and athletes.

Statement of the Problem

The problem addressed in this study was the negative impact of inadequate sleep on athletes' physical health, psychological health, and social factors. The Centers for Disease Control (CDC, 2023) highlighted a general shortfall in sleep among adults, stating that 72.3% got sufficient sleep in 2020, a concern that extended into the athletic domain (Fox et al., 2020; Riegler et al., 2023). Miller et al. (2022) called for further exploration of sleep needs in endurance athletes, specifically in ultra-marathons, echoing the sentiments of Kirschen et al. (2020) and Roberts et al. (2022). Substantial consequences of sleep loss in sports requiring precision and sustained focus may be countered with extended sleep and improved sleep hygiene (Fullagar et al., 2023).

Research has shown extended sleep positively correlates with improved recovery, emphasizing personalized approaches and exploring sleep's multifaceted impact on athletes (Cunha et al., 2023; Nikolaidis et al., 2023; Roberts et al., 2022). Ultra-marathon runners, in particular, have been directly impacted by the problem due to the extreme physical and psychological stresses they endure during their intense training and racing schedules. However, what had not been fully understood was the efficacy of sleep interventions specifically tailored to meet the unique needs of ultra-marathon athletes (Miller et al., 2022). Research into sleep strategies across various sports had called for a better understanding of the interventions that can effectively improve sleep quality and athletic performance (Bender & Lambing, 2024; de Blasiis

et al., 2021; Dunican et al., 2022). If the problem had not been addressed, the negative consequences of sleep insufficiency in athletes would have continued to escalate, leading to increased injury rates, impaired performance, and deteriorated mental health outcomes (Gattoni et al., 2022; Smith et al., 2023).

Purpose of the Study

The purpose of this qualitative descriptive single-case study was to explore how ultra-marathon runners in the United States perceived the role of sleep in relation to their physical health, psychological health, and social factors during endurance events. The purpose served as a logical, explicit response to the problem in that it provided insights into effective sleep management practices tailored to the extreme demands of ultra-marathon participation, which are often characterized by prolonged physical exertion and disrupted sleep patterns (Fox et al., 2020; Miller et al., 2022; Riegler et al., 2023).

The study was conducted across various regions within the United States to ensure geographic diversity and representation. A purposive sampling approach was utilized to recruit participants through running clubs, online forums, and social media platforms (Creswell & Poth, 2018; Luborsky & Rubinstein, 1995). A total of 15 participants were included in the study, fully encompassing the originally proposed range of 12 to 18 participants. The study achieved data saturation to ensure comprehensive insights into sleep strategies (Guest et al., 2006).

Using an interview guide (Appendix A), data were collected through in-depth, semi-structured interviews conducted remotely via video conferencing tools to accommodate participants' geographic distribution and schedules. The interviews focused on eliciting detailed descriptions of sleep quality and quantity, impacts on performance and recovery, and adaptations to training and event schedules. To ensure the validity and reliability of the findings, data were

triangulated by incorporating multiple strategies. First, the interview data were cross-referenced with participants' self-reported sleep patterns, training logs, or any additional data provided during the interviews. Second, member checking was conducted by sharing preliminary themes with participants for feedback to confirm the accuracy of the interpretations (Birt et al., 2016). Third, bracketing was applied to minimize researcher bias by identifying and setting aside preconceptions during data analysis (Tufford & Newman, 2012). Finally, peer debriefing with colleagues or advisors was used to review and refine the identified themes. Yin (2018) emphasizes that integrating multiple data sources enhances the credibility and reliability of case study findings, a principle that underpins this study's triangulation efforts.

Thematic analysis of the interview transcripts was conducted manually aligning with Braun and Clarke's (2023) reflexive thematic analysis framework. The researcher used a structured Excel workbook to facilitate a rigorous and transparent coding process, which included 918 meaning-rich data excerpts, 144 initial codes, and multiple rounds of refinement. This method enabled the systematic identification of recurring concepts and patterns related to sleep management strategies among ultra-marathon runners. Although NVivo software was not used for data analysis, it was employed after theme finalization to visually represent the thematic structure and code relationships. This analytic approach enhanced the study's credibility and trustworthiness through transparency, reflexivity, and a fully auditable decision trail (Braun & Clarke, 2023; Nowell et al., 2017), consistent with broader principles of rigor in qualitative inquiry (Silverman, 2016). The findings contribute to the literature on athletic performance and sleep by offering detailed, experience-based insights into how ultra-marathon runners manage sleep within the physiological, psychological, and social demands of their sport.

Introduction to Theoretical Framework

The biopsychosocial model, first proposed by George Engel in 1977, is the theoretical framework guiding this study. The model offers a comprehensive approach to understanding health and performance by integrating biological, psychological, and social factors. Engel (1977) emphasizes the need to move beyond the traditional biomedical model to consider the complex interplay of the three dimensions. This model is well-suited for comprehending the complex nature of sleep management among ultra-marathon runners.

The first key concept is biological factors. Sleep is crucial for athletes' physiological recovery and performance (Fullagar et al., 2015). Inadequate sleep can compromise muscle recovery, slow metabolic processes, and heighten the risk of injury, all of which are critical concerns for ultra-marathon runners (Fox et al., 2020; Fullagar et al., 2015). Furthermore, Roberts et al. (2022) emphasized the impact of sufficient sleep on markers of physical fitness, such as heart rate variability, underscoring the biological importance of sleep in athletic performance. The model's psychological factors highlight sleep’s influence on cognitive function, mood, and emotional states. Athletes rely on mental readiness and precision, and sleep deprivation can impair cognitive abilities, leading to decreased decision-making capacity and increased mental fatigue (Miller et al., 2022; Riegler et al., 2023). The model thus underlines the importance of psychological health and its intrinsic link to physical performance, highlighting how sleep deprivation can be both a contributor to and a consequence of psychological distress (Engel, 1980).

The social factors in the biopsychosocial model emphasize how social structures, cultural norms, and interpersonal relationships impact health (Engel, 1977). Ultra-marathon athletes often face the pressures of competition, training schedules, and support systems that can either

facilitate or hinder adequate sleep (de Blasiis et al., 2021). The social environment can influence athletes' sleep patterns, either positively or negatively, through supportive practices or stressful demands, thereby impacting overall health and performance (Bender & Lambing, 2024).

The biopsychosocial model framework informs the study's guiding research decisions, including the problem statement, purpose statement, and research questions. The problem statement reflects the comprehensive impact of inadequate sleep on ultra-marathon runners' physical, mental, and social well-being (CDC, 2023; Engel, 1977). The purpose statement aligns with the biopsychosocial model, emphasizing the need to explore personalized sleep management strategies considering biological, psychological, and social factors (Engel, 1977). Finally, the research questions delve into the specific effects of sleep deprivation on physical health, psychological experiences, and social factors surrounding ultra-marathon events.

The biopsychosocial model is an integral framework for exploring the complex nature of sleep management among ultra-marathon runners, emphasizing the interplay between biological, psychological, and social factors (Engel, 1977). The model underscores the need to explore the relationship between sleep and performance beyond a singular dimension, instead exploring how various factors interact to affect athletes' health and performance. Through the biopsychosocial model, this study explores how inadequate sleep affects athletes' physiological recovery, cognitive function, and emotional states while recognizing the significant role of social influences on sleep (Roberts et al., 2022). By investigating sleep's impact across the three dimensions, this study provides insights into how inadequate sleep affects ultra-marathon runners' performance and health.

Introduction to Research Methodology and Design

The qualitative approach enabled an in-depth investigation of complex experiences, facilitating the exploration of personal narratives and perceptions of participants (Stake, 1995; Yin, 2018). The primary data collection method was semi-structured interviews, which provided detailed insights into participants' sleep strategies, quality, and quantity while revealing the impacts on their performance and recovery (Braun & Clarke, 2023; Creswell & Poth, 2018). Thematic analysis was used to identify recurring patterns and themes, highlighting critical insights into ultra-marathon athletes' sleep management practices (Braun & Clarke, 2023).

The case study design drew heavily from the seminal works of Yin (2018) and Stake (1995), who emphasized the value of investigating the specificities of experiences within their natural contexts. According to Creswell and Poth (2018), qualitative research approaches should align closely with the research problem, which this study achieved by leveraging the flexibility inherent in qualitative case studies. To ensure a robust and comprehensive analysis, this study employed triangulated data sources, including interview transcripts, self-reported sleep logs, training records, and additional data provided during interviews. Where applicable, researcher field notes and observational insights were integrated. This triangulation strengthened the validity of the findings and ensured that all available data sources were included in the thematic analysis process. Yin (2018) emphasizes the importance of drawing on multiple sources of evidence to enhance credibility and develop a more comprehensive understanding of the experiences being explored.

Thematic analysis, as outlined by Braun and Clarke (2023), was employed to analyze the triangulated data, identifying patterns that reflected the lived experiences and perceptions of ultra-marathon athletes. The researcher conducted a manual, reflexive analysis using a structured

Excel workbook to code 918 meaning-rich data excerpts across 15 participant interviews. This process enabled the inductive development and refinement of themes grounded in participants' narratives and aligned with the Biopsychosocial Model. Although NVivo qualitative data analysis software was not used during coding, it was later utilized to create visual representations of finalized themes and code relationships, supporting interpretation and dissemination. A total of 15 participants were included in this study, meeting the proposed range of 12 to 18 participants. This analytic approach was particularly well-suited to exploring the multidimensional effects of inadequate sleep on physical performance, psychological well-being, and social interactions. By integrating multiple forms of data, including interview content, reflexive notes, and participant demographics, this study provided a comprehensive and context-rich examination of sleep management practices within ultra-endurance sports.

A qualitative descriptive single-case study was particularly suitable for this research as it allowed for an in-depth exploration of sleep management among ultra-marathon runners (Miller et al., 2022). This approach aligns with Engel's biopsychosocial model (1977), which provides a comprehensive framework to examine how inadequate sleep affects physical health, psychological experiences, and social factors. The research questions reflect the descriptive nature of the study, focusing on the detailed examination of the lived experiences and strategies used by ultra-marathon runners to manage sleep.

Using semi-structured interviews, the qualitative descriptive single-case study approach facilitated a detailed and systematic exploration of personal, contextual, and multifaceted sleep-related issues (Creswell & Poth, 2018; Stake, 1995). This study design is descriptive as it seeks to provide a rich, detailed account of sleep management practices rather than testing a hypothesis or comparing multiple cases. As recommended by Braun and Clarke (2023), thematic analysis is

particularly well-suited to answer the study's research questions and address the problem statement by identifying recurring themes and patterns. Through the lens of a descriptive single-case study, this methodology enabled a nuanced understanding of how inadequate sleep impacts ultra-marathon runners across various dimensions. Furthermore, it supports the identification of effective strategies and interventions to enrich the broader exploration of sleep and performance in endurance athletes (Miller et al., 2022).

In conclusion, the selected qualitative descriptive single-case study methodology and design offered a well-suited framework to explore the intricate sleep strategies of ultra-marathon runners. By facilitating a deep exploration into the nuanced dimensions of sleep management, a qualitative descriptive single-case study approach allowed for a detailed investigation to reveal meaningful insights into the relationship between sleep and athletic performance. The flexibility and adaptability of the qualitative descriptive single-case study design empower a comprehensive exploration of how sleep insufficiency impacts the physical, psychological, and social facets of ultra-marathon runners, aligning with the study's purpose and research questions (Engel, 1977; Stake, 1995; Yin, 2018). Through rigorous data collection and thematic analysis, this study contributes significantly to the literature on sports science, specifically in addressing ultra-marathon runners' challenges in achieving adequate sleep, ultimately guiding interventions and support mechanisms that enhance athlete health and performance.

Research Questions

RQ1

How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their physical health during endurance events?

RQ2

How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their psychological health during endurance events?

RQ3

How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their social factors during endurance events?

Significance of the Study

Ultra-marathon runners often endure extreme physical and psychological stresses, which inadequate sleep exacerbates, affecting recovery and overall athletic performance (Roberts et al., 2022). This study contributes to the literature qualitatively by comprehensively exploring sleep management among ultra-marathon runners, a demographic uniquely affected by the interplay between sleep, training, and performance. The qualitative descriptive single-case study approach provided a detailed exploration of participants' perceptions and unique challenges, offering valuable insights that extend beyond existing quantitative research in sports science (Fox et al., 2020).

Engel's (1977) biopsychosocial model was applied as the guiding framework to explore how biological, psychological, and social factors impact the sleep of ultra-marathon runners. Applying this model in sports science enriches the understanding of holistic health in high-performance settings and guides future research directions (Engel, 1980). This research contributes to Engel's (1977) biopsychosocial model by examining how these three dimensions influence sleep management strategies in the context of ultra-endurance sports.

Addressing the problem of inadequate sleep among ultra-marathon runners yielded practical benefits, such as identifying considerations for developing interventions to enhance

athletes' health, improve performance, and reduce injury rates (Fullagar et al., 2015). Insights from this research can guide coaches and sports organizations in creating sleep interventions that promote overall health and psychological well-being (de Blasiis et al., 2021). By exploring the comprehensive experiences of athletes, this study aligns with the biopsychosocial model's holistic approach to health, offering significant theoretical, practical, and health-related contributions (Engel, 1977; Roberts et al., 2022).

Definitions of Key Terms

Cognitive Function

Cognitive function involves the mental processes of acquiring knowledge and understanding, including thinking, knowing, remembering, judging, and problem-solving (Miller et al., 2022; Riegler et al., 2023).

Physical Health

Physical health describes the overall condition of an individual's body, including the efficient functioning of bodily systems, the absence of disease, and the ability to perform physical activities effectively (Fullagar et al., 2015).

Psychological Health

Psychological health involves an individual's emotional and mental well-being, including managing stress, maintaining satisfying relationships, and coping with challenges (Miller et al., 2022).

Sleep Hygiene

Sleep hygiene encompasses the habits and practices conducive to sleeping well regularly (Fullagar et al., 2015). These practices, such as maintaining a regular sleep schedule and creating a restful environment, are essential for athletes' recovery (Fullagar et al., 2015).

Sleep Insufficiency

Sleep insufficiency is a condition in which an individual does not get enough sleep. It can adversely affect health, performance, and well-being and is a common issue among ultra-marathon runners (CDC, 2023).

Sleep Management

Sleep management involves strategies and practices to improve sleep quality and quantity to support optimal performance and recovery, a crucial component for athletes (Bender & Lambing, 2024).

Ultra-Endurance Sports

Ultra-endurance sports involve exceptionally long distances or durations that require extraordinary physical and mental stamina, such as ultra-marathons (Miller et al., 2022).

Ultra-Marathon Athletes

Ultra-marathon athletes participate in ultra-marathons, which are races longer than the traditional marathon distance of 42.195 kilometers (26.219 miles). These races require extreme physical endurance and mental resilience to cope with the prolonged exertion and demanding conditions (Roberts et al., 2022).

Summary

Sleep is critical for human health and athletic performance, especially within sports science (Byrne et al., 2024; Fullagar et al., 2015). Ultra-marathon runners often face sleep insufficiency, which negatively impacts their performance and health (Brace et al., 2023; Miller et al., 2022). The intense training and significant physiological and psychological strain of ultra-marathons disrupt sleep patterns and impair cognitive and physical performance (Bianchi et al., 2023; Roberts et al., 2022). Existing research has primarily focused on team or individual sports

with shorter durations, leaving a gap in understanding the unique sleep needs of ultra-marathon runners (Fox et al., 2020; Fullagar et al., 2015).

Inadequate sleep affects approximately 27.7% of adults, exacerbating the effects of modern lifestyles (CDC, 2023; Tähkämö et al., 2019). Economically, sleep insufficiency leads to reduced productivity and increased healthcare costs (Hafner et al., 2017). Exploring sleep strategies in ultra-marathon athletes is crucial because sleep quality significantly impacts cognitive function, emotional regulation, and mental well-being (Fox et al., 2020). Ultra-marathon runners require effective sleep management to maintain health and performance (Miller et al., 2022; Walsh et al., 2020). The biopsychosocial model, proposed by George Engel in 1977, integrates biological, psychological, and social factors, making it well-suited for studying sleep management in ultra-marathon runners (Engel, 1977). Guided by this model, this qualitative descriptive single-case study explored how ultra-marathon runners perceived inadequate sleep's effects on their physical health, psychological health, and social factors during endurance events.

Using semi-structured interviews with 15 participants and triangulated data sources, this study collected rich, in-depth descriptions of sleep strategies, sleep quality, and their impacts on performance and recovery. Thematic analysis was conducted manually in accordance with Braun and Clarke’s (2023) reflexive thematic analysis framework. Coding and theme development were completed in a structured Excel workbook to ensure transparency and analytic rigor. Although NVivo software was not used during the coding process, it was later utilized to generate visual representations of theme clusters and code relationships. Through this comprehensive analysis, the study provided valuable insights into how ultra-marathon runners

navigate the complex relationship between sleep and athletic performance (Braun & Clarke, 2023; Creswell & Poth, 2018).

Chapter 2: Literature Review

The purpose of this qualitative descriptive single-case study was to explore how ultra-marathon runners in the United States perceive the role of sleep in relation to their physical health, psychological health, and social factors during endurance events. Research has demonstrated that ultra-marathon runners frequently experience sleep insufficiency due to the rigorous demands of their sport, exacerbated by factors such as race schedules, travel, and the high-stress environment of competitive sports (Fox et al., 2020; Fullagar et al., 2015). However, the problem addressed by this study was the lack of clear understanding regarding the efficacy of sleep interventions specifically tailored to meet the unique needs of ultra-marathon athletes (Miller et al., 2022). Without addressing this problem, the negative consequences of sleep insufficiency may continue to escalate, leading to increased injury rates, impaired performance, and deteriorated mental health outcomes (Gattoni et al., 2022; Smith et al., 2023).

This chapter explores research on the impact of sleep deprivation on ultra-marathon runners, aiming to synthesize existing knowledge and identify gaps that this study sought to address. The study of sleep in the literature is organized into several key themes, each of which is discussed in detail. These themes include the physiological and psychological effects of sleep deprivation, strategies for sleep improvement, the relationship between sleep management and performance, psychological processes related to sleep, and individual differences highlighted in case studies. The literature review begins with an examination of the effects of sleep deprivation on ultra-marathon runners, focusing on both physiological impacts, such as increased fatigue and slower recovery times, and psychological effects, such as impaired cognitive functions and mood disturbances (Benchetrit et al., 2024; Bender & Lambing, 2024). The discussion then turns to strategies for sleep improvement, including interventions such as sleep hygiene practices,

mindfulness and relaxation techniques, and strategic napping (Cunha et al., 2023; Fullagar et al., 2023).

The relationship between sleep management and performance is analyzed, highlighting how effective sleep management practices can optimize recovery and enhance athletic performance (Fox et al., 2020; Fullagar et al., 2015). The review also delves into the psychological processes related to sleep, investigating how stress, anxiety, and mental toughness influence sleep patterns and overall well-being (Brace et al., 2024; Nicolas et al., 2022). Finally, the review considers individual differences in sleep needs and management strategies, drawing on case studies to illustrate how personalized approaches can improve performance and recovery for ultra-marathon runners (Bianchi et al., 2022; Byrne et al., 2024).

The literature search for this review was conducted using various databases, including PubMed, PsycINFO, EBSCOHost, and Google Scholar, supplemented by institutional access provided by the university's library services through the search engine Roadrunner. Search terms included "ultra-marathon runners," "sleep deprivation," "athletic performance," "psychological impact," and "sleep management strategies," among others. The search focused on peer-reviewed journal articles, case studies, and systematic reviews published within the past decade, specifically between 2019 and 2024, to ensure the relevancy and applicability of the findings to current ultra-marathon runners' experiences and challenges (Bianchi et al., 2022; Brace et al., 2024).

The extensive literature search aimed to identify critical gaps in existing research and to synthesize findings across various studies. This approach allowed for a detailed examination of how sleep deprivation affects ultra-marathon runners and the effectiveness of different sleep management strategies. By integrating peer-reviewed journal articles, case studies, and

systematic reviews, this literature review provides a robust foundation for understanding the complex interplay between sleep, health, and performance in ultra-marathon athletes (Benchetrit et al., 2024; Bender & Lambing, 2024).

Theoretical Framework

The biopsychosocial model guided this study, integrating biological, psychological, and social factors to understand health and illness (Engel, 1977). This model is particularly relevant for examining the multifaceted impact of sleep on ultra-marathon runners, as it encompasses the physiological, psychological, and social dimensions of their experiences. The biopsychosocial model originated from the work of George Engel in the late 1970s and has since been widely adopted in health psychology and medicine (Bender & Lambing, 2024; Fullagar et al., 2015). Initially, the biopsychosocial model faced resistance due to its departure from the reductionist biomedical approach. However, as research in health psychology and behavioral medicine advanced, the utility of this model became increasingly apparent. Studies began to show that psychological factors, such as stress, and social factors, such as support systems, played crucial roles in the onset, progression, and management of various diseases (Engel, 1980).

Throughout the 1980s and 1990s, the biopsychosocial model gained prominence in various fields, including psychiatry, where it was used to better understand mental health disorders through a more holistic lens. This period saw significant contributions from researchers who applied the model to conditions such as chronic pain, cardiovascular diseases, and mental health disorders, demonstrating that treatments addressing all three domains were more effective (Schwartz, 1999; Smith & Gallo, 2001). In the 2000s, the model continued to evolve with advancements in psychoneuroimmunology, which studies the interactions between psychological processes, the nervous system, and the immune system. This interdisciplinary field provided

empirical support for the biopsychosocial model by showing how stress and psychological factors can directly influence immune function and disease outcomes (Ader et al., 2001; Cohen & Herbert, 1996).

Existing research utilizing the biopsychosocial model in similar contexts provides valuable insights into its applicability. Studies on sleep and athletic performance often highlight the complex interactions between biological, psychological, and social factors, supporting the relevance of this model for the study of ultra-marathon runners. For instance, Fullagar et al. (2015) used the biopsychosocial model to investigate how sleep impacts recovery and performance in athletes, integrating factors such as stress, social support, and biological recovery processes. Similarly, Fox et al. (2020) applied this model to examine the role of sleep in cognitive and physical performance in athletes, emphasizing the interplay between mental health, social influences, and physiological recovery.

Alternative frameworks, such as the cognitive-behavioral and transactional models of stress and coping, offer different perspectives on the relationship between sleep and performance but may only partially capture the multifaceted nature of this interaction. The cognitive-behavioral model focuses on the role of thoughts and behaviors in shaping sleep patterns and performance, emphasizing the need for cognitive and behavioral interventions. While valuable, this model primarily addresses psychological factors and may not adequately consider the biological and social dimensions (Bianchi et al., 2022; Brace et al., 2024). The transactional model of stress and coping, developed by Lazarus and Folkman (1984), highlights the dynamic process of coping with stressors, including sleep deprivation. This model considers the interplay between stressors and coping mechanisms, emphasizing how individuals appraise and respond to stress. However, while it provides valuable insights into psychological and social coping

processes, it may not fully integrate the biological aspects critical for understanding athletic performance (Fox et al., 2020).

The biopsychosocial model is particularly well-suited for this study due to its comprehensive approach to health and illness. By integrating biological, psychological, and social factors, this model provides a holistic understanding of how sleep impacts ultra-marathon runners. It allows for the consideration of multiple interacting factors, which is essential for developing effective sleep management strategies tailored to the unique needs of these athletes (Engel, 1977; Fullagar et al., 2015). The selected framework guided the development of the problem statement, purpose statement, and research questions by offering a comprehensive perspective on the factors influencing sleep and performance in ultra-marathon runners. The problem statement reflects the multifaceted impact of inadequate sleep on ultra-marathon runners' physical, psychological, and social well-being. The purpose statement aligns with the biopsychosocial model by emphasizing the need to explore personalized sleep management strategies considering these interconnected factors. The research questions delved into the specific effects of sleep deprivation on physical health, psychological experiences, and social factors surrounding ultra-marathon events, all framed within the biopsychosocial model.

Biological Factors

Biological factors play a crucial role in understanding the impact of sleep on ultra-marathon runners. Physiologically, sleep is essential for muscle repair, immune function, and metabolic regulation. Inadequate sleep can lead to increased fatigue, slower recovery times, and a higher risk of injury (Benchetrit et al., 2024; Bender & Lambing, 2024). Studies have shown that sleep deprivation affects hormonal balance, including the production of growth hormone and cortisol, which are critical for athletic performance and recovery (Fullagar et al., 2015; Miller et

al., 2022). Research indicates that sleep affects cardiovascular health and thermoregulation, which is vital for endurance sports (Riegler et al., 2023; Roberts et al., 2022).

Moreover, sleep plays a crucial role in metabolic processes, influencing glucose metabolism and appetite regulation. Studies indicate that sleep deprivation can lead to insulin resistance, increased appetite, and weight gain, negatively impacting an athlete's performance and health (Medic et al., 2017; Scheer & Krabak, 2021). These physiological disruptions highlight the importance of adequate sleep for maintaining optimal health and performance in ultra-marathon runners.

Psychological Factors

Psychologically, sleep is integral to cognitive function, emotional regulation, and mental resilience. Sleep deprivation can impair cognitive processes such as attention, memory, and decision-making, which are crucial for ultra-marathon runners during races (Bianchi et al., 2022; Brace et al., 2024). Mood disturbances, including increased anxiety and depression, are also common consequences of inadequate sleep, potentially affecting motivation and overall mental health (Fox et al., 2020; Fullagar et al., 2015). Research highlights the role of sleep in maintaining psychological resilience, which is essential for coping with prolonged stress and physical exertion (Brace et al., 2024). The relationship between sleep and psychological well-being is complex, involving various cognitive and emotional processes. For instance, studies suggest that sleep deprivation can lead to increased emotional reactivity and decreased emotional regulation, making it more challenging for athletes to manage stress and maintain motivation during competitions (Colangelo et al., 2023; Nicolas et al., 2022). Additionally, chronic sleep deprivation has been linked to higher rates of depression and anxiety, further impacting an athlete's mental health and performance (Graham et al., 2021; Thuany et al., 2023).

Social Factors

Social factors, including support systems and cultural norms, influence ultra-marathon runners' sleep patterns and management strategies. Social support from family, friends, and coaches can be critical in promoting healthy sleep habits and providing the emotional and logistical support needed to prioritize sleep (Bender & Lambing, 2024; Byrne et al., 2024). Conversely, the demands of competitive sports, including travel, irregular schedules, and social pressures, can disrupt sleep and contribute to sleep insufficiency (Fox et al., 2020; Miller et al., 2022). The biopsychosocial model emphasizes the interconnectedness of these factors, suggesting that effective sleep management strategies must address the biological, psychological, and social dimensions of health. The impact of social and environmental factors on sleep quality is evident in various studies. For instance, research indicates that traveling for competitions can lead to jet lag and disrupted sleep patterns, affecting performance (Fullagar et al., 2023; Roberts et al., 2022). Additionally, cultural norms and societal pressures, such as the glorification of minimal sleep and the emphasis on constant training, can negatively influence athletes' sleep behaviors (Smith et al., 2023; Walsh et al., 2020). Understanding these social influences is essential for developing comprehensive sleep management strategies that address the unique challenges faced by ultra-marathon runners.

Effects of Sleep Deprivation

Sleep deprivation is a significant factor impacting the performance, recovery, and overall well-being of ultra-marathon runners, a population particularly vulnerable to the effects of disrupted sleep due to the unique demands of their sport. Research consistently demonstrates that inadequate sleep not only impairs physiological and psychological functions but also exacerbates pre-existing stressors that long-distance endurance athletes face (Charest & Grandner, 2022;

Craven et al., 2022; Lastella et al., 2020; Montero et al., 2022). Sleep is a critical factor for recovery, mental health, cognitive processing, and overall performance, and its deprivation can have acute and long-term consequences on ultra-endurance athletes. From a physiological perspective, sleep plays a vital role in energy conservation, thermoregulation, and immune system functioning—crucial elements for athletes who push their bodies to extreme limits during ultra-marathon events.

Charest and Grandner (2022) conducted a quantitative study examining the multifaceted impacts of sleep deprivation on elite athletes' performance. The research utilized a mixed-methods approach, incorporating actigraphy for objective sleep measurements and self-reported assessments to evaluate fatigue, cognitive function, and physical performance. The study included 50 endurance athletes who underwent sleep restriction protocols over a two-week period. Findings revealed significant declines in performance metrics, including a 17% reduction in time to exhaustion and a 12% decrease in maximal oxygen uptake (VO_2 max)—both critical for ultra-marathoners. Furthermore, metabolic disturbances such as elevated cortisol levels by 28% and impairments in glucose metabolism were observed, indicating the physiological strain induced by inadequate sleep. These results underscore the essential role of maintaining adequate sleep to optimize endurance athletes' health and performance. However, limitations such as the reliance on self-reported cognitive measures and the moderate sample size highlighted the need for future studies with larger, more diverse populations. Despite these limitations, the study provides valuable insights into the impacts of sleep deprivation on endurance athletes and underscores the necessity for interventions aimed at improving sleep quality.

Acute sleep loss, even when consisting of just a few hours of missed sleep, significantly impairs physical performance by disrupting coordination, balance, and endurance levels (Craven

et al., 2022). Craven et al. (2022) conducted a longitudinal study with 75 professional athletes, using actigraphy and performance testing protocols over a four-week period. Results showed that just two hours of sleep loss resulted in a 22% decrease in coordination accuracy and a 16% reduction in balance scores, emphasizing the acute impact of even minor sleep deprivation. While the study employed objective actigraphy measurements, the reliance on self-reported fatigue ratings introduced potential bias, as subjective assessments can vary based on individual perceptions.

Doherty et al. (2021) expanded on these findings in their cross-sectional study with 50 endurance athletes, demonstrating a 19% reduction in time to exhaustion and impaired metabolic processes, including a 12% decrease in insulin sensitivity. Doherty et al. (2021) included comprehensive metabolic panel testing, enhancing the reliability of their results. However, the small sample size limited the generalizability of findings, particularly regarding the varied metabolic impacts on athletes with different training intensities. Notably, Doherty et al. (2021) observed stronger effects on glucose metabolism in female athletes, a divergence not reported by Craven et al. (2022), possibly due to differing sample demographics and study designs.

Muscle repair and tissue regeneration, crucial for recovery in ultra-marathoners, are heavily impacted by poor sleep quality. Charest and Grandner (2022) observed that 28% of athletes with chronic sleep deprivation reported delays in protein synthesis and reduced growth hormone secretion. This correlated with a 34% increased risk of overuse injuries such as stress fractures and muscle strains. While Charest and Grandner (2022) supported their findings with clinical evaluations, their reliance on injury self-reports introduces recall bias, as athletes may underreport or overestimate the severity of injuries. Clemente et al. (2021) reported similar metabolic disturbances, including a 21% increase in cortisol levels and a 14% decline in VO_2

max after three consecutive nights of insufficient sleep. In contrast, Cook and Charest (2023), studying 80 amateur athletes, found no significant decline in VO_2 max, highlighting a divergence possibly explained by differences in training levels and baseline fitness. Clemente et al.'s (2021) larger sample size lends greater authority, but Cook and Charest's (2023) focus on amateur athletes reflects variability in sleep demands and performance metrics.

Sleep deprivation also profoundly affects cognitive performance, emotional regulation, and psychological resilience. Montero et al. (2022) conducted a mixed-methods study with 45 ultra-endurance athletes, measuring attention, reaction time, and decision-making under varying levels of sleep restriction. Results included a 25% slower reaction time and 30% more decision-making errors after a single night of restricted sleep. Montero et al. (2022) included interviews to reveal subjective experiences of heightened irritability and reduced resilience, though the qualitative component limits the ability to quantify these outcomes for broader application. In comparison, Cunha et al. (2023) studied 150 endurance athletes and highlighted a twofold increase in burnout risk among those with irregular sleep patterns. Unlike Montero et al. (2022), Cunha et al. (2023) focused on chronic sleep deprivation, providing insights into long-term psychological effects. The larger sample size in Cunha et al.'s (2023) study enhances its authority, but the reliance on survey data introduces potential response bias. Divergences between acute and chronic effects in these studies underscore the complexity of sleep deprivation's impact on psychological resilience.

Ultra-marathon events, lasting 24 to 48 hours or longer, present unique challenges related to sleep deprivation, as athletes may go extended periods without rest. Cunha et al. (2023) reported that prolonged wakefulness resulted in a 35% increase in perceived fatigue and 28% higher susceptibility to injury. These effects extended beyond the event itself, with athletes

experiencing delayed recovery times of up to 72 hours (Charest & Grandner, 2022). While both studies support the negative impacts of sleep deprivation on recovery, Cunha et al.'s (2023) findings emphasize the acute effects of wakefulness, whereas Charest and Grandner's (2022) findings highlight prolonged recovery phases, reflecting differences in focus and methodology.

Given the profound impact of sleep deprivation, developing strategies to mitigate these effects is essential. Research highlights the efficacy of structured sleep interventions, such as sleep extension protocols (e.g., increasing sleep duration before races), strategic napping, and sleep hygiene practices during training (Doherty et al., 2021). Cunha et al. (2023) demonstrated that strategic napping during long races reduced cognitive decline by 18% and improved physical performance by 15%. Additionally, improving sleep hygiene—such as controlling light exposure, limiting caffeine intake, and maintaining consistent sleep schedules—has been shown to enhance overall recovery and minimize performance deficits. Integrating these strategies into training regimens and competition plans is crucial for ultra-marathon athletes to maintain resilience and optimize performance (Cook & Charest, 2023). Coaches and athletes should consider sleep a critical element of training, alongside nutrition, physical conditioning, and mental preparation, to address both acute and chronic impacts of sleep deprivation.

Physiological Impacts

Sleep deprivation has a well-documented impact on athletic performance, particularly in endurance sports like ultra-marathons. Endurance athletes rely heavily on sustained energy output, efficient recovery processes, and mental sharpness, all of which are significantly compromised by inadequate sleep. Research consistently shows that sleep deprivation increases fatigue, reduces endurance, and prolongs recovery, making it a significant concern for ultra-endurance athletes. For instance, Fullagar et al. (2015) conducted a longitudinal study with 60

team-sport athletes and found that sleep deprivation caused a 15% decline in endurance capacity and impaired cognitive functions such as attention and decision-making. Although the study highlighted these critical effects, its lack of focus on ultra-endurance athletes limits its direct application to this population.

Roberts et al. (2022) investigated the pre-race relationships between sleep, perceived stress, and recovery in 36 ultra-marathon runners (18 male and 18 female), using actigraphy to measure sleep patterns and the Short Recovery and Stress Scale (SRSS) to assess stress and recovery. The study found that while female athletes had 10% better sleep efficiency than their male counterparts, they reported 25% higher perceived stress and 20% lower emotional balance before the race. These findings highlight sex-specific differences in how stress and sleep quality interact, emphasizing the need for tailored interventions. However, the small sample size and potential confounding factors, such as hormonal fluctuations, limit the generalizability of these results.

Vitale et al. (2019) found that sleep deprivation impaired glycogen metabolism, resulting in a 22% decrease in glycogen storage and increased fatigue during endurance events. Similarly, Simim et al. (2020), in a study of 30 athletes, observed a 15% reduction in glycogen utilization among sleep-deprived athletes but noted that participants with higher carbohydrate intake before the event experienced less fatigue. This divergence underscores the importance of standardized dietary protocols in sleep-related studies to reduce variability in outcomes.

Cunha et al. (2023) explored the effects of chronic sleep deprivation on muscular endurance in 120 endurance athletes, demonstrating 18% reductions in strength, 15% decreases in speed, and 12% declines in flexibility. These findings align with Doherty et al. (2021), who reported a 20% increase in injury rates among athletes with insufficient sleep due to impaired

muscle repair and heightened inflammation. However, Brace et al. (2024) found only an 8% increase in injury rates, suggesting that additional factors, such as training intensity and injury history, may play critical roles in injury outcomes. These discrepancies highlight the complexity of assessing injury risk in relation to sleep deprivation.

Benchetrit et al. (2024) studied the cognitive effects of sleep deprivation on 40 ultra-marathon runners, reporting a 28% slower reaction time and 35% more decision-making errors among participants with restricted sleep. These cognitive impairments increased the likelihood of pacing, hydration, and navigation errors, especially in extreme environmental conditions. Montero et al. (2022) corroborated these findings, showing a 30% decline in executive function and a 25% reduction in working memory after 24 hours of sleep deprivation. However, Montero et al. (2022) also found that athletes with consistent sleep extension protocols before races exhibited fewer cognitive deficits, suggesting that pre-race sleep strategies could mitigate some adverse effects of acute sleep loss.

Bender and Lambing (2024) demonstrated that inadequate sleep disrupts slow-wave sleep, reducing protein synthesis and delaying muscle recovery. Their study of 75 athletes found a 30% decrease in muscle repair rates among sleep-deprived participants. Erlacher and Vorster (2023) supported these findings, observing 25% higher rates of muscle atrophy and slower recovery times among sleep-deprived athletes. Trommelen et al. (2023) noted that pre-sleep protein ingestion improved overnight protein synthesis by 15%, potentially counteracting some adverse effects of sleep deprivation on recovery. This divergence emphasizes the need for dietary interventions alongside sleep-focused strategies to enhance recovery in ultra-marathon runners.

Riegler et al. (2023) and Roberts et al. (2022) reported cardiovascular consequences of sleep deprivation, including increased heart rate and decreased heart rate variability. Riegler et

al.'s (2023) study of 50 athletes showed a 12% increase in resting heart rate and a 15% reduction in heart rate variability after one night of sleep restriction. Roberts et al. (2022), focusing exclusively on male ultra-endurance athletes, reported a 10% increase in blood pressure, emphasizing the need for gender-specific research on cardiovascular responses to sleep deprivation. The differences in findings could stem from varying participant demographics or the duration of sleep restriction, highlighting the complexity of cardiovascular responses to inadequate sleep.

Sleep deprivation also compromises thermoregulation and immune function, both critical for ultra-endurance athletes. Medic et al. (2017) and Scheer and Krabak (2021) found that sleep-deprived athletes experienced a 20% reduction in core temperature stability and increased risks of heat-related illnesses, such as dehydration and heat stroke. Landers-Ramos et al. (2021) and Walsh et al. (2020) observed that chronic sleep deprivation reduced T-cell production by 15%, weakening the immune system and increasing the likelihood of upper respiratory tract infections. For ultra-marathon runners, maintaining immune health is essential, as illness can significantly hinder performance and prolong recovery times.

The physiological consequences of sleep deprivation underscore the critical need for targeted interventions to optimize recovery and performance in ultra-marathon athletes. However, the impact of inadequate sleep extends beyond the physical, influencing cognitive resilience and psychological well-being. These factors are equally important to address, as mental endurance plays a vital role in navigating the challenges of ultra-marathon events.

Psychological Impacts

Sleep deprivation has significant psychological effects that are especially important for ultra-marathon runners, who must maintain high levels of focus, motivation, and emotional

regulation during races that span over 24 hours. Cognitive and emotional functioning are both impacted by inadequate sleep, with mood disturbances such as anxiety, depression, and emotional instability becoming more prevalent under conditions of sleep deprivation (Bianchi et al., 2022; Brace et al., 2024). These mood disturbances are particularly problematic for ultra-marathoners, whose psychological resilience is critical to enduring the race's prolonged stress and physical demands. Sleep-deprived athletes often experience emotional volatility, which makes it increasingly difficult to remain motivated and focused during the physically and mentally grueling stages of ultra-endurance events.

Mood Disturbances and Psychological Resilience. The study by Brace et al. (2020) provides valuable insight into the psychological processes underlying ultra-marathon performance. This research explored the relationship between mental toughness, self-efficacy, and performance among elite ultra-marathon runners competing in the HURT100 endurance event. Using the Sports Mental Toughness Questionnaire (SMTQ) and the Endurance Sport Self-Efficacy Scale (ESSES), the study assessed 56 elite participants. Results revealed a strong correlation between mental toughness and self-efficacy ($r = 0.72$, $p < 0.001$), emphasizing the interdependence of these constructs. Although mental toughness and self-efficacy were not significantly associated with race outcomes, the research highlighted the importance of a mental toughness threshold that athletes must meet to compete at an elite level (Brace et al., 2020). These findings suggest that while psychological resilience does not directly determine performance outcomes, it remains essential for enduring the physical and mental demands of ultra-marathons.

While the study provided critical insights, its reliance on self-reported data introduced potential bias. Self-reported measures of mental toughness and self-efficacy may reflect athletes'

subjective perceptions rather than their actual capacities, potentially skewing the findings. Additionally, the relatively small sample size (n = 56) limits the generalizability of the results to broader populations of ultra-marathon runners. The use of elite participants may also introduce bias, as their psychological characteristics might differ significantly from those of amateur or recreational runners. Despite these limitations, the study's strong methodology, including validated scales like the SMTQ and ESSES, enhances the reliability of its conclusions.

Research by Fox et al. (2020) aligns with Brace et al. (2020) in highlighting the psychological toll of sleep deprivation. Fox et al. assessed 120 endurance athletes and found that athletes with poor sleep quality reported 35% higher stress levels, 40% reduced motivation, and a 20% increase in burnout rates compared to those with sufficient sleep. These findings emphasize the cumulative effects of sleep deprivation on emotional volatility, making athletes more prone to frustration, anxiety, and depressive symptoms. The use of validated stress and burnout scales strengthens the study's authority, though the reliance on cross-sectional data limits its ability to establish causation.

Walsh et al. (2021) further examined mood disturbances among 150 ultra-endurance athletes, demonstrating that those with chronic sleep deprivation exhibited a 25% increase in depressive symptoms and 30% more frequent episodes of anxiety compared to their well-rested counterparts. These findings diverge from Fox et al. (2020), who reported a higher prevalence of burnout but less emphasis on depressive symptoms. The discrepancy could stem from differences in participant demographics; Walsh et al.'s sample included a mix of amateur and elite athletes, whereas Fox et al. focused exclusively on elite performers. Methodological variations, such as Walsh et al.'s longitudinal design versus Fox et al.'s cross-sectional approach, may also account for these differences.

The cumulative psychological effects of sleep deprivation significantly hinder athletes' ability to stay motivated and focused throughout a race. Walsh et al. (2021) identified impaired decision-making and reduced emotional resilience as key contributors to poor performance outcomes. Specifically, athletes with higher anxiety levels were twice as likely to make pacing errors and 1.8 times more likely to misjudge hydration needs during ultra-endurance events. Although these findings align with Fox et al. (2020), they underscore the variability in how psychological factors manifest across different athlete populations.

A notable divergence arises when considering the impact of self-efficacy on performance. Brace et al. (2020) found no significant relationship between self-efficacy and race outcomes, whereas other studies, such as Fox et al. (2020), reported a moderate positive correlation ($r = 0.45$) between self-efficacy and pacing consistency. The divergence may be attributed to differences in measurement tools or the unique demands of the HURT100 event, which involves extreme environmental challenges that may overshadow psychological factors.

The limitations of these studies highlight the need for further research into the psychological impacts of sleep deprivation in ultra-marathon athletes. Incorporating objective measures of mental resilience, such as physiological stress markers, alongside self-reported data, could provide a more comprehensive understanding of these phenomena. Despite these challenges, the collective findings underscore the critical role of psychological resilience in buffering the emotional and cognitive impacts of sleep deprivation. As endurance athletes face the dual challenges of physical exhaustion and psychological strain, developing interventions that enhance mental toughness, self-efficacy, and emotional regulation will be essential for optimizing performance in ultra-marathons.

Cognitive Impairments. Cognitive impairments related to sleep deprivation are a critical concern for ultra-marathon runners, as mental sharpness, decision-making, and reaction times are essential for success and safety during extreme endurance events. Benchetrit et al. (2024) examined the effects of sleep deprivation and extreme exertion on cognitive performance among ultra-endurance athletes participating in the Suffolk Back Yard Ultra-marathon. This observational study included 15 participants (1 female and 14 males) with an average age of 40 years (± 8.6). Participants completed a 6.4 km loop every hour, with cognitive performance assessed pre- and post-race using tools such as the 2 Choice Reaction Time (2CRT) task, Stroop task, and Tower Puzzle. The findings revealed significant cognitive declines, including slower reaction times (an increase of 77 ms in the 2CRT task, $p = 0.004$), reduced throughput in reaction tasks (a decrease of 17.0 arbitrary units, $p < 0.001$), and impaired executive function (e.g., a 2.5% decrease in Stroop Task accuracy, $p = 0.014$). These metrics highlight the profound effects of combined sleep deprivation and physical exertion on critical cognitive domains necessary for ultra-endurance performance. However, the small sample size and reliance on self-reported sleep patterns introduce potential limitations to the study's generalizability and raise questions about subjective bias.

Fullagar et al. (2015) also explored the relationship between sleep and performance, focusing on team-sport athletes. Although this study primarily investigated recovery, its findings on slower reaction times and impaired decision-making accuracy due to sleep deprivation are highly relevant for ultra-marathon athletes. The review highlighted how consistent sleep deficits result in cognitive "fog," leading to increased risks of errors and accidents. For ultra-marathoners, this mental fog can impede race strategies, reduce judgment during critical moments, and increase susceptibility to injury. Specific metrics, such as cognitive reaction times

and decision-making tasks, underline the cumulative impact of insufficient sleep on mental sharpness.

Walsh et al. (2020) provided a narrative review and expert consensus recommendations on sleep's role in athletic performance. The review highlighted that inadequate sleep is prevalent among elite athletes, with 50%–78% experiencing significant disturbances. It emphasized the importance of sleep for cognitive recovery, with strategies such as napping and structured sleep education recommended to mitigate cognitive impairments. While the study did not present original experimental data, it synthesized existing research on the effects of poor sleep quality and duration on reaction times, attention, and memory—key factors for success in ultra-marathon events.

Cognitive recovery strategies are increasingly integrated into training regimens to counteract the detrimental effects of sleep loss. For example, mindfulness exercises and structured naps have shown promise in improving cognitive performance during prolonged events (Walsh et al., 2020). However, the reliability of self-reported data in studies like those by Benchetrit et al. (2024) and the need for larger sample sizes remain important considerations. Divergences between findings, such as the extent of cognitive decline measured in Benchetrit et al. (2024) versus the broader observations in Walsh et al. (2020), may stem from differences in methodologies or participant populations.

Future research should focus on refining measurement tools and expanding study populations to ensure that ultra-marathon athletes maintain cognitive function during races. Additionally, exploring the interplay between pre-race sleep quality and race-day performance could provide actionable insights into optimizing cognitive resilience during extreme events. While studies like Benchetrit et al. (2024) offer valuable specific metrics, larger-scale

investigations with diverse populations and more robust methodologies are critical to advancing this field.

Emotional Regulation and Stress Management. Emotional regulation is a critical area impacted by sleep deprivation, especially for ultra-marathon runners who must manage prolonged stress during competitions. Studies indicate that sleep deprivation amplifies emotional reactivity, making it increasingly difficult for athletes to maintain motivation and resilience during ultra-endurance events (Colangelo et al., 2023; Nicolas et al., 2022). For example, Nicolas et al. (2022) conducted a quantitative study with 13 athletes participating in the Tor des Géants® (TdG) race, one of the most challenging mountain ultra-marathons globally. The study utilized validated tools, such as the Brief Emotional Intelligence Scale (BEIS-10) and the RestQ-36-R-Sport questionnaire, to assess emotional intelligence (EI) and recovery-stress states before, during, and after the race. Results revealed that athletes with higher EI exhibited significantly better recovery scores and lower stress levels throughout the event, underscoring the importance of EI as a psychological buffer against the stressors of ultra-endurance racing. However, the study's small sample size (n = 13) and reliance on self-report measures may limit the generalizability of its findings, introducing potential response bias (Nicolas et al., 2022).

Similarly, Colangelo et al. (2023) conducted a narrative review synthesizing data from 25 studies on mental health disorders among ultra-endurance athletes, highlighting the prevalence of anxiety, depression, and other psychological challenges. The review revealed that up to 80% of some athlete cohorts experienced clinically significant mood disturbances during high-volume training periods, a clear indication of the mental health risks associated with ultra-endurance sports. However, the absence of epidemiological comparisons with non-athlete populations limits the ability to contextualize these findings within a broader framework. Additionally, the

reviewed studies exhibited methodological variability, such as differences in diagnostic tools and sample sizes, which could contribute to inconsistencies in reported prevalence rates (Colangelo et al., 2023).

Brace et al. (2020) further examined the role of mental toughness in stress management among elite ultra-marathon runners. Using the Sports Mental Toughness Questionnaire (SMTQ) and the Endurance Sport Self-Efficacy Scale (ESSES), this study found a strong correlation ($r = 0.72$, $p < 0.001$) between mental toughness and self-efficacy, indicating their interdependence in coping with psychological stress. However, the study's findings also revealed no significant relationship between mental toughness and race completion outcomes, suggesting that additional factors, such as physical conditioning and race-day strategies, play a significant role in performance. The study's reliance on self-reported data may have introduced social desirability bias, and the Cronbach's alpha scores for some SMTQ subscales (e.g., Confidence = 0.52) indicate lower internal consistency, potentially affecting the robustness of these results (Brace et al., 2020).

The narrative review by Walsh et al. (2020) highlighted the impact of sleep deprivation on emotional regulation and stress management in athletes, emphasizing its detrimental effects on both mental health and performance. This review, based on a combination of quantitative and qualitative studies, underscored that elite athletes experiencing habitual short sleep durations (less than 7 hours per night) report heightened emotional reactivity and reduced stress resilience. The prevalence of sleep disturbances among athletes was cited as 50% to 78%, with contributing factors including intense training schedules, travel demands, and competition stress. However, the lack of detailed demographic data in some studies limits the applicability of these findings to diverse athletic populations. Additionally, inconsistencies in sleep measurement tools across the

reviewed studies—ranging from subjective diaries to objective polysomnography—may influence the reliability of the reported outcomes (Walsh et al., 2020).

These findings highlight several methodological divergences among the cited studies. For instance, Nicolas et al. (2022) focused specifically on emotional intelligence as a mediator of stress, while Walsh et al. (2020) examined broader sleep patterns and their psychological implications. The former's small, homogeneous sample contrasts with the latter's synthesis of diverse athlete cohorts, illustrating the challenges of drawing direct comparisons across studies with differing scopes and methodologies. Moreover, Colangelo et al. (2023) identified a high prevalence of mood disturbances in ultra-endurance athletes but did not explore how sleep interventions might mitigate these effects, leaving a gap addressed by Walsh et al.'s (2020) recommendations for structured sleep management strategies. These methodological differences underscore the need for standardized approaches to studying emotional regulation and stress in ultra-endurance athletes.

Addressing the profound psychological impacts of sleep deprivation, researchers advocate for evidence-based interventions to enhance mental resilience and sleep quality. Cognitive-behavioral therapy for insomnia (CBT-I) and mindfulness-based stress reduction (MBSR) have shown efficacy in improving psychological resilience and emotional regulation among athletes (Walsh et al., 2020). Nicolas et al. (2022) suggested that incorporating EI training into athletic programs could further bolster recovery and stress management capabilities, particularly in high-stakes endurance events. These strategies align with broader calls for integrating mental health and sleep optimization into ultra-marathon training regimens, emphasizing their critical role in sustaining performance and well-being. In conclusion, the psychological effects of sleep deprivation—including its impact on emotional regulation and

stress management—underscore the necessity of adopting comprehensive interventions tailored to the unique demands of ultra-endurance athletes. Future research should prioritize longitudinal designs and larger, more diverse samples to refine understanding of the interplay between sleep, mental health, and performance in this population.

Sleep Improvement Strategies

Effective sleep improvement strategies are vital for ultra-marathon runners to enhance their performance, recovery, and overall health. Given the extreme physical and psychological demands of ultra-marathons, developing and implementing strategies to improve sleep quality and duration is critical for athletes to maximize their potential (Cunha et al., 2023; Doherty et al., 2021). Research has identified various interventions, including behavioral, nutritional, and technological approaches, all of which contribute to better sleep and, consequently, improved performance outcomes for endurance athletes (Driller et al., 2023; Gratwicke et al., 2021; Simim et al., 2020).

Cunha et al. (2023) conducted a systematic review of multiple sleep interventions, including strategies such as sleep hygiene, naps, sleep extension, and light manipulation. The study, which followed PRISMA guidelines, reviewed 25 intervention studies published between 2011 and 2021 involving athletes from both individual and team sports. The results indicated that the most effective intervention was extending sleep duration through nighttime or daytime naps. However, Cunha et al. (2023) noted limitations in their review, such as the heterogeneity of the athlete samples and a high risk of bias in several studies. The inclusion of athletes at various training levels, from trained to elite, could have influenced the results, as the physiological and recovery needs of these groups differ significantly. Additionally, the reliance on subjective measures in some studies introduced the potential for bias in the findings. Despite these

limitations, the study concluded that increasing sleep duration is crucial for optimizing physical and cognitive performance.

Behavioral strategies, such as Cognitive Behavioral Therapy for Insomnia (CBT-I), have shown promising results in reducing sleep disturbances and improving sleep quality, with further evidence supporting the benefits of nutritional interventions like melatonin-rich foods in extending sleep duration and minimizing muscle soreness (Gratwicke et al., 2021; Trommelen et al., 2023). Nutritional interventions, specifically the consumption of tart cherry juice, have demonstrated efficacy in improving sleep quality, as shown by Gratwicke et al. (2021), who highlighted the role of certain foods and supplements in enhancing sleep for team-sport athletes. Their review emphasized that nutritional strategies, such as high-glycemic index carbohydrates and protein sources rich in tryptophan, could help improve sleep quality by reducing sleep onset latency and increasing total sleep time. However, the review also pointed out methodological limitations, such as small sample sizes and inconsistent outcomes across studies, which could be attributed to variability in athlete populations (elite vs. sub-elite athletes) and specific study designs. The authors called for more robust, well-controlled clinical trials to confirm these findings. The potential for bias was also noted, particularly regarding funding support from the Australian Rugby Foundation, which could influence the interpretation of the findings.

Driller et al. (2023) explored the role of wearable sleep-tracking technology in optimizing sleep patterns for professional athletes. This study indicated that wearable devices, such as wrist monitors and actigraphy, could provide valuable insights into sleep efficiency and disturbances, allowing athletes to adjust their routines for better sleep outcomes. However, the study also highlighted limitations of these devices, particularly their accuracy in detecting sleep stages compared to the gold standard of polysomnography (PSG). Wearable devices, although useful

for monitoring sleep over extended periods, often suffer from discrepancies in data, especially regarding sleep stages. This divergence in findings may be due to proprietary algorithms used by these devices, which may not always align with PSG results. Additionally, the phenomenon of "orthosomnia," where athletes become overly focused on achieving perfect sleep metrics, could introduce potential mental health risks, including anxiety about sleep data. While wearable technology shows promise, the involvement of authors with affiliations to a sleep technology company raises concerns about potential bias, as it could favor these devices over other sleep monitoring methods.

Simim et al. (2020) conducted a systematic review to investigate the methods and parameters used to monitor sleep quality in individual sports athletes. While actigraphy was the most commonly used tool for sleep measurement, there was significant variability in how sleep quality was defined across studies. This lack of standardization in sleep quality parameters, such as sleep efficiency and duration, made comparing findings across different studies difficult. The review also noted that athletes in individual sports reported poorer sleep quality than those in team sports, which the authors attributed to factors such as pre-competition stress and the lack of social support during training and competition. Divergences between studies could be attributed to the different sleep monitoring tools used, such as actigraphy versus subjective questionnaires, and the wide range of sports represented, which may have influenced the results. The review concluded that more standardized definitions of sleep quality parameters are needed to improve the comparison of research findings and the application of sleep interventions for athletes.

Cook and Charest (2023) reviewed the impact of sleep on performance in professional athletes, emphasizing the role of sleep in enhancing both physical and mental health. They highlighted that insufficient sleep not only impairs physical recovery and performance but also

contributes to mental health issues, such as stress, anxiety, and depression. These mental health challenges can further exacerbate sleep disturbances, creating a vicious cycle. The review pointed out that athletes face unique challenges to sleep, such as travel-induced circadian disruption, which can lead to jet lag and impaired sleep initiation and maintenance. Studies consistently show that sleep deprivation negatively impacts athletic performance, including slower reaction times and reduced physical output. Cook and Charest (2023) also noted that while much research supports the link between sleep and physical recovery, the immediate impact of sleep on competitive performance is often inconsistent, which could be due to variations in how sleep disturbances are measured and the specific performance outcomes assessed. The authors called for more rigorous studies using standardized methods to evaluate the effects of sleep on performance outcomes in professional athletes.

In conclusion, while the research presents compelling evidence for the importance of sleep improvement strategies in enhancing athletic performance and recovery, several issues related to methodological variability, sample size, and measurement tools remain. The divergence in findings across studies, particularly regarding the efficacy of different sleep interventions, can often be attributed to these factors. Furthermore, potential biases in study design, funding, and sample characteristics must be considered when interpreting the results. Despite these limitations, the evidence consistently supports the need for athletes, especially ultra-marathon runners, to implement strategies that improve sleep quality and duration, with sleep extension, behavioral approaches, and technological innovations offering promising avenues for enhancing performance and well-being.

Nutritional Approaches

Nutrition plays a crucial role in sleep quality, especially for ultra-marathon runners who often face muscle soreness, inflammation, and fatigue due to the demands of prolonged physical exertion. Specific nutritional strategies can aid sleep and recovery, enhancing an athlete's ability to perform during training and competition (Gratwicke et al., 2021). Research suggests that consuming tart cherry juice and kiwifruit before bedtime can improve sleep by increasing melatonin levels and reducing oxidative stress. In particular, tart cherry juice has been linked to enhanced sleep duration and quality by promoting relaxation and reducing muscle soreness, making it a valuable dietary addition for endurance athletes (Gratwicke et al., 2021).

A narrative review by Gratwicke et al. (2021) examined the impact of dietary interventions, such as melatonin-rich foods, on sleep and recovery among athletes. The review analyzed multiple trials, including randomized controlled studies, and found significant improvements in sleep duration and efficiency when athletes consumed melatonin-rich foods like tart cherry juice. These benefits were associated with increased melatonin production and decreased oxidative stress, both of which are crucial for recovery. However, the review also noted limitations, such as inconsistent dosages of tart cherry juice and small sample sizes, which may reduce the generalizability of the results. As such, further research is needed to determine optimal dosages and to extend research to ultra-endurance athletes, whose physiological needs may differ from those of athletes in other sports (Gratwicke et al., 2021).

In addition to antioxidant-rich foods, protein-rich foods consumed before sleep are essential for stimulating muscle protein synthesis and accelerating recovery during sleep. Slow-wave sleep, which is vital for muscle repair and regeneration, is particularly responsive to protein intake. Trommelen et al. (2023) highlighted that pre-sleep ingestion of casein protein could

enhance overnight recovery by maintaining a steady supply of amino acids throughout the night. This process helps optimize the body's repair mechanisms, ensuring that athletes are physically prepared for the demands of ultra-endurance events.

The role of protein in sleep recovery is also emphasized by Tiller et al. (2019), who stressed the importance of maintaining adequate protein intake to support recovery during training and racing. Their review underlined the necessity of adjusting dietary strategies to meet the specific demands of ultra-marathon runners, ensuring they consume sufficient calories, protein, and carbohydrates to optimize their performance and recovery. The comprehensive approach outlined by Tiller et al. (2019) provides a broad nutritional framework that complements the more specific sleep and recovery-focused strategies discussed by Gratwicke et al. (2021) and Trommelen et al. (2023).

Overall, these studies emphasize the importance of tailored nutritional strategies to enhance sleep and recovery in ultra-marathon runners. While Gratwicke et al. (2021) focused on the role of melatonin-rich foods like tart cherry juice, Trommelen et al. (2023) concentrated on the benefits of protein for muscle repair during sleep. The divergence in these findings suggests that while both antioxidant-rich foods and protein play distinct roles in recovery, a combined approach may be most beneficial for ultra-endurance athletes. Further research is needed to explore the optimal combination of these nutritional strategies, considering the unique physiological demands of ultra-marathon runners.

Structured Sleep Strategies

In ultra-marathon events that span multiple days, structured sleep strategies, such as napping, have been shown to significantly enhance cognitive performance and delay the onset of fatigue (Doherty et al., 2021; Driller et al., 2023). These naps are highly effective in maintaining

alertness, improving decision-making, and sustaining physical performance during periods of extreme exertion (Driller et al., 2023). For ultra-endurance athletes who experience prolonged wakefulness during events, these bursts of sleep can provide critical recovery, allowing them to maintain focus and avoid cognitive and physical burnout (Doherty et al., 2021; Walsh et al., 2021).

Doherty et al. (2021) conducted a cross-sectional study involving 338 athletes, including 115 elite and 223 sub-elite athletes from a range of sports, such as athletics, boxing, rugby, and swimming. The study utilized validated measures, including the Pittsburgh Sleep Quality Index (PSQI), Epworth Sleepiness Scale (ESS), and Recovery Stress Questionnaire for Athletes (RESTQ-Sport), to assess sleep quality. The results indicated that over 60% of the athletes, regardless of their level, were classified as poor sleepers, with PSQI scores indicating suboptimal sleep quality. Despite the higher training demands of elite athletes, these athletes demonstrated better sport-specific recovery practices compared to their sub-elite counterparts. However, the study's reliance on self-reported data introduces potential bias, such as social desirability bias, where athletes may overstate their recovery practices. Additionally, the subjective nature of these measures limits the ability to definitively evaluate sleep quality, especially compared to objective tools like actigraphy or polysomnography (PSG).

Regarding sleep interventions, Doherty et al. (2021) emphasized the importance of pre-race sleep routines, including adhering to a regular sleep schedule. Athletes who maintained consistent sleep patterns reported improvements in their sleep quantity and quality (Doherty et al., 2021). The authority of Doherty et al. (2021) is strengthened by the large and diverse sample of athletes, enhancing the findings' generalizability. However, the self-reported nature of the study introduces bias, as athletes' subjective assessments of their sleep may not always reflect

actual sleep patterns. Moreover, the absence of objective sleep measures such as actigraphy or PSG reduces the study's ability to capture sleep quality precisely. In contrast, Cunha et al. (2023) conducted a systematic review primarily based on randomized controlled trials and crossover designs, providing more substantial evidence for causal relationships regarding sleep interventions in athletes. Cunha et al. (2023) found that sleep extension, particularly when athletes aimed for more than 9 hours of sleep per night, was particularly beneficial. This aligns with other research, such as Driller et al. (2023), which also highlighted the importance of sleep duration in supporting cognitive and physical recovery.

However, there is some divergence regarding the optimal sleep duration for athletes. While some studies, including those by Cunha et al. (2023) and Driller et al. (2023), advocate for 9-10 hours of sleep during intense training or competition, other research suggests that 7-9 hours is sufficient for most athletes (Doherty et al., 2021). This discrepancy may stem from methodological differences, with studies like Doherty et al. (2021) using a cross-sectional approach, which identifies associations but cannot establish causality, while Cunha et al. (2023) and Driller et al. (2023) employed experimental designs that offer more substantial evidence of causal relationships. Despite the methodological differences, all studies highlight the significant role that structured sleep strategies play in optimizing performance and recovery for ultra-endurance athletes.

In conclusion, structured sleep strategies, including napping and sleep extension, are essential for ultra-endurance athletes, especially during multi-day events. While evidence supports the benefits of these strategies, the divergence in recommendations regarding the optimal duration of sleep reflects ongoing debates in the field. Methodological differences in the studies, including the reliance on self-reported data and the use of experimental versus

observational designs, further complicate the conclusions. However, the overall consensus underscores the importance of individualized sleep interventions to enhance both athletic performance and recovery.

Technological Approaches

The integration of wearable technology with sleep strategies has proven effective for athletes, enabling them to monitor their sleep patterns and receive personalized feedback to optimize recovery and performance (Driller et al., 2023). According to Driller et al. (2023), wearable devices such as actigraphy wristbands and finger-worn monitors provide objective measurements of sleep duration, efficiency, and patterns over extended periods. These devices are particularly beneficial for tracking longitudinal sleep data, allowing for tailored interventions aimed at improving sleep hygiene and routines. However, the validity of wearable devices compared to gold-standard polysomnography (PSG) has been questioned, as these devices often rely on proprietary algorithms that may not accurately stage sleep or measure quality. Driller et al. (2023) emphasized the importance of selecting appropriate devices based on the specific objectives of monitoring, whether for general behavioral insights or clinical assessments.

The systematic review conducted by Simim et al. (2020) further highlighted the prevalence of wearable technology in sleep monitoring among individual sport athletes. Analyzing 75 studies with a total of 2,841 participants, Simim et al. (2020) identified actigraphy as the most commonly used method, representing 25% of the instruments employed. Actigraphy provides detailed, objective data on sleep parameters, including sleep duration and wake after sleep onset, making it a practical choice for non-invasive monitoring. Despite its utility, Simim et al. (2020) noted inconsistencies in how sleep parameters, such as efficiency and latency, were

defined across studies, which complicates the interpretation of findings and their implications for ultra-endurance athletes.

Issues of authority and bias arise from the methodological diversity and funding sources associated with the studies reviewed by Simim et al. (2020). For example, while all included studies were published in peer-reviewed journals and scored an average of 7 out of 8 on a risk of bias assessment, the lack of standardization in defining key metrics such as sleep quality introduces variability. Additionally, the reliance on self-reported data from sleep diaries and Likert scales in some studies, though valuable for subjective insights, can introduce biases related to participant accuracy and recall. These methodological limitations underscore the need for combining subjective and objective measures to enhance the reliability of sleep data (Simim et al., 2020).

Moreover, divergence exists in the findings of Driller et al. (2023) and Simim et al. (2020) regarding the role of wearable technology in improving sleep outcomes. While Driller et al. (2023) highlighted the potential for wearable technology to facilitate behavioral changes and optimize recovery, Simim et al. (2020) cautioned against over-reliance on these devices due to inconsistencies in their accuracy. For instance, Driller et al. (2023) discussed the phenomenon of "orthosomnia," where athletes become overly focused on achieving ideal sleep metrics, which can potentially lead to increased anxiety and decreased performance. This concern aligns with Simim et al.'s (2020) findings, which emphasized the limitations of actigraphy in precisely staging sleep compared to PSG.

Despite these challenges, wearable technology has shown promise in enabling ultra-marathoners to monitor sleep disruptions during events, facilitating strategic adjustments, such as planned naps, to maintain optimal performance levels (Driller et al., 2023). These devices also

help track deep sleep, which is critical for muscle recovery, hormonal regulation, and cognitive functioning. However, Driller et al. (2023) and Simim et al. (2020) emphasized the importance of education on sleep hygiene and the careful interpretation of sleep data to prevent misapplication or undue stress on athletes. In conclusion, wearable technology represents a valuable tool for monitoring and improving sleep among athletes, but its effectiveness depends on methodological rigor and proper application. Future research should focus on standardizing sleep quality metrics and refining wearable technology to align more closely with PSG standards, ensuring practical and reliable insights for ultra-endurance athletes.

Techniques for Sleep Improvement

To optimize performance, recovery, and overall health, ultra-marathon runners can adopt evidence-based strategies to enhance sleep quality and duration. Sleep hygiene forms the foundation of these interventions, with research highlighting the importance of consistent sleep schedules, minimizing environmental disruptions, and limiting stimulant consumption such as caffeine and alcohol before bedtime (Bender & Lambing, 2024). Gratwicke et al. (2021) emphasized that creating a cool, quiet, and dark sleep environment facilitates deeper stages of sleep, which are crucial for muscle repair and recovery. These findings were underscored by Dunican et al. (2022), who observed modest improvements in sleep patterns after a structured 16-week sleep hygiene education program for athletes. Participants exhibited a statistically significant 12-minute delay in both sleep onset and offset times ($p < 0.001$). However, no substantial changes in total sleep time or efficiency were observed, underscoring the challenge of translating behavioral interventions into consistent long-term outcomes.

Light exposure management also plays a pivotal role in optimizing sleep. Bender and Lambing (2024) discussed the adverse effects of artificial blue light on melatonin production,

recommending blue light-blocking glasses as an effective intervention. While Dunican et al. (2022) noted improvements in sleep readiness when athletes minimized evening light exposure, Walsh et al. (2021) identified variability in individual responses to such interventions, suggesting that factors like chronotype may influence outcomes. These differences highlight the importance of tailoring interventions to individual athletes and conducting further research into blue light's impact on circadian rhythms.

Mindfulness and relaxation techniques are additional tools for improving sleep quality, particularly for athletes managing pre-competition anxiety. Gratwicke et al. (2021) reported that athletes who practiced mindfulness experienced fewer nocturnal awakenings and improved emotional regulation. Similarly, Cunha et al. (2023) found that mindfulness-based strategies, such as progressive muscle relaxation and meditation, reduced cortisol levels and facilitated faster sleep onset. However, adherence to these practices varied among participants, indicating the need for personalized approaches. Walsh et al. (2021) further emphasized the role of these techniques in mitigating anxiety-related sleep disturbances, particularly during periods of heightened competition stress.

Strategic napping is a critical strategy for ultra-marathoners during multi-day events. While specific nap durations were not identified in the studies provided, Fullagar et al. (2023) highlighted the restorative benefits of short naps for cognitive function and decision-making. Simim et al. (2020) similarly noted that napping can help delay cognitive fatigue and maintain focus, particularly during the later stages of endurance events. These findings, however, are contingent on logistical feasibility, as athletes may lack opportunities to nap effectively during competitions. Further research is needed to determine optimal napping protocols for ultra-endurance athletes.

Sleep extension—prolonging sleep duration before and after events—has shown significant benefits for recovery and performance. Doherty et al. (2021) observed that athletes who practiced sleep extension experienced enhanced energy levels, improved cognitive function, and accelerated muscle repair. Simim et al. (2020) also emphasized that even a modest increase in nightly sleep duration led to measurable reductions in fatigue. However, implementing sleep extension consistently may be challenging due to training demands and external commitments, highlighting the importance of integrating these strategies into broader training regimens.

Cognitive Behavioral Therapy for Insomnia (CBT-I) has emerged as an effective intervention for athletes experiencing persistent sleep disturbances. Cunha et al. (2023) discussed how CBT-I targets maladaptive sleep-related thoughts and behaviors, replacing them with healthier habits. Athletes undergoing CBT-I reported faster sleep onset and improved sleep efficiency, as noted by Walsh et al. (2021). However, accessibility to trained practitioners and the athlete's willingness to engage in therapy remain significant barriers to its widespread implementation. These findings underscore the need for scalable CBT-I approaches tailored to the unique challenges of athletic populations.

Wearable sleep-tracking devices offer valuable insights into sleep patterns, enabling athletes to make data-driven adjustments to their recovery strategies. Driller et al. (2023) highlighted the utility of actigraphy-based devices in monitoring sleep duration, stages, and interruptions. However, the accuracy of these devices varies, with Driller et al. (2023) cautioning against over-reliance on wearable data due to potential algorithmic inaccuracies. Combining wearable data with professional guidance can enhance the reliability of these tools, ensuring athletes can make informed decisions to optimize sleep and recovery. By integrating these evidence-based techniques—ranging from sleep hygiene practices to mindfulness, napping, and

advanced technologies—ultra-marathon runners can better manage the physical and psychological demands of their sport. Future research should address the limitations and divergences identified in current studies, providing athletes with refined, individualized strategies to enhance performance and well-being.

Impact on Performance

Improved sleep is critical in enhancing athletic performance, particularly for ultra-marathon runners facing extreme physical and mental demands. Adequate sleep reduces fatigue, enhances cognitive function, and accelerates recovery, all of which are essential for optimal performance. Research consistently shows that athletes who prioritize sleep demonstrate better physical performance, faster reaction times, and enhanced mood stability (Bender & Lambing, 2024; Cunha et al., 2023; Fullagar et al., 2023). For instance, Bender and Lambing (2024) highlighted that strategies such as sleep banking and napping improve recovery and performance metrics. However, their reliance on tools such as the Athlete Sleep Screening Questionnaire (ASSQ) may introduce self-report biases, as the ASSQ depends on athletes' subjective perceptions of sleep quality rather than objective measures.

Cunha et al. (2023) conducted a systematic review of 25 studies, finding that sleep extension was among the most effective interventions, with improvements in cognitive and physical performance reported in many cases. However, 60% of the included studies used crossover designs, which are prone to carryover effects that could influence results. Additionally, five studies in the review were rated as having a high risk of bias due to methodological concerns, such as subjective outcome measures and inconsistent pre-registration of study protocols. These limitations highlight the need for caution in interpreting their conclusions.

Fullagar et al. (2023) explored the impacts of sleep deprivation, finding that fine motor skills and reaction times were significantly impaired after restricted sleep. For example, tennis players restricted to 2.5 hours of sleep showed noticeable declines in serving accuracy, while handball goalkeepers and dart players exhibited reduced reaction times and accuracy. However, the studies reviewed by Fullagar et al. (2023) often used actigraphy and self-reported questionnaires to measure sleep, which, while practical, may not provide the accuracy of polysomnography (PSG). This limitation partly explains the divergence between their findings and those of Cunha et al. (2023), who emphasized the positive effects of sleep extension but found mixed results for other interventions like napping and mindfulness.

A key divergence exists regarding the benefits of sleep hygiene education. While Cunha et al. (2023) reported limited performance improvements resulting from sleep hygiene interventions, Fullagar et al. (2023) noted that better sleep environments and routines, such as managing light exposure and establishing pre-sleep rituals, can contribute to improved sleep quality. This discrepancy may arise from the differing methodologies of the studies included in each review, with some using objective measures and others relying heavily on self-reports.

The articles also differ in their evaluation of naps as an intervention. Cunha et al. (2023) suggested that naps can mitigate the effects of partial sleep deprivation, while Fullagar et al. (2023) cautioned that longer naps may lead to sleep inertia, temporarily impairing cognitive and physical performance. This divergence likely reflects differences in study designs, with Cunha et al.'s systematic review focusing on controlled durations and timing, whereas Fullagar et al. (2023) referenced field-based research where nap parameters were less standardized.

Bender and Lambing (2024) emphasized the importance of sleep strategies tailored to athletes' specific challenges, such as jet lag and circadian rhythm disruptions. Their findings

suggested that interventions like sleep banking and light exposure management can mitigate the adverse effects of travel and extended competitions. However, potential conflicts of interest—such as funding from Gainful Nutrition and Gatorade—may introduce biases, particularly if the studies cited prioritize interventions that align with sponsors' products. In conclusion, while the reviewed studies underscore sleep's importance for athletic performance, particularly in ultra-marathon contexts, methodological limitations and potential biases highlight the need for careful interpretation. Divergences in findings, particularly regarding napping and sleep hygiene, underscore the necessity of standardizing methodologies in future research to provide clearer insights into effective sleep strategies for athletes.

Physical Resilience and Endurance. Sleep is fundamental for physical resilience, particularly in ultra-marathons where endurance is tested to its limits. Athletes who achieve sufficient sleep consistently exhibit superior endurance, strength, and overall physical output compared to those who are sleep-deprived (Fullagar et al., 2015). However, Fullagar et al.'s (2015) observational design limits its ability to establish causal relationships between sleep and endurance. The reliance on subjective measures, such as self-reported sleep quality, introduces potential recall bias, which may skew the findings. Additionally, the participants' demographics—primarily elite athletes from team sports—might not generalize well to ultra-marathon runners, whose sleep challenges and recovery needs differ significantly.

Research by Fullagar et al. (2023) examined the relationship between sleep loss and physical performance in elite athletes using polysomnography and actigraphy to measure sleep patterns. The study revealed that partial sleep deprivation (3–5 hours per night) significantly reduced muscle strength and time to exhaustion, highlighting the physiological toll of insufficient sleep. Nevertheless, the study's field-based approach introduced variability in sleep

measurement, as polysomnography is typically impractical in competitive settings, potentially reducing sleep tracking accuracy. Diverging results from Kishi et al. (2024) showed that ultra-marathon runners who increased sleep before a race experienced a lower prevalence of muscle fatigue and falls. This discrepancy could stem from differences in study populations and methodologies, as Kishi et al. (2024) relied on retrospective self-reports, which are subject to recall bias, unlike the more controlled measurements used by Fullagar et al. (2023).

The study by Cook and Charest (2023) emphasized the role of recovery processes, such as muscle protein synthesis and anabolic hormone release, in maintaining physical performance. They found that inadequate sleep delayed these processes, increasing injury risk. However, the study's small and sport-specific samples—e.g., eight male mixed martial artists and 29 rugby athletes—limit its broader applicability to ultra-marathon runners. These findings contrast with Cunha et al. (2023), whose systematic review highlighted sleep extension as universally beneficial across various sports. The divergence could be attributed to Cook and Charest's (2023) focus on sleep deficits during intensive training periods, whereas Cunha et al. (2023) examined interventions aimed at improving pre-existing sleep conditions.

Athletes who prioritize sleep experience fewer instances of overtraining syndrome, characterized by chronic fatigue, muscle soreness, and performance plateaus (Medic et al., 2017). However, Medic et al.'s (2017) nonsystematic review design may introduce selection bias, as the studies included were not subjected to a uniform risk-of-bias assessment. Moreover, the review relies heavily on self-reported athlete experiences, which can be influenced by subjective factors such as stress or motivation levels. Diverging from Medic et al. (2017), Simim et al. (2020) observed that individual sport athletes reported higher rates of sleep disturbances than team sport athletes, potentially explaining variations in overtraining syndrome prevalence.

Simim et al.'s (2020) findings stemmed from objective measures like actigraphy, contrasting with Medic et al.'s (2017) reliance on subjective sleep quality assessments, thus providing more robust evidence for individual sports contexts.

Overtraining syndrome can lead to long-term declines in performance, highlighting the importance of sleep as a protective measure against the physical toll of ultra-endurance training. Kishi et al. (2024) found that increasing sleep duration before ultra-marathons reduced the risk of falls during races and injuries. These findings underscore the practical value of sleep management strategies, though the retrospective nature of their survey introduces potential biases. Participants may have underreported adverse outcomes to present themselves in a favorable light. Additionally, Cunha et al. (2023) noted that napping during races mitigated fatigue but could induce sleep inertia if improperly timed, suggesting that both sleep quantity and timing play critical roles in endurance sports.

By prioritizing sleep, ultra-marathon runners can maintain consistent training volumes and intensities over time, improving race outcomes and reducing injuries (Cunha et al., 2023). However, discrepancies in findings across studies underscore the need for standardized sleep measurement protocols to account for diverse athlete populations, sleep intervention types, and sport-specific demands. These findings collectively highlight the necessity of incorporating tailored sleep improvement strategies into the training regimens of ultra-marathon runners to maximize endurance, resilience, and overall performance.

Cognitive Function and Mental Endurance. Cognitive function is crucial for ultra-marathon runners, particularly in navigating complex terrains, making strategic race decisions, and maintaining mental sharpness over prolonged periods of physical exertion. Sleep deprivation significantly impairs cognitive processes such as attention, memory, reaction times, and

decision-making, all critical for ultra-endurance events (Kirschen et al., 2020; Montero et al., 2022). Fullagar et al. (2023) reported that total sleep deprivation reduced prefrontal cortex activity and decreased cerebral metabolism, leading to a 25% reduction in accuracy on reaction time tests and a measurable decline in strategic decision-making capabilities. The researchers noted that these effects were more pronounced in athletes who experienced cumulative sleep deficits compared to those undergoing short-term sleep deprivation, highlighting the compounding effects of inadequate recovery.

While these studies provide robust insights, they have limitations. Fullagar et al. (2023) relied on a sample predominantly composed of male athletes, which could limit the generalizability of the findings to female ultra-marathon runners or mixed-gender groups. Furthermore, the study's reliance on self-reported sleep measures in some trials introduces a risk of recall bias, potentially skewing the results. Similarly, Montero et al. (2022) emphasized the impact of sleep deprivation on cognitive performance but highlighted that many studies included in their review lacked longitudinal designs, which are necessary to evaluate long-term effects on mental endurance.

Divergences in findings regarding the extent of sleep deprivation's impact are noteworthy. For example, Kirschen et al. (2020) noted a 9% decline in psychomotor vigilance after one night of sleep restriction, whereas Martin et al. (2018) found that short naps during prolonged wakefulness could mitigate up to 50% of these performance deficits. The difference in outcomes could stem from methodological variations, such as Kirschen et al.'s use of controlled laboratory conditions versus Martin et al.'s field-based assessments of ultra-marathon runners. The former provides a controlled environment but lacks ecological validity, while the latter

reflects real-world settings but may include confounding variables such as hydration status or nutritional intake.

The benefits of sleep interventions are also well-documented. Cunha et al. (2023) conducted randomized controlled trials and found that sleep extension improved endurance performance by up to 12% in athletes, with strategic napping yielding similar benefits in cognitive performance metrics. However, the authors acknowledged potential carryover effects in their crossover trial design, which could have influenced the magnitude of reported benefits. Moreover, only 8% of the studies in Cunha et al.'s (2023) systematic review were randomized controlled trials, raising concerns about the overall robustness of the evidence base.

While Bender and Lambing (2024) observed correlations between sleep deprivation and cognitive impairments, they cautioned against overstating causality due to the correlational nature of their findings. Their analysis also noted potential funding bias, as one author disclosed affiliations with Gainful Nutrition and Gatorade, which might influence the interpretation of results. This contrasts Walsh et al. (2021), who presented a consensus statement based on a broader range of evidence, including both experimental and observational studies. Walsh et al. highlighted that while short naps improved reaction times and emotional regulation during prolonged events, the effects were highly variable and contingent on factors such as timing and duration of naps, which were not standardized across studies.

Lastly, there is divergence regarding the prevalence of sleep disturbances among athletes. Martin et al. (2018) reported that only 24.5% of ultra-marathon runners experienced significant sleep disorders, whereas Montero et al. (2022) suggested a higher prevalence of sleep disturbances in general athletic populations, ranging from 27% to 37%. This discrepancy could be attributed to differences in measurement tools; Martin et al. utilized the Epworth Sleepiness

Scale, which assesses daytime sleepiness, while Montero et al. included broader criteria, such as insomnia and obstructive sleep apnea. These methodological differences underscore the need for standardized assessment tools to ensure comparability across studies. In conclusion, while the evidence strongly supports the critical role of sleep in cognitive function and mental endurance for ultra-marathon runners, methodological variations, sample limitations, and potential biases must be considered when interpreting findings. Addressing these gaps in future research through larger, more diverse samples and standardized methodologies will be essential for refining our understanding of the interplay between sleep and ultra-endurance performance.

Recovery and Long-Term Performance. Recovery is another critical area in which sleep plays a pivotal role. Adequate sleep is essential for effective recovery from both training and competition. Studies have demonstrated that sleep facilitates muscle repair by promoting anabolic processes such as protein synthesis and the release of growth hormones, which are crucial for recovery after intense physical exertion (Fullagar et al., 2015; Kishi et al., 2024). For instance, Fullagar et al. (2015) observed that rugby league footballers who experienced sleep deprivation exhibited significant impairments in both cognitive and physical recovery markers, such as mean countermovement jump height and reaction time. However, the study utilized a randomized crossover design with only 11 participants, which limits the generalizability of its findings to broader populations or ultra-endurance athletes. Similarly, Kishi et al. (2024) reported that ultra-marathon runners who increased their sleep duration before races demonstrated a lower prevalence of falls attributed to sleep deprivation (12.3% compared to 17.3% for those who did not). Yet, the retrospective nature of Kishi et al.'s (2024) study introduces the potential for recall bias, as participants self-reported their sleep patterns and behaviors.

Sleep also aids in glycogen synthesis, replenishing the body's energy stores, which is vital for athletes preparing for subsequent training sessions or competitions (Simim et al., 2020). In a systematic review of 75 studies, Simim et al. (2020) highlighted significant variability in how sleep parameters were defined and measured, such as sleep efficiency and duration. This inconsistency complicates direct comparisons between studies and may contribute to divergent findings regarding the impact of sleep on glycogen replenishment. For example, while some studies included in Simim et al.'s (2020) review reported a positive correlation between longer sleep durations and improved energy restoration, others did not find statistically significant relationships. Methodological differences, such as the reliance on subjective sleep diaries versus objective actigraphy, likely contributed to these inconsistencies.

Enhanced recovery allows athletes to maintain higher training volumes and intensities, leading to better performance outcomes in ultra-marathons (Dunican et al., 2022). Dunican et al. (2022) conducted a prospective study that evaluated the effects of a 42-night sleep hygiene education intervention on ultra-marathon swimmers. While the intervention resulted in statistically significant changes in sleep onset and offset times (both delayed by 12 minutes; $p < 0.001$), there were no significant improvements in total sleep time or sleep efficiency. The limited sample size of 24 participants, combined with seasonal factors like increased daylight during the intervention, may have influenced these findings, as acknowledged by the authors. These limitations underscore the need for caution when generalizing results to other athletic populations or sports.

Sleep also promotes immune function, reducing the likelihood of illness or infections, which can derail training and competition plans. Landers-Ramos et al. (2021) found that athletes who consistently experienced high-quality sleep were better equipped to fend off infections, as

evidenced by stable levels of inflammatory markers such as TNF-α and CRP post-ultramarathon. However, much of the data cited in Landers-Ramos's review was derived from small-scale studies, including one involving just nine middle-aged male ultra-marathon runners, which raises questions about the applicability of these findings to younger or female athletes. In contrast, Medic et al. (2017) reported broader trends linking chronic sleep disruptions to elevated risks of cardiovascular disease, with long-term implications for overall athletic health. However, the review's nonsystematic methodology may introduce selection bias, as it relied on a handpicked set of 97 studies rather than a comprehensive or systematic search.

Athletes who prioritize sleep management report fewer injuries and reduced instances of overtraining syndrome, further underscoring the role sleep plays in long-term athletic success (Medic et al., 2017). Divergences exist, however, in how overtraining is measured and defined across studies. Doherty et al. (2021) emphasized that individualized sleep education tailored to athletes' needs significantly improved recovery outcomes, but the cross-sectional design of their study limited the ability to establish causal relationships between improved sleep and reduced overtraining. Furthermore, the study's reliance on self-reported data may have introduced social desirability bias, as athletes might have overstated their adherence to recommended recovery practices.

By fully allowing the body to recover during sleep, athletes can sustain a higher level of performance across multiple events, making sleep a critical component of long-term success in ultra-endurance sports (Doherty et al., 2021). However, differences in training schedules, competition stress, and demographic characteristics between elite and sub-elite athletes may influence recovery outcomes, as Doherty et al. (2021) suggested. For instance, elite athletes in their study reported poorer sleep quality (higher PSQI scores) than sub-elite athletes, potentially

due to greater training loads and psychological pressures. Future research should account for these contextual factors to better understand the nuanced relationship between sleep and recovery in diverse athletic populations.

The Role of Sleep in Mood and Motivation. In addition to its physical and cognitive benefits, sleep plays an essential role in regulating mood and motivation, which are critical factors in long-duration events. Research indicates that sleep deprivation exacerbates negative emotions, such as anxiety and irritability, while diminishing positive emotional states, like optimism and motivation (Fox et al., 2020). For instance, Fox et al. (2020) examined the effects of insufficient sleep in young athletes and reported that a 36-minute reduction in sleep duration was associated with increased levels of irritability and decreased motivation. These findings emphasize that even moderate reductions in sleep can have tangible effects on mood and perseverance, which are essential for ultra-endurance athletes. However, a limitation of this study is its reliance on self-reported measures, which can introduce recall bias and limit the precision of the findings.

Ultra-marathoners, who already endure significant physical pain and mental stress, rely on strong emotional regulation to push through the more challenging parts of a race. Walsh et al. (2021) highlighted that athletes who achieved at least eight hours of sleep reported 20% higher levels of motivation and perseverance than those averaging six hours or less. Walsh et al. (2021) also emphasized the importance of using objective measures, such as actigraphy, alongside subjective reports to better understand sleep's influence on mood. This dual-method approach enhances the reliability of the findings, although the study's generalizability may be limited due to its focus on a specific demographic of elite athletes.

Athletes who get sufficient sleep report higher levels of motivation and perseverance, which can make the difference between completing a race or withdrawing early due to mental or physical fatigue. Interestingly, Gratwicke et al. (2021) found that tart cherry juice supplementation improved sleep efficiency by reducing wake-after-sleep-onset by 16.8 minutes and correlated with improved mood in athletes reporting prior sleep disturbances. This finding supports sleep's physiological and psychological benefits, though the limited participant pool (n = 54) in Gratwicke et al.'s (2021) study raises concerns about its broader applicability. The potential for publication bias should also be considered, as the study was funded by an organization interested in sports nutrition.

These findings collectively suggest that sleep not only prepares the body physically but also fortifies an athlete's mental resilience, making it easier to remain focused, calm, and motivated during extreme challenges. However, Fullagar et al. (2015) diverged in their conclusions, noting that while sleep extension significantly reduced fatigue in team sport athletes, it had less pronounced effects on mood, potentially due to the shorter sleep deprivation periods studied. This divergence highlights the need for future research to address how varying durations of sleep deprivation impact mood across different athletic contexts.

Future Research and Individualized Approaches. Future research should focus on implementing more rigorous experimental designs, such as randomized controlled trials (RCTs), to evaluate the effectiveness of various sleep improvement strategies. Studies like those by Fullagar et al. (2015) and Charest and Grandner (2022) underscore the importance of using larger, more diverse samples to enhance the generalizability of findings. For instance, Fullagar et al. (2015) analyzed data from 11 rugby league players using a randomized crossover design to assess the effects of sleep deprivation. While this design reduces within-subject variability and

strengthens internal validity, the small sample size limits the broader applicability of the findings to ultra-marathon runners, whose physiological and psychological demands differ significantly from those of team-sport athletes.

Similarly, Charest and Grandner (2022) reviewed experimental studies involving both sleep extension and sleep deprivation protocols, highlighting significant improvements in endurance and cognitive performance with extended sleep. However, they noted discrepancies in the magnitude of performance gains across studies, which they attributed to methodological differences—such as the use of polysomnography (PSG) in some studies and less precise actigraphy in others. This methodological divergence underscores the need for standardizing sleep assessment measures in future research to ensure greater consistency, validity, and reliability in outcomes across studies involving ultra-endurance athletes.

Moreover, individualized approaches to sleep management are necessary, as different athletes may respond to sleep interventions in unique ways. Byrne et al. (2024) emphasized this point in their case study of an elite ultra-marathon runner, noting that a 52.8% reduction in training impulse during tapering periods led to significant sleep improvements and better race outcomes. While this in-depth analysis provides valuable insights into personalized training and sleep adjustments, its reliance on a single participant raises questions about the generalizability of the findings to broader ultra-marathon populations. Diverging from Byrne et al. (2024), Bender and Lambing (2024) reviewed multiple studies and found that interventions such as sleep banking were effective across a wide range of athletes. However, they also noted potential conflicts of interest, as one author disclosed affiliations with Gainful Nutrition and Gatorade, which may influence interpretations of sleep-related interventions aligned with sponsored products.

Additionally, future research should explore the long-term impacts of consistent sleep improvement on athletic performance, physiological recovery, and mental well-being. Gratwicke et al. (2021) highlighted the promising effects of tart cherry juice on sleep efficiency and post-exercise recovery but acknowledged the need for longitudinal studies to validate these benefits over time and across ultra-endurance athletes. These findings contrast with those of Fox et al. (2020), who found that nutritional interventions were less effective for young athletes compared to behavioral strategies such as sleep hygiene education. This divergence may stem from differences in participant age, sport type, and athletic experience, suggesting that tailored strategies are essential to meet the diverse and individualized needs of ultra-marathon runners. As athletes and sports scientists continue to explore the dynamic relationship between sleep and performance, future research into personalized and context-specific sleep management strategies will be vital to understanding how to optimize sleep for maximizing athletic success in ultra-endurance events. Standardizing methodologies, employing diverse athlete samples, and addressing potential biases will be essential for advancing evidence-based practices that effectively support the health, well-being, and performance of ultra-marathon athletes.

Sleep Management and Performance

Sleep management is fundamentally linked to athletic performance, making it a critical area of focus for ultra-marathon runners. Effective sleep management strategies, such as maintaining consistent sleep schedules and optimizing sleep hygiene practices, continue to significantly enhance athletes' physical and mental performance (Bonnar et al., 2018; Clemente et al., 2021; Cunha et al., 2023). Athletes who have implemented these practices reported improved sleep quality, longer sleep duration, and better recovery outcomes, contributing to greater readiness for the physical and psychological demands of ultra-marathon events

(Gratwicke et al., 2021). However, despite these promising outcomes, the evidence supporting sleep management strategies was often limited by methodological weaknesses and population-specific constraints in the reviewed studies.

A significant component of effective sleep management is the incorporation of sleep extension, which supports critical restorative processes such as muscle repair, glycogen synthesis, and hormonal regulation—functions essential for endurance athletes. Bonnar et al. (2018) conducted a systematic review analyzing the effects of various sleep interventions, including sleep extension and napping, across ten studies involving 218 participants aged 18–24 years. The review found that sleep extension improved specific performance metrics, such as reaction times and skill execution, particularly in sports like swimming and tennis. However, eight of the ten studies included in the review were rated as moderate in quality, with only one study achieving a "good" rating. Additionally, most studies did not adequately blind assessors, which introduced a potential bias in the reported outcomes. The narrow participant age range and predominant focus on male athletes further limited the generalizability of these findings to ultra-marathon runners, who represent a more diverse and often older athletic population.

Further supporting the relevance of sleep extension, Doherty et al. (2021), in a large study involving 338 athletes, found that elite athletes exhibited significantly poorer sleep quality than their sub-elite counterparts, as indicated by Pittsburgh Sleep Quality Index (PSQI) scores. Approximately 64% of all athletes reported poor sleep quality, reflecting a widespread issue that may undermine both recovery and performance. Nonetheless, this study relied on self-reported data, raising concerns about social desirability bias and the potential underreporting of relevant factors such as competition-related stress or mental health issues.

Despite the overall support for sleep extension, findings on sleep interventions diverged across studies. While Bonnar et al. (2018) emphasized sleep extension as a reliable strategy for enhancing performance, Clemente et al. (2021) noted that inconsistent sleep patterns, or sleep variability, negatively affected soccer players' performance outcomes. Clemente et al.'s (2021) systematic review of 32 studies highlighted that inadequate or inconsistent sleep was associated with increased injury risk and diminished match performance. However, many of the studies included in their review were rated as "fair" in quality, and some relied heavily on subjective sleep logs rather than objective tools like actigraphy, which may have contributed to inconsistencies in reported outcomes and limited the reliability of the conclusions.

Another divergence arose in relation to the efficacy of sleep hygiene practices. For example, Gratwicke et al. (2021) focused on nutritional interventions, such as tart cherry juice supplementation, which was shown to reduce wake after sleep onset (WASO) by an average of 16.8 minutes across multiple studies. In contrast, Cunha et al. (2023) reviewed mindfulness and behavioral strategies, which produced mixed results regarding their effectiveness in enhancing sleep quality. It is worth noting that Gratwicke et al.'s (2021) review relied on small participant samples, including a study with only six elite track cyclists, which raises questions about the applicability of these findings to broader populations such as ultra-marathon runners. Similarly, Cunha et al. (2023) acknowledged high heterogeneity among the interventions reviewed, complicating efforts to draw definitive conclusions about which specific sleep hygiene strategies are most effective for endurance athletes.

Further complicating the evaluation of sleep management strategies, Simim et al. (2020) provided a systematic review of 75 studies, which emphasized significant variability in how sleep quality was defined and measured. Tools such as actigraphy, Likert scales, and sleep

diaries were used inconsistently across studies, limiting comparability and synthesis of findings. For example, Simim et al. (2020) noted that sleep efficiency dropped by 3%–4% in individual sport athletes prior to competitions, but the lack of standardization in measuring sleep parameters reduced the reliability and interpretability of such outcomes. This inconsistency across studies demonstrates a clear need for uniform operational definitions and standardized assessment tools in future research on sleep and athletic performance.

In conclusion, while sleep management strategies, including sleep extension and optimized sleep hygiene, have demonstrated potential to improve athletic performance and recovery, the current evidence base was limited by methodological inconsistencies, small and homogeneous samples, and varying definitions of sleep quality and duration. Future research should focus on employing standardized methodologies, diverse participant populations, and objective sleep assessments, such as polysomnography and validated actigraphy tools, to clarify the relationship between sleep interventions and ultra-endurance performance. By advancing rigorous and inclusive research approaches, the field can better determine how sleep management strategies can be tailored to meet the complex demands of ultra-marathon runners.

Circadian Rhythm and Performance

Understanding the relationship between sleep quality, circadian rhythms, and athletic performance remains crucial for ultra-endurance athletes. The circadian rhythm is the body's natural 24-hour cycle that regulates sleep-wake patterns, hormonal release, and other physiological processes. Disruptions to this cycle, such as inconsistent sleep patterns, travel across time zones, or nighttime training, can lead to reduced performance, impaired recovery, and an increased risk of injury (Bonnar et al., 2018; Thun et al., 2015). These disruptions are particularly challenging for ultra-marathon runners, whose races often extend beyond normal

waking hours. Research from Clemente et al. (2021) highlighted the importance of consistent sleep patterns in reducing the risk of musculoskeletal injuries among athletes, as inconsistent or poor-quality sleep often correlated with elevated fatigue levels and impaired reaction times during high-demand activities.

A comprehensive review by Pradhan et al. (2024) explored the impact of circadian rhythms on athletic performance, emphasizing the role of individual chronotypes—morning, intermediate, and evening types. The study synthesized data from cross-sectional and longitudinal studies with participant samples ranging from as few as 12 to as many as 380 athletes. Methodologically, the review noted considerable variation in the tools used to assess circadian typology and performance, such as actigraphy, psychomotor vigilance tests, and sport-specific measures. Findings revealed that morning-type athletes tended to perform better earlier in the day, whereas evening-types excelled later. However, the review identified limitations in existing research, including reliance on self-reported data and lack of standardization in performance assessment, which could have introduced biases and reduced the generalizability of findings.

A notable divergence emerged between the findings of Pradhan et al. (2024) and Facer-Childs and Brandstaetter (2015). Both studies emphasized the alignment of performance schedules with individual chronotypes, but Facer-Childs and Brandstaetter (2015) found more pronounced performance variations across the day, with up to a 26% difference between peak and off-peak performance times. This difference could have stemmed from the smaller sample size in Facer-Childs and Brandstaetter's (2015) study (n = 121) and the use of the BLEEP test, which measures cardiovascular endurance and may not reflect all aspects of athletic

performance. In contrast, Pradhan et al. (2024) reviewed a broader range of studies with varying methodologies, potentially diluting the magnitude of performance variation reported.

Additional evidence from Clemente et al. (2021) aligned with these findings but emphasized the role of broader lifestyle factors, such as sleep hygiene and training schedules, over chronotype alone. The review incorporated 32 studies on soccer players and highlighted that inconsistent sleep schedules—not merely circadian misalignment—were the primary contributors to impaired performance and increased injury risk. This perspective diverged from the conclusions of Facer-Childs and Brandstaetter (2015), who attributed performance variability predominantly to circadian typology. Methodological differences may explain these contrasting conclusions, such as Clemente et al.'s (2021) use of larger sample sizes and more diverse populations.

Thun et al. (2015) expanded on the role of circadian rhythms by identifying that peak athletic performance aligns with core body temperature rhythms, which tend to peak in the early evening. The review included 113 articles but acknowledged that varying methodologies—such as differences in sample sizes, performance measures, and sleep assessments—limited the ability to draw definitive conclusions. Additionally, some studies within the review relied heavily on subjective questionnaires, like the Profile of Mood States (POMS), which may have skewed findings due to the subjective nature of self-reported data.

Future research should address these methodological gaps by incorporating larger, more diverse athlete populations and leveraging objective tools like actigraphy and hormonal assays to validate findings. Tailored interventions, such as light exposure adjustments and training schedules aligned with individual chronotypes, hold promise for optimizing performance in ultra-endurance athletes. Moreover, a broader understanding of how environmental and lifestyle

factors interact with circadian rhythms can enhance the development of comprehensive performance strategies.

Jet Lag and Time Zone Management

Managing jet lag remains one of the most significant challenges that ultra-endurance athletes face when traveling for competitions. Traveling across time zones can disrupt the body's circadian rhythm, leading to difficulty falling asleep, fragmented sleep, and daytime fatigue. Jet lag impairs cognitive function, reduces physical endurance, and increases the likelihood of injury due to delayed reaction times and decreased alertness (Vitale et al., 2019; Walsh et al., 2020). To mitigate the effects of jet lag, athletes can adopt strategies such as light exposure therapy and sleep scheduling adjustments. According to Vitale et al. (2019), natural light exposure is one of the most effective tools for synchronizing the body's internal clock to the new time zone. They reviewed 40 studies and found that maximizing exposure to natural daylight during the early morning hours while minimizing artificial light in the evening significantly improved circadian adaptation. However, the heterogeneity of the reviewed studies posed challenges in drawing definitive conclusions. Many of the included studies involved small cohorts of fewer than 20 participants, limiting the findings' generalizability.

Walsh et al. (2020) highlighted the importance of pre-travel sleep banking—extending sleep duration in the days leading up to travel—as an additional strategy for mitigating jet lag. This approach can reduce the sleep deficit accumulated during travel and provide athletes with a buffer to perform optimally despite circadian misalignment. However, Walsh et al. (2020) noted that the reliance on subjective measures, such as sleep diaries, in some studies may have introduced bias due to the self-reported nature of the data. This contrasted with the use of more

objective measures, such as actigraphy and polysomnography, which were used in only a subset of the reviewed research.

Divergence existed regarding the role of sleep duration in reducing jet lag symptoms. Vitale et al. (2019) emphasized that extending sleep by even 30 minutes per night before travel could have measurable benefits, while Walsh et al. (2020) found mixed evidence on the efficacy of such minor adjustments. These differences may have been attributed to variations in participant populations and study designs, with Walsh et al. (2020) focusing on elite athletes and Vitale et al. (2019) reviewing a broader range of athletic levels.

Additionally, Dunican et al. (2022) provided insights into the role of structured sleep hygiene programs in managing jet lag. Their prospective study involved a two-phase intervention, demonstrating that athletes who received a 2-hour education session on sleep hygiene experienced improved circadian adjustment. However, the potential for bias existed due to the funding source (Sleep4Performance), which is vested in promoting sleep hygiene practices. Dunican et al. (2022) also acknowledged limitations such as not accounting for psychological factors like anxiety, which could influence both sleep quality and performance outcomes. Another methodological divergence arose in how these studies addressed the timing of interventions. While Walsh et al. (2020) recommended strategies such as melatonin supplementation and gradual adjustments to sleep schedules several days before travel, Dunican et al. (2022) focused on post-arrival interventions like strategic light exposure and sleep hygiene education. These differences highlight the need for a combined approach to address both pre-travel and post-arrival circadian misalignment.

Vetter et al. (2020) further explored the physiological consequences of circadian disruption caused by time zone changes. Using experimental protocols, Vetter et al. (2020)

demonstrated that misalignment between internal body clocks and environmental light-dark cycles can reduce insulin sensitivity, impair cognitive performance, and elevate risks for injury. These findings underscore circadian alignment's importance for maintaining metabolic health and athletic performance. However, Vetter et al. (2019) pointed out that metrics for assessing circadian disruption vary widely across studies, making it challenging to compare findings or establish standardized guidelines.

In conclusion, managing jet lag requires a multifaceted approach tailored to the specific needs of athletes. Combining strategies like light exposure therapy, sleep hygiene education, and pre-travel sleep adjustments offers the most promise for mitigating the negative impacts of time zone changes on performance. However, methodological inconsistencies and potential biases across studies underscore the need for further research to refine and standardize best practices for jet lag management in ultra-endurance athletes.

Wearable Technology in Sleep Management

The integration of wearable technology into sleep management strategies has gained popularity among ultra-marathon runners due to its ability to monitor sleep patterns, heart rate variability, and other physiological markers. These devices provide athletes with real-time data to optimize recovery and performance. Wearable technology allows athletes to track sleep quantity and quality, identify disruptions, and receive personalized feedback to adjust their sleep strategies (Cook & Charest, 2023; Driller et al., 2023). For instance, data on the time spent in light, deep, and REM sleep stages can help athletes assess whether they are obtaining sufficient restorative sleep. This data-driven approach supports individualized interventions to meet each athlete's specific performance goals.

Despite the growing use of these tools, there are significant concerns regarding the accuracy and reliability of wearable devices. Driller et al. (2023) conducted a systematic review of 113 articles and found that while many devices were sensitive in detecting sleep onset and duration, they often overestimated total sleep time and struggled to accurately differentiate between sleep stages when compared to polysomnography (PSG), the gold standard in sleep research. Similarly, Simim et al. (2020) highlighted discrepancies in wearable devices' ability to detect wakefulness, which further questioned their precision. These limitations suggest that practitioners should use wearable data as a guide rather than an absolute measure of sleep quality.

Disclosures regarding funding and conflicts of interest provide valuable context for interpreting findings about wearable technology. Driller et al. (2023) explicitly stated that their research received no external funding, reducing concerns about financial influence. However, one author's affiliation with a sleep technology startup introduces potential bias, as the study could have indirectly benefited from positive results related to wearable devices. Walsh et al. (2020) similarly noted that their narrative review did not receive specific grant funding, strengthening its credibility. In contrast, neither Simim et al. (2020) nor Cook and Charest (2023) provided detailed information on funding or conflicts of interest in their summaries, making it challenging to assess the potential influence of funding in these works fully. The absence of explicit funding information in some articles highlighted a gap that should be addressed to ensure transparency and accountability in wearable technology research.

The psychological impacts of wearable technology also demonstrated conflicting findings across the literature. Driller et al. (2023) described a phenomenon known as "orthosomnia," where athletes become overly fixated on achieving "perfect" sleep metrics, potentially

exacerbating anxiety and impairing performance. Conversely, Walsh et al. (2020) suggested that wearable devices can reduce sleep-related anxiety by offering actionable insights that empower athletes to improve their sleep quality. These conflicting conclusions may reflect differences in study populations, with elite athletes experiencing greater performance pressures compared to recreational athletes who benefit from more flexible expectations. Additionally, methodological differences between studies contributed to divergences in findings. For instance, Cook and Charest (2023) emphasized the advantages of longitudinal designs for capturing dynamic changes in sleep patterns over time, whereas Thuany et al. (2023) employed a cross-sectional approach, which limits causal inferences. The lack of temporal data in cross-sectional studies makes it challenging to determine whether performance improvements are directly attributable to wearable use or other factors, such as training regimens or baseline sleep health.

Despite these limitations, wearable technology remains valuable for enhancing sleep strategies, particularly when integrated into broader recovery frameworks. Devices like wrist-worn actigraphy monitors offer accessible and non-invasive methods for tracking sleep during multi-day competitions, enabling athletes to plan naps and strategically minimize cognitive fatigue (Driller et al., 2023; Walsh et al., 2020). Additionally, wearable technology can complement sleep hygiene education programs, such as those outlined by Vitale et al. (2019), which emphasize creating conducive sleep environments and maintaining consistent sleep schedules. However, the limitations of wearable technology, including overestimated sleep durations and reliance on proprietary algorithms, highlight the need for practitioners to interpret wearable data within the context of athletes' overall recovery strategies. By combining objective metrics from wearable devices with subjective assessments, practitioners can develop holistic sleep management plans tailored to the unique needs of ultra-marathon runners. This balanced

approach ensures that wearable technology supports rather than detracts from athletes' performance and psychological well-being.

The Impact of Sleep on Recovery

Recovery is another critical area where sleep management plays a pivotal role. During sleep, the body undergoes numerous recovery processes essential for muscle repair, immune function, and overall well-being. For example, Doherty et al. (2021) demonstrated that sleep enhances muscle recovery by promoting protein synthesis and releasing growth hormones necessary for repairing muscle tissue damaged during ultra-endurance events. Their study, which included 338 athletes (115 elite and 223 sub-elite), utilized validated tools such as the Pittsburgh Sleep Quality Index (PSQI) to assess sleep quality. However, the cross-sectional design of their research limited causal interpretations and the reliance on self-reported data introduced potential recall bias. Furthermore, differences in demographic characteristics between elite and sub-elite athletes (e.g., training loads and age) could have influenced the results, highlighting the need for a more controlled design.

Similarly, Kishi et al. (2024) explored recovery processes in ultramarathon runners by analyzing sleep patterns in 1,154 finishers across two races. They found that runners who increased their average daily sleep duration (ADSD) before the race reported a lower prevalence of falls attributed to sleep deprivation (12.3%) compared to those who did not (17.3%). While this indicates a strong association between increased pre-race sleep and reduced risk of falls, the study’s retrospective design may have introduced recall bias, as participants self-reported their sleep data post-race. Moreover, the response rate of 30.4% raises questions about sample representativeness, as the experiences of non-respondents could differ significantly from those included in the analysis.

Interestingly, Simim et al. (2020) found that individual sport athletes, such as swimmers and cyclists, reported reduced sleep efficiency (3%–4%) before competitions compared to non-competition periods, which they attributed to heightened pre-competition stress. Their systematic review highlighted inconsistencies in how sleep parameters were measured across studies, with tools ranging from subjective sleep diaries to objective actigraphy. This methodological variation limits the comparability of results and underscores the need for standardized measurement practices in future research. Additionally, while the review included 2,841 athletes across 75 studies, the average age of participants (22.8 ± 6.2 years) and the predominance of Olympic and Paralympic athletes may reduce the generalizability of findings to recreational or ultra-endurance athletes.

Dunican et al. (2022) further emphasized the importance of sleep hygiene education in promoting recovery, reporting that a two-hour intervention led to significant delays in sleep onset and offset (12 minutes on average). However, total sleep time (TST) did not improve, remaining at 6 hours and 51 minutes on average—well below the recommended 7–9 hours. The study's small sample size of 24 participants limits the robustness of its conclusions, and external factors such as seasonal changes and social commitments during the intervention phase may have confounded the results. Additionally, one of the authors, Ian C. Dunican, is affiliated with Fatigue Science, which supplied the monitoring devices used in the study, raising potential concerns about conflicts of interest.

A divergence emerged when comparing Doherty et al. (2021) and Dunican et al. (2022) regarding the impact of sleep education on recovery. Doherty et al. (2022) advocated for individualized education and support strategies, emphasizing the role of coaches in helping athletes optimize sleep routines. In contrast, Dunican et al. (2022) suggested that a one-time

education session may not be sufficient to achieve meaningful improvements in sleep quality, pointing to the need for ongoing reinforcement. This divergence could have stemmed from differences in study design: while Doherty et al. (2021) assessed a larger and more diverse sample, Dunican et al. (2022) employed a prospective design focusing on a niche population of ultra-marathon swimmers, which may not generalize to other athletes.

Another notable point of divergence arose between Simim et al. (2020) and Kishi et al. (2024) regarding the relationship between sleep efficiency and recovery. While Simim et al. (2020) identified a 3%–4% drop in sleep efficiency before competitions, Kishi et al. (2024) did not report changes in sleep efficiency during ultramarathons but instead highlighted the importance of pre-race ADSD in reducing falls. These differences may be attributed to the populations studied: Simim et al. (2020) focused on individual sport athletes across various disciplines, while Kishi et al. (2024) concentrated on ultra-endurance runners, who may have unique sleep and recovery demands.

By managing sleep effectively, athletes can ensure these critical recovery processes occur, reducing the likelihood of injuries and improving their ability to perform at high levels across multiple events. However, the studies reviewed underscore the complexity of sleep management, as variations in methodology, population characteristics, and intervention designs yield differing conclusions. Coaches play a crucial role in helping athletes understand how to integrate sleep management techniques into their training routines, emphasizing that sleep is just as important as physical training and nutrition. As athletes and coaches refine their understanding of sleep management, the relationship between sleep and overall performance becomes increasingly evident, providing a foundation for further exploration of how sleep impacts every aspect of athletic success.

Relationship Between Sleep and Performance

The relationship between sleep and athletic performance is well-documented, with numerous studies highlighting the essential role of adequate sleep in optimizing physical, cognitive, and emotional processes critical for athletic success. In ultra-endurance events such as ultra-marathons, the impact of sleep is particularly pronounced due to the prolonged physical and mental demands. Fox et al. (2020) reported that insufficient sleep significantly impacts cognitive function, including reduced reaction time and decision-making abilities. For instance, they noted that habitual sleep durations of less than 8 hours per night among athletes were linked to an increased risk of musculoskeletal injuries. However, a limitation in their analysis was the reliance on self-reported sleep data, which may have introduced inaccuracies, as subjective measures often underestimate actual sleep duration. Additionally, variability in sleep monitoring methods—such as the use of subjective sleep diaries versus objective actigraphy—created inconsistencies in how sleep patterns were assessed across studies.

Knechtle and Nikolaidis (2018) provided a comprehensive review of ultra-marathon running, analyzing over 700 studies related to performance and health impacts. They emphasized that sleep deprivation during ultra-marathons contributes to delayed recovery, exacerbated musculoskeletal injuries, and increased risks of renal and gastrointestinal complications. While their review offered valuable insights, it was primarily narrative in nature and included observational studies with variable methodologies. For example, many of the included studies did not use control groups, and sample sizes were often small, which could have limited the generalizability of their conclusions to broader populations of ultra-endurance athletes.

A divergence existed between Knechtle and Nikolaidis (2018) and Fullagar et al. (2015) regarding the specific mechanisms through which sleep influences recovery. Knechtle and

Nikolaidis (2018) focused on the physiological stress associated with sleep deprivation, such as renal strain and gastrointestinal disruptions, whereas Fullagar et al. (2015) highlighted the importance of sleep for muscle repair and metabolic regulation. Fullagar et al. (2015) also emphasized strategies like sleep extension, which has been shown to improve mood and reaction time among athletes. The differences in focus may have stemmed from the populations studied; Knechtle and Nikolaidis (2018) concentrated on ultra-endurance athletes, while Fullagar et al. (2015) included team-sport athletes with more regimented schedules.

Fox et al. (2020) and Knechtle and Nikolaidis (2018) also differed in their assessment of the long-term versus short-term impacts of sleep deprivation. Fox et al. (2020) primarily addressed acute outcomes, such as reduced cognitive and physical performance, while Knechtle and Nikolaidis (2018) acknowledged the lack of longitudinal studies examining the chronic effects of sleep deprivation on ultra-endurance athletes. This gap in the literature underscores the importance of future research using standardized methodologies and longer timeframes to assess cumulative effects.

Fullagar et al. (2015) highlighted additional situational factors contributing to disturbed sleep among athletes, such as travel schedules, late-night competitions, and psychological stress during competitive periods. Their analysis revealed that team-sport athletes averaged approximately seven hours of sleep per night, falling short of the recommended 7–9 hours for optimal recovery. However, the reliance on elite-level athletes in their studies raises questions about the applicability of these findings to recreational or amateur athletes. Moreover, the use of subjective sleep measures across their referenced studies introduces potential bias, as athletes often misreport sleep quality and duration.

These divergences and limitations collectively underscore the complexity of studying the relationship between sleep and performance in ultra-endurance athletes. Despite methodological inconsistencies and sample size limitations, the existing literature highlights the critical role of sleep in maintaining endurance, reaction time, and mental clarity. Addressing these gaps through standardized methodologies and diverse participant samples will be essential to advancing the understanding of sleep's impact on ultra-endurance performance. The following section will explore advanced strategies to mitigate the adverse effects of sleep deprivation and optimize performance outcomes for ultra-marathoners.

Impact on Cognitive Function and Decision-Making. Sleep plays a crucial role in cognitive function, including attention, memory, and decision-making, which are vital for ultra-endurance athletes who face complex physical and environmental challenges during races. Sleep deprivation negatively affects reaction times and cognitive flexibility, impairing an athlete's ability to make quick, accurate pacing, nutrition, and hydration decisions. In a study conducted by Fox et al. (2020), the researchers aimed to understand the specific cognitive impacts of insufficient sleep on young athletes. The study employed a combination of subjective and objective measures, such as self-reported sleep diaries and activity monitors. Findings indicated that athletes with reduced sleep duration exhibited slower reaction times and impaired decision-making, emphasizing the detrimental consequences of insufficient sleep on performance. For instance, athletes who slept less than 8 hours per night were at an increased risk of musculoskeletal injuries, with specific reductions in reaction time and endurance metrics. However, the reliance on self-reported sleep data introduced potential bias, as athletes may have underestimated or overestimated their sleep duration, impacting the study's validity. Additionally, Fox et al.'s (2020) study highlighted the lack of consistent findings regarding sleep

quality, as it remains underexplored compared to sleep duration. This methodological gap underscores the need for further objective assessments, such as polysomnography, to provide a more accurate understanding of sleep quality's role in athletic performance.

In a study by Benchetrit et al. (2024), ultra-marathon participants displayed a significant decrease in cognitive performance after prolonged sleep deprivation during a Backyard Ultra running race. Specifically, reaction times increased by 77 milliseconds in the 2 Choice Reaction Time (2CRT) task ($p = 0.004$), and throughput decreased by 17.0 arbitrary units ($p < 0.001$). Additionally, Stroop Task Level 3 accuracy declined by 2.5% ($p = 0.014$), highlighting the measurable cognitive impairments linked to sleep deprivation and extreme exertion. Despite these precise findings, the study's small sample size ($n = 15$) and the self-reported nature of pre-race sleep patterns limited its generalizability and introduced potential bias. The authors also acknowledged the challenges of conducting research in extreme environments, which may have further affected the study's outcomes.

Interestingly, studies by Netzer et al. (2021) and Smith et al. (2023) presented diverging conclusions regarding the impact of sleep deprivation on ultra-endurance performance. Netzer et al. (2021) monitored a cyclist during the Race Across America and reported that the participant maintained high performance despite averaging only 7 hours and 52 minutes of fragmented sleep over 8.5 days. Conversely, Smith et al. (2023) emphasized the mental health risks associated with sleep deprivation, such as emotional dysregulation and impaired decision-making. This divergence may have stemmed from the small sample sizes in both studies (e.g., Netzer et al.'s study included two athletes, and some studies reviewed by Smith et al. had only one participant), which limits the ability to draw broader conclusions. Furthermore, Netzer et al. (2021) relied on

sleep logs and subjective measures rather than objective methods like polysomnography, potentially skewing the findings.

The variability in methodologies across studies further complicates comparisons. While Benchetrit et al. (2024) employed a structured neuropsychological assessment, other studies, such as Charest and Grandner (2022), relied on survey-based methods, which may have introduced inconsistencies in the data. For example, Charest and Grandner (2022) found that sleep extension significantly improved reaction times and cognitive performance, highlighting the positive effects of additional rest. This finding aligns with Benchetrit et al.'s (2024) emphasis on the cognitive impairments caused by insufficient sleep but contrasts with Netzer et al.'s (2021) observations of sustained performance under severe sleep deprivation. Differences in sample sizes, study designs, and the specific cognitive tasks used likely contributed to these conflicting results.

These cognitive deficits increase the likelihood of errors, such as mismanaging hydration or pacing strategies, leading to suboptimal race outcomes or injury. Cognitive resilience is essential for ultra-marathon runners, as mental sharpness is needed throughout races that can last 24 to 48 hours or longer. Athletes prioritizing sleep report sharper cognitive performance and improved decision-making abilities, contributing to better race results and enhanced physical endurance (Fullagar et al., 2015). However, Fullagar et al. (2015) highlighted that reduced sleep durations are prevalent among athletes during competitive periods, with team-sport athletes averaging only 7 hours per night. This falls short of the optimal duration recommended for recovery, raising concerns about the cumulative effects of sleep loss on decision-making and performance over time. Moreover, while Fullagar et al. (2015) emphasized the role of sleep hygiene practices in improving cognitive performance, they did not account for other factors,

such as circadian misalignment or individual variability in sleep needs, which may limit the applicability of their recommendations.

The evidence strongly supports the need for continued research into individualized sleep interventions, as the physiological and psychological demands of ultra-endurance sports make sleep a critical factor for peak performance. Divergences in findings, particularly concerning the role of sleep quality versus sleep duration, highlight the importance of standardized methodologies and larger sample sizes in future studies. Addressing these gaps will provide a clearer understanding of how to optimize cognitive function and decision-making in ultra-endurance athletes.

Physical Performance and Recovery. The relationship between sleep and physical performance is equally significant. Sleep deprivation impacts the musculoskeletal system, impairing muscle repair and growth, which are essential for recovery after intense physical exertion (Knechtle & Nikolaidis, 2018). In a comprehensive review, Fullagar et al. (2015) aimed to explore the influence of sleep on post-exercise recovery among professional team sport athletes, emphasizing sleep's role in muscle repair, metabolic processes, and overall physical and psychological recuperation. The review revealed that inadequate sleep disrupts these recovery processes, leading to muscle fatigue, increased soreness, and a heightened risk of injury, which directly translates to reduced athletic performance. Fullagar et al. (2015) highlighted significant impairments in countermovement jump height and cognitive reaction times under sleep deprivation, but specific percentages were not provided. These metrics highlight the tangible impact of sleep loss on athletic recovery and performance.

The review methodology involved analyzing studies that used objective measures such as actigraphy and polysomnography to evaluate sleep and recovery in athletic contexts. However,

Fullagar et al. (2015) noted significant methodological limitations, including small sample sizes—one study had only 11 participants—and a reliance on cross-sectional designs. These limitations may restrict the generalizability of their findings and suggest potential bias from the underrepresentation of diverse athletic populations. Additionally, the lack of longitudinal studies makes it difficult to assess the long-term effects of sleep deprivation on athletic performance, as highlighted in their conclusion.

These findings are highly relevant for ultra-marathon runners, who rely heavily on efficient recovery to sustain performance over long distances. Landers-Ramos et al. (2021) further emphasized that chronic sleep deprivation can exacerbate cardiovascular strain, evidenced by impaired arterial compliance. Their findings showed significant reductions in pulse wave velocity at distances exceeding 50 km, illustrating the physiological strain induced by prolonged endurance activity. This divergence in focus—team-sport athletes versus ultra-endurance runners—may have stemmed from differences in sample demographics and study designs. For example, Landers-Ramos et al. (2021) relied on longitudinal assessments of ultramarathon participants, while Fullagar et al. (2015) aggregated data primarily from cross-sectional studies. The variability in methodological approaches highlights the need for more standardized research protocols to enable direct comparisons.

Moreover, insufficient sleep has been shown to compromise immune function, leaving athletes more susceptible to infections and illness, which can further hinder performance during training and races (Medic et al., 2017). This review summarized findings from 97 studies, noting that short sleep durations were associated with increased susceptibility to infections. However, Medic et al. (2017) acknowledged a lack of consensus on the threshold of sleep deprivation that leads to significant immune compromise, attributing discrepancies to heterogeneity in study

populations and varying definitions of "sleep disruption." This methodological divergence underlines the importance of standardizing definitions and measurement tools in sleep research.

Ultra-marathon runners often face grueling conditions and high physical demands and must prioritize sleep as an essential recovery tool. Implementing strategic sleep practices, such as sleep extension and scheduled naps, can help mitigate these adverse effects and support muscle repair, energy replenishment, and overall physical well-being. Knechtle and Nikolaidis (2018) highlighted that sleep extension improved endurance athletes' reaction times and mood states. These results underscore the potential benefits of targeted sleep interventions for maintaining higher training volumes and intensities, ultimately enhancing performance and reducing injury risk over the long term. However, the authors noted a potential publication bias in favor of studies reporting positive effects of sleep extension, as studies with null results were less likely to be published.

Thermoregulation and Hydration. Thermoregulation and hydration are critical for ultra-marathon runners, particularly those competing in extreme environmental conditions. Research shows that sleep deprivation impairs the body's ability to regulate temperature, increasing the risk of heat-related illnesses such as dehydration, heat stroke, and heat exhaustion during ultra-endurance events (Medic et al., 2017; Scheer & Krabak, 2021). Proper thermoregulation is essential for maintaining performance in ultra-marathons, where athletes face fluctuations in temperature and must adapt to varying environmental conditions. Medic et al. (2017) reported that sleep deprivation reduced core temperature regulation efficiency, significantly heightening the risk of hyperthermia during prolonged exertion. However, these findings were based on laboratory studies with controlled conditions, which may not fully replicate the complexities of real-world ultramarathon environments.

A scoping review by Scheer and Krabak (2021) explored the prevalence and risk factors of musculoskeletal injuries in ultra-endurance running, emphasizing the compounded impact of environmental stressors, like heat and cold, on athletes' thermoregulatory capacity. The review analyzed 13 studies, highlighting variability in injury prevalence linked to terrain, race duration, and inconsistencies in injury reporting standards. For instance, some studies defined injuries based on medical diagnoses, while others relied on self-reported data, leading to potential underreporting or overestimating injury rates. These inconsistencies limit the ability to draw definitive conclusions about the prevalence of heat-related injuries in ultra-endurance events.

Additionally, sleep deprivation affects the body’s ability to maintain fluid balance and regulate electrolytes, which are critical for preventing dehydration (Knechtle & Nikolaidis, 2018). Dehydration impairs physical performance and increases the risk of cramps, muscle fatigue, and cognitive decline. Knechtle and Nikolaidis (2018) found that ultramarathon runners who lost significant body weight due to dehydration exhibited reduced performance and endurance. Studies by Scheer and Krabak (2021) emphasized the importance of hydration strategies for ultra-marathon runners, highlighting the need for individualized hydration plans that consider the effects of sleep deprivation on fluid balance. However, the authors identified significant knowledge gaps in hydration research, particularly regarding sex differences and the impact of pre-race hydration status on performance. Understanding the interplay between sleep, hydration, and thermoregulation is crucial for developing comprehensive sleep and hydration management strategies that support optimal performance and recovery in ultra-endurance athletes (Medic et al., 2017). Addressing these interconnected factors can mitigate performance decrements and injury risks, enabling athletes to compete at their highest potential even in extreme conditions.

Heart Rate Variability, Cortisol Levels, and Stress. Sleep quality and duration are closely linked to physiological performance markers such as heart rate variability (HRV) and cortisol levels, indicators of physical stress and recovery. Studies have shown that poor sleep quality is associated with decreased HRV and elevated cortisol levels, which are signs of heightened physiological stress (Riegler et al., 2023). Elevated cortisol levels, often caused by insufficient sleep, impair the body's ability to recover and increase the likelihood of overtraining and injuries (Roberts et al., 2022). For example, Riegler et al. (2023) found that insufficient sleepers were nearly twice as likely to sustain a sport-related concussion (SRC), with 15.69% of insufficient sleepers experiencing an SRC compared to 8.79% of sufficient sleepers, highlighting a clear link between poor sleep and increased injury risk.

In a study conducted by Roberts et al. (2022), researchers employed a counterbalanced crossover design with nine endurance athletes to examine HR indices' sensitivity to changes in athlete readiness following sleep extension (SE) and sleep restriction (SR). During SR, participants averaged 4.8 hours of sleep per night (±0.7 hours), compared to 6.8 hours in the normal sleep (NS) condition and 8.4 hours during SE. The study found that SE led to significantly faster time trial (TT) performance and lower perceived exertion, while SR resulted in slower performance and higher exertion levels. However, the small sample size of nine participants, all male endurance athletes, limits the generalizability of the findings. Additionally, the reliance on self-reported dietary intake and perceived exertion measures may have introduced bias, as participants' subjective reporting may not accurately reflect physiological responses.

The study by Roberts et al. (2022) reported moderate correlations between HRV changes and TT performance, emphasizing the role of adequate sleep in sustaining physical performance. Yet, these findings differ from those of Fullagar et al. (2015), who noted that while sleep

extension improved recovery markers such as reduced soreness and fatigue, it did not significantly enhance cognitive recovery for team sport athletes. This divergence may have stemmed from differences in study design and sample characteristics, as Fullagar et al.'s (2015) study focused on team-sport athletes, whose recovery needs may differ from those of endurance athletes. Furthermore, Fullagar et al. (2015) used larger, more diverse participant samples across various sports, which may enhance the applicability of their findings but also introduce variability that could obscure the effects seen in smaller, controlled samples.

High-quality sleep has been shown to improve HRV, indicating better autonomic nervous system balance, which supports endurance and faster recovery. By managing sleep effectively, athletes can regulate cortisol levels and improve HRV, optimizing their body's ability to perform under the extreme demands of ultra-marathons (Fullagar et al., 2015). However, a critical review of Fullagar et al.'s (2015) methodology reveals potential challenges in generalizing their findings, as their reliance on subjective sleep diaries rather than objective measures such as actigraphy may have led to underreporting or inaccuracies in sleep duration. Conversely, Roberts et al. (2022) combined actigraphy with time trials, which provided more precise data but limited the study to a smaller, less diverse group, raising questions about its broader applicability.

The findings from Roberts et al. (2022) and Fullagar et al. (2015) highlight the need to tailor sleep interventions to the specific demands of athletes. While both studies affirm the critical role of sleep in performance and recovery, differences in sample demographics, sleep assessment methods, and sport-specific requirements likely contribute to the divergence in results. Future research should explore these variations in more depth, using larger, more diverse samples and combining subjective and objective measures to provide a more comprehensive understanding.

Future Implications and Research Directions. The relationship between sleep and performance continues to be an area of significant interest in sports science, particularly for ultra-endurance athletes. As researchers continue to explore how sleep affects athletic performance, it is clear that individualized sleep management strategies are essential. Different athletes may uniquely respond to various sleep interventions, depending on their circadian rhythms, sleep architecture, and stress levels. For instance, while Roberts et al. (2022) highlighted significant benefits of SE in endurance athletes, Medic et al. (2017) reported that fragmented sleep, even without significant reductions in sleep duration, can negatively impact long-term physical and psychological well-being. This divergence underscores the complexity of sleep's effects on performance, which may be influenced by both acute and chronic sleep patterns.

Future research should focus on developing personalized sleep management plans that optimize performance while addressing the specific needs of ultra-marathon runners (Bender & Lambing, 2024). Longitudinal studies exploring the long-term effects of consistent sleep improvement on recovery, endurance, and overall well-being will help refine sleep strategies to maximize athletic success (Medic et al., 2017). Such studies should also address potential biases by incorporating objective measures like polysomnography and ensuring diverse, representative samples to enhance the applicability of findings. With a deeper understanding of the critical relationship between sleep and performance, athletes and coaches can implement effective sleep management practices to enhance recovery, cognitive function, and physical endurance.

Effective Sleep Management Practices

Effective sleep management practices are essential for ultra-marathon runners to maintain peak performance, enhance recovery, and improve overall well-being. These practices include

maintaining a regular sleep schedule, creating a conducive sleep environment, and using relaxation techniques to promote better sleep (Bender & Lambing, 2024; Dunican et al., 2022). While these concepts may sound familiar, their specific application in the context of ultra-endurance athletes requires careful attention to the unique physical and mental demands of ultra-marathons.

Ultra-marathon runners, who face extreme physical stress, must ensure their sleep environment is meticulously controlled to maximize recovery. Sleep hygiene, which promotes uninterrupted and restorative sleep, plays a crucial role. This includes controlling environmental factors such as room temperature, light exposure, and noise levels, which can significantly impact sleep quality (Gratwicke et al., 2021). For example, Gratwicke et al. (2021) found that tart cherry juice, which contains melatonin, improved sleep efficiency by up to 16.8 minutes when consumed regularly. For ultra-endurance athletes, optimizing their sleep environment by keeping the room cool, dark, and quiet directly supports deeper sleep stages, such as slow-wave sleep, which is critical for muscle repair (Doherty et al., 2021). Furthermore, controlling blue light exposure from electronic devices in the hours before bed remains essential to promote melatonin production and ease the transition to sleep. Bender and Lambing (2024) emphasized the role of blue light in disrupting circadian rhythms and suggest practical interventions, including blue light-blocking glasses or adjusted device settings, to reduce emissions. These strategies are particularly relevant for athletes relying on devices for race planning and communication.

In the high-pressure world of ultra-endurance sports, effective stress management is essential for improving sleep quality. Ultra-marathon runners often experience significant pre-race anxiety, which can negatively impact sleep duration and quality. Techniques such as

progressive muscle relaxation, meditation, and deep breathing exercises reduce stress and calm the body's physiological responses before sleep (Walsh et al., 2021). For example, Fullagar et al. (2015) noted that pre-competition stress correlated with a decrease in sleep efficiency by approximately 3–4%, especially among athletes competing in high-stakes events. These practices not only facilitate faster sleep onset but also improve emotional regulation and reduce cortisol levels, which can remain elevated during periods of stress. Unlike typical athletes, ultra-marathoners often endure mental fatigue from race planning and the knowledge of long periods of physical exertion ahead. By integrating relaxation techniques into their daily routines, runners can better manage psychological stress, enhance sleep quality, and improve performance during competition (Cunha et al., 2023). This is particularly valuable for multiple-day races, where managing physical and mental fatigue becomes crucial to success.

While strategic napping and sleep extension have already been introduced, exploring their practical application during multi-day ultra-endurance events is essential. Research has shown that short naps during ultra-endurance events can help mitigate the effects of cognitive and physical fatigue. Kirschen et al. (2020) highlighted the restorative potential of naps in athletic contexts, particularly in reducing cognitive fatigue and aiding decision-making. While the exact optimal duration of naps for ultra-marathon runners is not universally defined, athletes are encouraged to experiment with napping strategies to find what works best for their individual needs during multi-day events. Simim et al. (2020) emphasized that napping helps sustain mental acuity during periods of acute sleep deprivation, such as overnight competitions. Strategic naps can be planned at key points in a race to help runners maintain focus and improve pacing.

Sleep extension—deliberately increasing sleep duration in the days leading up to a race—has enhanced pre-race recovery and minimized performance declines. Simim et al. (2020) found

that extending sleep duration reduced sleep debt and contributed to improved endurance during multi-day competitions. Post-race recovery is also positively influenced by extended sleep, as it facilitates muscle repair and supports immune system restoration (Doherty et al., 2021). By incorporating pre-race sleep extension and strategic napping during events, ultra-marathon runners can better manage their sport's physical and mental challenges.

Incorporating wearable technology into sleep management practices allows ultra-marathon runners to take a data-driven approach to optimize their recovery and performance. Devices such as fitness trackers and smartwatches offer valuable insights into sleep duration, stages of sleep (light, deep, and REM), and sleep disruptions (Landers-Ramos et al., 2021). Kirschen et al. (2020) found that athletes who monitored their sleep with actigraphy were able to identify patterns that negatively impacted their performance, such as disruptions caused by inconsistent pre-race routines. This real-time feedback enables athletes to make informed decisions about their sleep strategies, adjusting routines to improve sleep quality (Driller et al., 2023). For example, athletes who consistently struggle with disrupted sleep can use wearable data to pinpoint the cause—whether it be environmental factors, inconsistent schedules, or elevated stress levels—and implement targeted solutions. Wearable technology can also track sleep patterns during races, allowing athletes to optimize napping schedules and recovery periods in real time (Simim et al., 2020). However, Landers-Ramos et al. (2021) cautioned that while wearable devices provide valuable data, their accuracy can vary depending on the device used, and over-reliance on these tools may introduce distractions.

A key aspect of effective sleep management is educating athletes and coaches about the importance of sleep for optimal performance and recovery. Fullagar et al. (2015) emphasized that many athletes underestimate the value of sleep, focusing instead on physical training and

nutrition. However, sleep is an equally critical factor that must be integrated into training plans. Coaches play a vital role in helping athletes understand the impact of sleep on performance, encouraging them to adopt sleep strategies tailored to their specific needs (Dunican et al., 2022). This includes teaching athletes to track their sleep patterns, use relaxation techniques, and optimize their sleep environment. By making sleep a core component of athletic training, ultra-marathon runners can reduce the risk of burnout, enhance recovery, and improve long-term performance (Cunha et al., 2023).

Future research should focus on refining the sleep management practices used by ultra-marathon runners. Studies such as those by Bianchi et al. (2022) and Fullagar et al. (2015) suggested that comprehensive sleep management programs tailored to the specific demands of ultra-endurance athletes will be vital. Furthermore, the effectiveness and safety of specific sleep aids or supplements need to be investigated to determine how they can be integrated into sleep routines for athletes without causing dependency or adverse effects (Bender & Lambing, 2024). While Charest and Grandner (2022) found that sleep hygiene practices improved sleep onset and efficiency, their study's funding from a sleep aid manufacturer introduces a potential bias that must be considered. Additionally, research should evaluate the long-term benefits of sleep strategies such as sleep extension, strategic napping, and wearable technology, particularly in recovery and endurance (Cunha et al., 2023). As ultra-endurance athletes explore how psychological processes, including mental resilience and emotional regulation, interact with sleep, tailored interventions will further optimize performance in ultra-marathons.

Psychological Processes and Sleep

Understanding the psychological processes related to sleep is essential for grasping how sleep impacts ultra-marathon runners' performance and well-being. Psychological factors like

stress, anxiety, and mental toughness significantly affect sleep quality and duration, influencing an athlete's ability to perform and recover effectively (Brace et al., 2020; Graham et al., 2021). Graham et al. (2021) noted that increased fatigue during multi-day events like Arctic ultra-marathons was correlated with lower vigor and higher tension, which impacted sleep quality. Ultra-marathon runners, who face extreme physical and mental challenges, often experience heightened stress levels before and during races. This can severely impair their ability to achieve restful sleep, ultimately affecting their endurance and decision-making abilities. Research showed that stress hormones, particularly cortisol, were elevated in athletes who experienced high levels of pre-race anxiety, leading to difficulties in falling asleep and reduced sleep quality (Walsh et al., 2020). Walsh et al. (2020) reported that athletes experiencing pre-race anxiety had reduced sleep efficiency, with sleep durations dropping to an average of 6 hours compared to their normal 7-8 hours. Elevated cortisol levels interfere with sleep onset and reduce the time spent in restorative deep sleep, which is crucial for recovery. For example, athletes with pre-race anxiety experienced sleep efficiency reductions of up to 10% compared to their baseline sleep measures (Walsh et al., 2020). The cyclical relationship between stress and sleep is particularly problematic for ultra-endurance athletes, as poor sleep exacerbates stress, creating a negative feedback loop that further undermines performance (Colangelo et al., 2023).

Graham et al. (2021) examined the interplay between mental toughness, sleep, and mood among runners participating in an Arctic ultra-marathon. The study aimed to identify injury patterns, sleep profiles, and mood states and analyze the relationships between these factors. The methodology included measuring mental toughness using the MT18 questionnaire and mood using the BRUMS scale. Injuries were recorded over the three-day, 120-mile race, during which participants experienced extreme conditions with temperatures ranging from -20°C to -6°C.

While the findings highlighted the importance of mental toughness in maintaining positive mood states, such as reductions in anger and depression and increases in vigor, the study's small sample size of 12 participants and reliance on self-reported injury data limited the generalizability of these results. The lack of a control group and the absence of objective sleep measurements further restricted the robustness of the conclusions. The divergence between Graham et al.'s (2021) findings and those of Bianchi et al. (2022), who observed a direct relationship between sleep and cognitive performance, may stem from methodological differences. Bianchi et al. (2022) utilized research-grade activity monitors to gather objective sleep data, whereas Graham et al. (2021) relied on self-reported measures of sleep quality and mood states, which are subject to participant bias. Bianchi et al. (2022) employed research-grade activity monitors, providing objective sleep data, whereas Graham et al. (2021) relied solely on self-reports, which are prone to bias.

Mental toughness plays a critical role in how athletes cope with sleep deprivation, particularly during multi-day ultra-marathon events where extended wakefulness is inevitable. Athletes with higher levels of mental toughness are more likely to sustain performance despite limited sleep, as they can better regulate their emotions, manage physical discomfort, and stay focused under extreme conditions (Brace et al., 2020). However, even the most mentally tough athletes are not immune to the cognitive impairments caused by sleep deprivation. Studies showed that sleep-deprived athletes experienced slower reaction times, impaired judgment, and reduced decision-making accuracy—skills essential for navigating ultra-endurance races' complex demands (Bianchi et al., 2022). Bianchi et al. (2022) reported that reaction times slowed during a 200-mile ultra-marathon, with athletes averaging 4.7 hours of sleep across fragmented sleep episodes, highlighting the cognitive toll of sleep deprivation. Bianchi et al. (2022) noted

that athletes experienced slower reaction times and impaired decision-making during a 200-mile race, attributed to fragmented sleep episodes averaging 4.7 hours over the race duration. While Brace et al. (2020) also noted the role of mental toughness in mitigating these effects, their findings did not include quantitative data on cognitive impairments, potentially due to a narrower focus on psychological self-efficacy rather than objective cognitive performance measures.

The connection between sleep and emotional regulation is another important psychological process that influences ultra-marathon runners' performance. Research indicates that sleep deprivation increases emotional reactivity and decreases emotional regulation, making it harder for athletes to manage stress and maintain focus during competitions (Nicolas et al., 2022). Nicolas et al. (2022) found that athletes with high emotional intelligence (EI) experienced smaller decreases in recovery scores during a mountain ultra-marathon ($p = 0.0009$) compared to their low-EI counterparts. Nicolas et al. (2022) found that runners with higher emotional intelligence (EI) experienced significantly smaller decreases in recovery scores (from a mean of 4.27 pre-race to 3.61 during the race, $p = 0.0009$) compared to runners with lower EI, who showed no significant changes. These findings contrast with those of Colangelo et al. (2023), who noted a broader prevalence of emotional instability among ultra-endurance athletes, attributing this to pre-existing mental health vulnerabilities and high training loads. The divergence may stem from Nicolas et al.'s (2022) small sample size ($n = 13$) and focus on a single mountain ultra-marathon, while Colangelo et al. (2023) synthesized data from 25 studies, capturing a wider range of events and contexts.

Chronic sleep deprivation is also closely linked to long-term mental health issues, such as anxiety and depression, which can further undermine an athlete's performance and overall well-being (Graham et al., 2021). Ultra-marathon runners, who often push their bodies and minds to

the limit, are particularly vulnerable to these mental health challenges. Research showed that athletes who experienced chronic sleep deprivation were 18.6% more likely to develop depressive symptoms, as reported in Thuany et al.'s (2023) systematic review. The review also highlighted that female runners faced unique vulnerabilities, with a higher prevalence of eating disorders and sleep disturbances compared to their male counterparts. This divergence may be attributed to differences in sample populations, as Thuany et al. (2023) combined data from both recreational and elite athletes, while other studies focused exclusively on elite-level competitors, whose mental health profiles may differ.

Addressing these psychological factors through targeted interventions is critical for improving sleep quality and enhancing mental resilience. One such intervention is Mindfulness-Based Stress Reduction (MBSR), which has been associated with improved emotional regulation, reduced anxiety, and enhanced sleep quality in athletes (Walsh et al., 2020). However, the absence of a control group in this study raises concerns about the internal validity of these findings, as other confounding factors, such as changes in training intensity or environmental conditions, could have influenced the results.

Suppiah et al. (2022) categorized athletes into three clusters based on sleep quality, finding that those in the "high-priority" cluster, characterized by poor sleep, made up 14.8% of their sample of 412 elite athletes. This group exhibited significantly reduced sleep efficiency, the lowest recovery scores, and the highest stress levels compared to the "low-priority" cluster. These findings suggest that targeted behavioral interventions could help mitigate these deficiencies. However, the study's reliance on convenience sampling introduced potential bias, as the recruited athletes may not represent the broader population of ultra-marathoners.

Additionally, the cross-sectional design limited the ability to draw causal inferences about the relationship between sleep quality and stress levels.

As researchers explore the psychological processes that influence sleep, it becomes evident that individual psychological factors, methodological differences, and study-specific biases significantly shape findings. Divergences in results, such as those between Bianchi et al. (2022) and Graham et al. (2021) or Nicolas et al. (2022) and Colangelo et al. (2023), highlight the need for standardized methodologies and larger, more diverse samples. For example, Bianchi et al.'s (2022) use of objective activity monitors offers precise sleep data, while Graham et al.'s (2021) reliance on self-reports introduces potential bias. Similarly, Nicolas et al.'s (2022) findings are limited by their small sample size of 13 participants, whereas Colangelo et al.'s (2023) synthesis of 25 studies provides a broader and more robust perspective. Addressing these methodological and sampling limitations will enhance the understanding of how sleep quality impacts athletic performance in ultra-marathon runners.

Psychological Factors Influencing Sleep

Psychological factors, such as stress, anxiety, mental toughness, and emotional regulation, play a significant role in determining the quality and duration of sleep for ultra-marathon runners. Ultra-endurance athletes, who are often subjected to extreme physical and mental stressors, must navigate the unique psychological demands of their sport, which can directly affect their ability to achieve restorative sleep. Research highlights the critical importance of toughness—the ability to remain resilient, focused, and determined in adversity (Nicolas et al., 2022). Athletes with higher levels of mental toughness tend to cope better with the rigors of sleep deprivation and are more likely to maintain performance levels even when sleep is limited (Brace et al., 2020). For example, Brace et al. (2020) found that mental

toughness correlated strongly with self-efficacy ($r = 0.72$, $p < 0.001$), but neither significantly predicted performance metrics such as Ultra-Trail World Tour rankings or race completion times. This highlights a divergence between mental toughness as a psychological buffer and its direct impact on measurable performance outcomes.

Stress and anxiety are two of the most prominent psychological factors that contribute to sleep disturbances in ultra-marathon runners. As athletes prepare for and engage in long-distance races, their stress levels often spike due to physical demands, pre-race anticipation, and logistical challenges. This heightened stress can lead to elevated cortisol levels, interfering with the body's ability to fall and stay asleep (Colangelo et al., 2023). Specifically, Colangelo et al. (2023) reviewed 25 studies and found that 80% of endurance athletes reported significant mood disturbances, including clinically significant depression, during high-volume training periods. However, this review's limitations included potential selection bias as articles focused only on ultra-endurance athletes without epidemiological comparisons to non-athletic populations. Furthermore, the self-reported nature of many included studies increased the potential for subjective bias, which may skew the interpretation of these findings.

The pre-race anxiety experienced by many athletes exacerbates sleep disturbances, as racing thoughts and concerns about performance often lead to prolonged sleep onset latency. Nicolas et al. (2022) identified a significant decrease in recovery scores among ultra-marathoners with high emotional intelligence (Mean = 4.27 pre-race vs. 3.46 post-race, $p = 0.0002$, $d = 3.11$). However, the study's small sample size ($n = 13$) limits its generalizability to broader populations. This divergence contrasts with findings from Brace et al. (2020), where mental toughness showed no significant association with recovery or sleep metrics, suggesting that emotional intelligence may have a unique role in stress regulation independent of mental toughness.

Studies have shown that sleep deprivation increases emotional reactivity, making it harder for athletes to manage stress and maintain motivation during competitions. For instance, Bianchi et al. (2022) documented that participants in a 200-mile ultra-marathon experienced a mean sleep latency of just 3.1 minutes during the race, indicating a rapid onset of sleep despite high fatigue levels. However, the study's small sample size (n = 4) and reliance on self-reported sleep diaries during the race phase introduced potential reporting bias and reduced the generalizability of findings. Conversely, Walsh et al. (2020) found that athletes with short habitual sleep durations (less than 7 hours per night) exhibited reduced performance and recovery metrics across various sports, supporting the critical role of adequate sleep for recovery. The divergence in findings between these studies could stem from methodological differences, such as the use of objective sleep tracking by Walsh et al. (2020) versus self-reporting by Bianchi et al. (2022).

In the study conducted by Graham et al. (2021), researchers observed that participants in the Arctic Ultra-Marathon reported an average of 0.78 injuries per day, with 83% of participants sustaining injuries such as musculoskeletal pain or gastrointestinal issues. Interestingly, sleep duration showed no significant correlation with injury rates, which diverges from findings by Kisiolek et al. (2021), where lower total sleep time (TST) correlated with slower race completion times ($r = -0.577$, $p = 0.019$). The contrasting outcomes may be attributed to the extreme environmental conditions of the Arctic Ultra-Marathon, where factors such as cold temperatures and unique injury risks potentially overshadow sleep's role in injury prevention. The small sample size (n = 12) in Graham et al. (2021) and reliance on self-reported injury data further limit the conclusions that can be drawn.

Ultra-marathon runners can benefit from psychological interventions such as CBT-I and MBSR to address the psychological factors that influence sleep. CBT-I is a well-established therapeutic approach that helps athletes identify and change the negative thoughts and behaviors contributing to sleep difficulties (Cunha et al., 2023). By teaching athletes to manage pre-race anxiety, reduce racing thoughts, and develop healthier sleep habits, CBT-I can improve both sleep quality and duration. Similarly, MBSR has been shown to reduce stress and anxiety, promote emotional regulation, and improve sleep by encouraging athletes to adopt mindfulness practices such as meditation and deep breathing exercises (Walsh et al., 2020). However, Cunha et al. (2023) noted methodological limitations in their systematic review, including high heterogeneity in study designs and a lack of rigorous controls, which weaken the reliability of their conclusions regarding the effectiveness of these interventions.

In conclusion, understanding the psychological factors influencing sleep is essential for developing comprehensive support systems tailored to the unique needs of ultra-endurance athletes. Divergences in findings across studies underscore the importance of rigorous methodologies, larger sample sizes, and objective measures to better elucidate the complex interplay between psychological factors and sleep in this population. By integrating evidence-based interventions into training routines, ultra-marathon runners can improve sleep quality, reduce the adverse effects of sleep deprivation, and enhance overall performance and well-being.

Impact of Sleep on Psychological Well-Being

The quality of sleep directly impacts psychological well-being, and inadequate sleep can lead to significant mental health challenges for ultra-marathon runners. Athletes in endurance sports are particularly susceptible to the effects of sleep deprivation, which can cause increased levels of anxiety, depression, and cognitive impairments. Bianchi et al. (2022) conducted a

longitudinal, observational study examining the sleep-wake behavior of four 200-mile ultra-marathon competitors, collecting data before, during, and after the event. The study's purpose was to understand how sleep patterns and deprivation affected cognitive and emotional functioning across various phases of the race. Using wrist-worn activity monitors and self-reported sleep diaries, the researchers observed that runners averaged only 4.7 hours of sleep in fragmented episodes during the race, compared to 6 hours per night pre-race and 6.3 hours post-race. The study highlighted that sleep deprivation was associated with increased emotional reactivity and slower reaction times, critical factors for ultra-endurance performance.

Issues of authority and bias in Bianchi et al.'s (2022) study must be considered. The study included only four participants, limiting the findings' generalizability to the broader ultra-marathon community. The self-selected nature of the participants, who volunteered through a social media platform, introduces potential selection bias. Additionally, self-reported sleep diaries may have contributed to inaccuracies, as subjective perceptions of sleep can vary significantly. Despite these limitations, including objective measures, such as wrist-worn activity monitors, adds a layer of reliability to the findings. Nonetheless, future studies with larger, more diverse samples are necessary to strengthen the evidence base.

Colangelo et al. (2023) reviewed 25 studies on the mental health of ultra-endurance athletes (UEAs) and emphasized that prolonged exposure to sleep deprivation, combined with the physical and mental demands of ultra-marathons, increases the risk of psychological distress, including anxiety and depression. The review noted that up to 80% of endurance athletes reported clinical depression during high-volume training periods. However, variations in study methodologies, including differences in sample sizes and diagnostic criteria, contribute to divergent findings across studies. The absence of direct epidemiological comparisons with the

general population further complicates interpretations of mental health prevalence rates among UEAs.

Emotional regulation plays a critical role in maintaining performance during long-duration races. Sleep deprivation disrupts this regulation, leading to mood swings, irritability, and emotional instability, which can affect an athlete's focus and ability to manage stress (Fox et al., 2020; Nicolas et al., 2022). Fox et al. (2020) emphasized that young athletes experiencing less than 8 hours of sleep per night reported increased cognitive deficits, mood disturbances, and injury risks. Nicolas et al. (2022) highlighted that athletes with higher emotional intelligence (EI) exhibited better recovery strategies and stress management, even under sleep-deprived conditions. This divergence highlights the importance of considering individual differences, such as EI, which may buffer against the adverse effects of insufficient sleep.

Graham et al. (2021) examined mood changes and injury rates during an Arctic ultra-marathon and reported significant increases in fatigue ($p = 0.014$) and reductions in vigor ($p = 0.029$) over three days. While the study observed that participants slept an average of 4.07 hours per night, no direct relationship was found between sleep duration and mood states, possibly due to the extreme environmental conditions. This contrasts with Bianchi et al. (2022), who reported that fragmented sleep episodes during a 200-mile ultra-marathon were associated with increased emotional reactivity and impaired decision-making. Divergences in findings may stem from differences in study designs, environmental contexts, and sample characteristics.

Cognitive impairments caused by sleep deprivation are another critical aspect of psychological well-being that impacts ultra-marathoners. Insufficient sleep reduces executive function, impairs decision-making, and slows reaction times, jeopardizing athletes' ability to navigate complex race strategies and environmental challenges (Bianchi et al., 2022; Fox et al.,

2020). Graham et al. (2021) noted that mental toughness mitigated some of these impairments, with higher mental toughness correlating with reduced confusion and depression. However, Fox et al. (2020) emphasized that cognitive deficits were predominantly linked to insufficient sleep, regardless of psychological resilience. Methodological differences, such as reliance on self-reported versus objective cognitive assessments, may account for these discrepancies.

The long-term effects of chronic sleep deprivation on psychological well-being are profound. Chronic sleep loss increases the risk of burnout, characterized by physical and emotional exhaustion, loss of motivation, and a reduced sense of accomplishment (Fox et al., 2020; Thuany et al., 2023). Thuany et al. (2023) identified training volume as a significant predictor of burnout risk, with higher weekly training loads correlating with increased psychological strain. However, the cross-sectional design of Thuany et al.'s (2023) study limits causal inferences, and the reliance on self-reported training data may introduce response biases. Future longitudinal studies are necessary to elucidate the causal pathways between sleep deprivation, training volume, and burnout.

Further exploration into the relationship between sleep and psychological well-being is crucial. Longitudinal studies like Bianchi et al.'s (2022), examining the cumulative effects of sleep deprivation on mental health and performance, would offer comprehensive insights into how sleep affects ultra-endurance athletes over time. Additionally, research into individualized sleep strategies based on athletes' unique psychological profiles could provide more effective ways to support their mental and physical health (Nicolas et al., 2022). Understanding the psychological factors that influence sleep is essential for developing comprehensive support systems that address the unique needs of ultra-endurance athletes. As psychological factors play

a significant role in influencing sleep, the broader impact of sleep on psychological well-being becomes a critical area of focus for ultra-marathon athletes striving for peak performance.

Role of Individual Differences

Individual differences, including age, gender, and psychological traits, play a significant role in how ultra-marathon runners manage sleep and cope with the demands of sleep deprivation. Roberts et al. (2022) highlighted significant sex differences in sleep patterns among endurance athletes, with females reporting lower emotional balance and higher perceived stress before races compared to males. Females also exhibited stronger associations between negative emotional states and disrupted sleep duration, whereas males showed an opposite trend, with stress correlating positively with increased sleep durations. Despite these findings, the study's small sample size (18 males and 18 females) limits generalizability, and the authors acknowledged that their underpowered design (<80% statistical power) may have prevented the detection of more nuanced differences. Additionally, the reliance on self-reported sleep diaries introduces potential recall bias, which could distort the accuracy of participants' reported sleep patterns and stress levels.

Brace et al. (2020) provided evidence that mental toughness and self-efficacy are critical psychological traits influencing ultra-endurance performance, finding a strong correlation ($r(54) = 0.72$, $p < 0.001$) between these constructs. However, neither mental toughness nor self-efficacy significantly predicted performance metrics such as finishing time or ranking in the HURT100 ultra-marathon. A key methodological limitation is the low reliability of the SMTQ subscales (e.g., Cronbach's alpha = 0.42 for Constancy), which likely weakened the predictive strength of their findings. This contrasts with Nicolas et al. (2022), who reported that athletes with higher emotional intelligence (EI) demonstrated significantly better recovery capacity during and after

ultra-endurance races. The divergence between these studies may stem from differences in their measurement tools. Nicolas et al. utilized the Brief Emotional Intelligence Scale (BEIS-10), which showed strong internal consistency (Cronbach's alpha = 0.84), whereas Brace et al.'s use of the less reliable SMTQ subscales may have obscured potential associations with performance outcomes.

Byrne et al. (2024) conducted a detailed case study of an elite ultramarathon runner who achieved a 24-hour world record by utilizing a highly individualized training and recovery regimen. Key strategies included alternating high-volume training blocks with structured recovery periods, such as tapering (a 52.8% reduction in training impulse during the final week before races) and incorporating cross-training activities like cycling and swimming, which maintained fitness while minimizing injury risk. Despite its practical implications, the study's reliance on data from a single athlete limits its generalizability, and potential bias may have arisen due to the authors' dual roles as researchers and trainers of the subject. In contrast, Cunha et al. (2023) reviewed 25 studies on sleep interventions and found that sleep extension (targeting 9–10 hours per night) was consistently associated with improved cognitive and physiological outcomes across a broader range of athletes. The divergence between these findings likely reflects the methodological scope: Byrne et al. focused on one individual's regimen, whereas Cunha et al.'s systematic review included a variety of interventions and athlete profiles, albeit with 20% of the studies rated as having a high risk of bias.

Kishi et al. (2024) explored sleep patterns and management strategies among 1,154 ultramarathon finishers, emphasizing the importance of pre-race sleep. Runners who increased their average daily sleep duration (ADSD) before races were 29% less likely to experience sleep deprivation-related falls during the event (12.3% prevalence compared to 17.3% among those

who did not increase ADSD). The large sample size strengthens the validity of these findings, though the retrospective design introduces recall bias, as participants were required to report sleep patterns and strategies after completing the race. Furthermore, the study's response rate of 30.4% raises concerns about potential selection bias, as runners who were more attuned to sleep management strategies may have been overrepresented in the sample. These findings align with Cunha et al.'s emphasis on the benefits of sleep extension but provide a more specific context regarding ultramarathon performance and safety.

Divergences between studies highlight the complex interplay between individual traits, sleep management, and recovery. For instance, Roberts et al. (2022) observed that females faced more pronounced pre-race stress and sleep disruptions than males, while Nicolas et al. (2022) found that higher EI facilitated recovery and stress adaptation across both genders. This contrast may reflect the distinct psychological constructs measured (e.g., emotional balance versus EI) and the broader focus on sex differences in Roberts et al.'s study. Similarly, while Byrne et al. (2024) emphasized physical recovery strategies tailored to a single elite athlete, Cunha et al. (2023) and Kishi et al. (2024) explored sleep-focused interventions across larger, more diverse samples. Differences in study design and participant characteristics likely account for these divergences.

Ultimately, these studies underscore the importance of tailoring sleep interventions to individual characteristics, such as gender, psychological traits, and resilience. For example, athletes with high resilience and EI may benefit from strategic napping and cognitive stress management techniques (Nicolas et al., 2022), whereas female athletes experiencing elevated pre-race stress may require structured sleep hygiene education and interventions (Roberts et al., 2022). Moreover, Byrne et al. (2024) highlighted the value of monitoring heart rate and adjusting

training intensities, which could be extended to personalized sleep strategies. Collectively, these findings demonstrate that individualized approaches to sleep and recovery are essential for optimizing ultra-endurance performance and minimizing risks such as injury or mental fatigue.

Synthesis of Findings

The synthesis of findings across the various themes explored in this chapter underscores critical trends and emerging gaps in the current literature surrounding ultra-marathon runners and sleep management. The effects of sleep deprivation on ultra-endurance athletes are extensively documented, demonstrating significant physiological and psychological impacts that hinder performance, recovery, and overall well-being (Bianchi et al., 2022; Clemente et al., 2021). For instance, Clemente et al. (2021) reported that prolonged sleep deprivation during ultra-endurance events is associated with reduced muscle repair rates, increased inflammation markers, and disrupted metabolic processes. These findings are supported by Roberts et al. (2022), who found that sleep restriction led to an average 30% decrease in total sleep time over three nights, significantly impairing recovery and endurance performance. This highlights the heightened injury risk among athletes, particularly when sleep deprivation exacerbates physiological stressors, although specific injury prevalence rates were not disclosed in these studies.

Psychologically, sleep deprivation contributes to heightened emotional reactivity and impaired decision-making. Bianchi et al. (2022) noted that ultra-endurance runners with lower emotional intelligence experienced significant stress increases during events, further compromising their resilience. In contrast, Nicolas et al. (2022) observed that runners with higher emotional intelligence had better stress management and recovery outcomes, highlighting the importance of psychological adaptability in mitigating the adverse effects of sleep deprivation.

Sleep improvement strategies, such as structured naps, sleep hygiene practices, and sleep extension protocols, have demonstrated promise in enhancing performance and psychological well-being (Roberts et al., 2022; Simim et al., 2020). Roberts et al. (2022) observed that sleep extension increased average sleep duration by 1.5 hours per night compared to normal sleep conditions, significantly improving time-trial performance and reducing perceived exertion levels. However, Simim et al. (2020) cautioned that while actigraphy-based studies provide valuable objective sleep data, the reliance on subjective self-reporting tools in some studies introduces potential recall bias. This discrepancy underscores the need for future research employing standardized methodologies, such as polysomnography, to validate findings.

The relationship between sleep management and performance is complex, influenced by biological, psychological, and social factors. For example, Simim et al. (2020) emphasized that individual variations in circadian rhythms significantly affect athletes' recovery capacities. Furthermore, Bianchi et al. (2022) demonstrated the interplay between psychological factors, such as mental toughness, and sleep quality, indicating that athletes experiencing heightened anxiety before events often report reduced sleep efficiency. However, discrepancies emerge when comparing findings across studies. For instance, Miller et al. (2022) found that athletes in 200-mile ultra-marathons achieved higher sleep efficiency (88%) despite sleep deprivation compared to participants in shorter ultra-endurance events reported in Haugen et al. (2022), who demonstrated significantly lower sleep efficiency levels. This divergence may be attributable to differences in race duration, environmental conditions, or participant demographics.

Case studies provide additional insights into the variability in sleep needs among ultra-endurance athletes. Nicolas et al. (2022) identified gender-based differences in stress and recovery patterns, with female athletes reporting higher stress levels and lower emotional

balance pre-race compared to their male counterparts. Meanwhile, Roberts et al. (2022) emphasized the role of training history and psychological traits, such as resilience, in determining individual responses to sleep deprivation. These findings highlight the necessity of personalized sleep management strategies tailored to each athlete's unique physiological and psychological profiles. However, methodological limitations, such as the small sample sizes in studies like Miller et al. (2022) (n = 4), raise questions about the generalizability of these findings.

Future research should address these limitations by employing larger, more diverse samples and robust experimental designs. For instance, longitudinal studies and randomized controlled trials could evaluate the long-term benefits of sleep interventions and their impact on performance, injury rates, and overall health. Additionally, multidisciplinary approaches combining sports psychology, physiology, and sleep science insights are essential to developing holistic sleep management programs (Nicolas et al., 2022; Simim et al., 2020). Such programs should consider genetic, environmental, and psychological factors, emphasizing individualized strategies to optimize recovery and performance while minimizing risks of injury or burnout.

Summary

The purpose of this qualitative descriptive single-case study was to explore the impact of inadequate sleep on the health and performance of ultra-marathon runners. This research addressed sleep deprivation's significant yet often overlooked effects on ultra-marathon athletes, which can hinder their performance and overall well-being (Benchetrit et al., 2024; Bender & Lambing, 2024; Brace et al., 2024). Ultra-marathon running, characterized by races exceeding the traditional marathon distance of 26.2 miles, presents unique challenges that amplify the effects of sleep deprivation. Such events' extreme physical and mental demands often lead to

disrupted sleep patterns and inadequate rest, exacerbating fatigue and impairing cognitive functions (Bianchi et al., 2022; Miller et al., 2022).

Sleep is a crucial component of athletic performance and recovery. Adequate sleep enhances muscle repair, consolidates memory, and regulates mood, all vital for athletes. However, ultra-marathon runners frequently experience sleep insufficiency due to the rigorous demands of their sport. This insufficiency is often exacerbated by factors such as race schedules, travel, and the high-stress environment of competitive sports (Fox et al., 2020; Fullagar et al., 2015). Understanding and addressing the specific sleep needs of ultra-marathon runners is essential for improving their performance and overall health (Riegler et al., 2023; Roberts et al., 2022).

The extensive literature search aimed to identify critical gaps in the existing research and to synthesize findings across various studies. This approach allowed for a detailed examination of how sleep deprivation affects ultra-marathon runners and the effectiveness of different sleep management strategies. By integrating peer-reviewed journal articles, case studies, and systematic reviews, this literature review provides a robust foundation for understanding the complex interplay between sleep, health, and performance in ultra-marathon athletes (Benchetrit et al., 2024; Bender & Lambing, 2024).

Chapter 3: Research Method

The problem addressed in this study was the negative impact of inadequate sleep on athletes' physical health, psychological health, and social factors. The Centers for Disease Control (CDC, 2023) highlighted a general shortfall in sleep among adults, with only 72.3% getting sufficient sleep in 2020, a concern that extends into the athletic domain (Fox et al., 2020; Riegler et al., 2023). Ultra-marathon runners, in particular, are directly impacted by this problem due to the extreme physical and psychological stresses endured during intense training and racing schedules. However, what has not been fully understood is the efficacy of sleep interventions specifically tailored to meet the unique needs of ultra-marathon athletes (Miller et al., 2022). Because the problem was not previously addressed, the negative consequences of sleep insufficiency in athletes may have continued to escalate, leading to increased injury rates, impaired performance, and deteriorated mental health outcomes (Gattoni et al., 2022; Smith et al., 2023). The purpose of this qualitative descriptive single-case study was to explore how ultra-marathon runners in the United States perceive the role of sleep in relation to physical health, psychological health, and social factors during endurance events. This research provides insights into effective sleep management practices tailored to the extreme demands of ultra-marathon participation, characterized by prolonged physical exertion and disrupted sleep patterns (Fox et al., 2020; Miller et al., 2022; Riegler et al., 2023).

This chapter outlines the research methodology and design, emphasizing relevance to the study's problem, purpose, and research questions. The chapter discusses the target population and sampling strategy, including criteria for participant selection and the sample size necessary for comprehensive data collection. The description of data collection instruments, such as semi-structured interviews, and an assessment of their suitability for the research objectives are

provided. Procedures for data collection, including the use of Zoom for interviews to accommodate participants' schedules and locations, are detailed. Analytical methods for ensuring accurate data interpretation are explained, followed by a discussion of the methodology's assumptions, limitations, and delimitations. Finally, ethical considerations are outlined to ensure the credibility and trustworthiness of the data collected for this study.

A qualitative descriptive single-case study approach was employed to explore the perceptions of ultra-marathon runners regarding the impact of sleep on health and performance. The study initially sought 12-18 participants to achieve data saturation; ultimately, 15 participants were included to provide diverse insights into the phenomena under investigation. Research questions focused on how ultra-marathon runners perceive the role of sleep in attention, endurance, recovery, and overall performance. The study captured nuanced perspectives and experiences, making a qualitative descriptive single-case study an appropriate design choice. This chapter comprehensively examines the research methodology and design, population and sample, materials and study procedures, data collection and analysis, assumptions and limitations, and ethical standards.

Research Methodology and Design

The design for this study was a qualitative descriptive single-case study approach. This approach is appropriate for exploring sleep's complex and multifaceted impact on ultra-marathon runners, as it enables an in-depth exploration of personal experiences and perceptions. Qualitative research provides rich, detailed insights and is well-suited for exploring phenomena where variables cannot be easily quantified (Creswell & Poth, 2018). The descriptive single-case study design allowed for a comprehensive exploration of ultra-marathon runners’ unique sleep strategies and challenges, which aligns closely with the study's problem, purpose, and research

questions. A qualitative descriptive single-case study design was selected due to its effectiveness in capturing the depth and breadth of experiences from a small, focused sample. This design is beneficial for studying phenomena within real-life contexts, providing a detailed exploration of the subject matter (Stake, 1995; Yin, 2018). In this case, the experience under investigation is the role of sleep in the health and performance of ultra-marathon runners, making the qualitative descriptive single-case study a fitting choice.

Alternative methodologies and designs were considered but found less suitable for this study. For instance, a quantitative approach was deemed inappropriate because it focuses on measuring variables and testing hypotheses, which aligns differently from the exploratory nature of this research (Creswell & Creswell, 2017; Maxwell, 2013). Quantitative methods are better suited for studies requiring statistical analysis of large datasets, whereas this researcher sought to explore the nuanced personal experiences of a specific group (Babbie, 2020; Patton, 2015). Several qualitative designs were also considered but ultimately not chosen. Narrative inquiry, for example, focuses on individuals' stories and personal experiences, aiming to provide a detailed account of those experiences (Creswell & Poth, 2018). While narrative inquiry could offer valuable insights into the individual stories of ultra-marathon runners, it was not selected because the researcher aimed to explore a broader range of experiences and strategies rather than focusing on the detailed life stories of a few individuals. Phenomenology was another potential design considered. This approach focuses on exploring the essence of a phenomenon by understanding the lived experiences of individuals who have encountered it (Moustakas, 1994). While phenomenology would provide deep insights into the subjective experiences of ultra-marathon runners regarding sleep, it was not chosen because the researcher sought to understand a more comprehensive array of factors, including social and contextual influences, which go

beyond the scope of phenomenological research. Action research was also considered. This methodology involves a cyclical process of planning, acting, observing, and reflecting, often used to solve practical problems through active participation (Stringer, 2013). Although action research could be valuable for implementing and assessing sleep interventions with ultra-marathon runners, it was not selected because the study's primary aim was exploratory rather than interventionist.

Ultimately, the qualitative descriptive single-case study design was selected for its ability to provide a detailed and contextualized exploration of the research problem. This design aligned well with the study's objectives and research questions, which sought to explore how ultra-marathon runners perceive the impact of sleep on physical, psychological, and social well-being during endurance events. By focusing on a specific case—ultra-marathon runners in the United States—the researcher gathered in-depth data and provided valuable insights into effective sleep management practices tailored to this unique population.

Population and Sample

The target population for this study comprised ultra-marathon runners in the United States aged 18 to 62 who participate in ultra-endurance events, often covering distances over 50 kilometers (National Institutes of Health, 2017). This population is appropriate for addressing the study problem because ultra-marathon runners face unique challenges related to sleep management due to their demanding training and competition schedules. Disrupted sleep patterns and insufficient rest are common among these athletes, adversely affecting their physical health, psychological well-being, and performance. Ultra-marathon runners often require more than the standard 7-9 hours of sleep to recover adequately, and they frequently employ sleep strategies, such as increasing sleep duration before races or incorporating naps during events, to mitigate

the effects of sleep deprivation (Kishi et al., 2024; Martin et al., 2018). The alignment between the research problem—addressing the negative impact of inadequate sleep on athletes' health and performance—and the chosen population underscores the significance of this study.

The increasing popularity of ultra-marathons has led to a growing number of participants, which makes this population particularly relevant to the study's purpose of exploring how ultra-marathon runners perceive the role of sleep in their overall health and performance. According to UltraRunning Magazine (2023), there were approximately 87,000 unique ultra-marathon runners in the United States, with more than 56,000 competing in 2024, including 19,000 first-time ultra-marathon athletes. Additionally, recent studies show that ultra-marathon runners are predominantly male (about 85%) and have a mean age of approximately 42.8 years (Kishi et al., 2024). The population's demographic characteristics and the growing participation trend further highlight this study's relevance in understanding ultra-endurance events' physical and psychological demands, particularly concerning sleep management.

A purposive sample of 12-18 participants was originally targeted from this population to address the research questions and achieve data saturation. Ultimately, 15 participants were included in the study to ensure sufficient depth and breadth of data. Purposive sampling involves intentionally selecting participants with specific characteristics or experiences relevant to the research topic, allowing for a more in-depth exploration of the phenomenon under study (Palinkas et al., 2015). This sample size was sufficient to achieve data saturation, a critical criterion in qualitative research that ensures comprehensive insights and meaningful patterns in the data (Guest et al., 2006). Guest et al. (2006) suggest that data saturation often occurs within the first 12 interviews, with basic themes emerging as early as six interviews. By selecting a sample of 12-18 participants and ultimately interviewing 15, the study ensured an adequate

exploration of the research questions concerning how ultra-marathon runners perceive the impact of sleep on their health, psychological well-being, and performance.

Participants were recruited through a multi-step process using online ultra-marathon communities, forums, and social media platforms. Recruitment targeted both public and private platforms, with procedures adapted to meet IRB requirements. Public platforms, which are openly accessible, allowed recruitment without site permissions, while private platforms required formal approval from group administrators prior to posting any recruitment materials. Recruitment materials, including a flyer (Appendix D), clearly outlined the study's purpose, eligibility criteria, and contact information. Platforms such as the American Trail Running Association, UltraRunning Magazine forums, and Facebook running groups were utilized due to their active ultra-marathon communities.

For private platforms, the researcher contacted administrators using a standardized email request for permission (see Appendix E). All permissions were documented and retained for IRB compliance. Interested participants were invited to contact the researcher via email for further details. Once contacted, participants received a follow-up email with comprehensive information about the study's objectives, procedures, and ethical considerations. Participants were also offered the opportunity to ask questions and clarify expectations before providing verbal informed consent (Appendix B). Informed consent was obtained verbally via Zoom immediately before each interview began. The interviews followed a semi-structured interview guide (Appendix A), ensuring consistency while allowing flexibility for emergent themes. Topics included participants' sleep routines, challenges in achieving adequate sleep, perceived impacts of sleep on physical and mental performance, and strategies for improving sleep quality. Interviews were conducted via Zoom to accommodate participants' schedules and geographical

locations, making the process flexible and accessible. Each interview lasted approximately 60 to 90 minutes and was audio-recorded only for accuracy. Transcripts were anonymized, with all identifying information removed to ensure participant confidentiality. Combining targeted outreach with ethical considerations for public and private platforms, this recruitment approach ensured that the sample was diverse, accessible, and reflective of individuals with direct experience of the phenomena under investigation.

The selected sample was appropriate for addressing the study's research questions because it included individuals with direct experience of the phenomena under investigation. A semi-structured interview guide ensured consistency while allowing for the exploration of topics that arose naturally during the conversation. Interview questions (Appendix A) focused on areas such as sleep routines, challenges in achieving adequate sleep, perceived impacts of sleep on physical and mental performance, and any strategies utilized to improve sleep quality. Conducting the interviews via Zoom accommodated participants' varying schedules and geographical locations, providing flexibility and enabling the researcher to reach a geographically dispersed population. Each interview lasted approximately 60 to 90 minutes, allowing for a detailed exploration of the research questions.

In conclusion, the sample of 15 ultra-marathon runners was highly relevant and appropriate for addressing the study's problem, purpose, and research questions. By focusing on this population, the study gathered in-depth insights into how these athletes perceive the role of sleep in their physical, psychological, and social well-being. The chosen sampling method and size, along with the data collection methods, ensured that the data collected were rich and detailed, allowing for a thorough exploration of the research questions. Data saturation was

monitored throughout the data collection process, and up to 18 participants would have been interviewed if necessary to achieve a robust analysis (Guest et al., 2006).

Materials

The primary method for data collection in this study was semi-structured interviews (Appendix A) guided by an interview protocol (Appendix C) designed to elicit detailed responses about the biopsychosocial impacts of sleep on ultra-marathon runners. This approach was chosen to gather rich, descriptive data that aligns with the research objectives derived from the biopsychosocial model (Engel, 1977). The interview guide is based on existing literature and the biopsychosocial framework, focusing on how sleep affects physiological, psychological, and social aspects of ultra-marathon runners' lives (Bloomberg & Volpe, 2016; Creswell & Poth, 2018; Engel, 1977).

The interview guide (Appendix A) includes open-ended questions that allow participants to elaborate on their experiences, ensuring a comprehensive understanding of the phenomena under study. For instance, participants were asked about their typical sleep routines, challenges in achieving adequate sleep, strategies to manage sleep during training and competition, and how sleep impacts their physical health, mental well-being, and social interactions. This semi-structured format balances interview consistency and flexibility to explore new emerging themes (Creswell & Poth, 2018).

An expert panel review was conducted to support the trustworthiness of the data collection instruments. This panel, consisting of the dissertation chair, an academic reviewer, and a subject matter expert in sports psychology and ultra-endurance sports, provided feedback to refine the interview questions, ensuring clarity and relevance (Bloomberg & Volpe, 2016; Creswell & Poth, 2018). Triangulation, member checking, and maintaining an audit trail were

employed to enhance trustworthiness further. Triangulation was achieved by using multiple data sources, including interviews with participants, existing literature on ultra-endurance athletes and sleep, and observational data from public ultra-marathon running events when possible. By integrating these diverse data sources, the study achieved convergence and corroborated evidence from different perspectives, reducing bias and increasing the validity of the findings (Lincoln & Guba, 1985; Shenton, 2004; Yin, 2018).

Member checking involved sharing preliminary findings and interpretations with a subset of participants to confirm accuracy and resonance with their experiences. Participants were invited to review summaries of their interview data via email or Zoom and provide feedback on whether the researcher's interpretations aligned with their intended meaning. Any discrepancies were addressed through follow-up discussions to refine the analysis (Birt et al., 2016; Merriam & Tisdell, 2016; Shenton, 2004). Maintaining an audit trail ensured transparency by documenting all methodological decisions, data collection processes, and analysis steps. Together, these methods ensure that the study's findings are credible, transferable, and dependable, offering a comprehensive understanding of the phenomenon under investigation.

Study Procedures

The study procedures for this qualitative descriptive single-case study were designed to explore how ultra-marathon runners perceive the role of sleep in their physical health, psychological well-being, and social interactions during endurance events. Platforms such as the American Trail Running Association, UltraRunning Magazine forums, and Facebook running groups were utilized, as they are ideal for reaching active ultra-marathon participants. These platforms host communities that align with the study's target population—ultra-marathon runners

in the United States who have participated in at least one ultra-marathon within the past year (Kishi et al., 2024; Martin et al., 2018).

Recruitment involved posting a study flyer (Appendix D) on these platforms. For private groups, formal permission was requested from group administrators before sharing recruitment materials. The flyer included the study's purpose, eligibility criteria, researcher contact information, and an invitation for interested participants to reach out via email. Upon receiving initial inquiries, participants received a follow-up email with detailed information about the study, including its objectives, procedures, and ethical considerations. This email emphasized that participation was voluntary and that participants could withdraw at any time.

Once participants confirmed their interest, interviews were scheduled at mutually convenient times to accommodate participants' training and racing schedules. Participants were also offered the opportunity to ask questions and clarify expectations before providing verbal informed consent (Appendix B). Informed consent was obtained verbally via Zoom immediately before each interview began. Data were collected through semi-structured interviews (Appendix A) conducted via Zoom, a platform that offers flexibility for participants regardless of their geographic location (Creswell & Creswell, 2017; Creswell & Poth, 2018). Each interview lasted approximately 60 to 90 minutes and followed an interview guide designed to ensure consistency while allowing for the emergence of new themes (Bloomberg & Volpe, 2016; Engel, 1977). The interview guide included open-ended questions focused on participants' sleep routines, challenges in achieving adequate sleep during training and competition, and perceived impacts of sleep on physical health, psychological well-being, and social interactions.

Interviews were audio-recorded only to ensure accuracy and transcribed verbatim using Zoom's automatic transcription feature. Transcriptions were then reviewed and verified by the

researcher to ensure completeness and accuracy. All identifying information was removed from transcripts to maintain participant confidentiality (Bloomberg & Volpe, 2016; Merriam & Tisdell, 2016).

Data collection continued until data saturation was achieved—which typically occurs after 12 to 18 interviews—and a total of 15 participants were interviewed to ensure rich and comprehensive data. The primary data source was the semi-structured interviews, which are well-suited to capturing participants' in-depth experiences and perceptions. Before interviews began, participants were fully informed about the study's purpose, procedures, and their rights through a verbal informed consent process (Appendix B). This consent was obtained and audio-recorded before data collection. Participants' identities remained confidential, and pseudonyms were used to replace names in all transcripts, reports, and final publications. All digital data, including audio recordings and transcripts, were stored securely on a personal password-protected, encrypted device to ensure data privacy (Lincoln & Guba, 1985; Merriam & Tisdell, 2016). These procedures were designed to ensure that data collection was rigorous, ethical, and replicable, enabling a comprehensive understanding of how ultra-marathon runners perceive the role of sleep in their overall health, performance, and well-being.

Data Analysis

The data analysis for this qualitative descriptive single-case study used a systematic approach, employing thematic analysis to code and interpret the interview data. Thematic analysis is particularly well-suited for qualitative research as it enables the identification, analysis, and reporting of patterns or themes within the data (Braun & Clarke, 2023). This method facilitated an in-depth exploration of ultra-marathon runners' perceptions of sleep and its impact on their physical, psychological, and social well-being. To ensure the data collected

aligned with the research questions, specific interview questions (Appendix A) were designed to elicit relevant responses. For example, to address Research Question 1 (RQ1)—"How do ultra-marathon runners perceive the role of sleep in their physical health?"—Interview Questions 1, 2, 3, 4, and 5 focused on participants' sleep routines, perceived effects of sleep on physical performance, and the impact of sleep deprivation on recovery and injury prevention. To explore Research Question 2 (RQ2)—"How do ultra-marathon runners perceive the role of sleep in their psychological well-being?"—Interview Questions 6, 7, 8, 9, and 10 examined participants' experiences related to the mental challenges associated with inadequate sleep, including stress, mood changes, and cognitive functioning. For Research Question 3 (RQ3)—"How do ultra-marathon runners perceive the role of sleep in their social well-being?"—Interview Questions 11, 12, 13, 14, and 15 assessed how participants' sleep patterns affect their social interactions, support networks, and overall social engagement within the ultra-marathon community.

Initially, the audio-recorded interviews were transcribed verbatim using Zoom's transcription feature and then verified by the researcher for accuracy and completeness. These verified transcripts were analyzed manually using Braun and Clarke's (2023) reflexive thematic analysis framework. A structured Excel workbook was used to conduct open coding, where the researcher assigned initial codes to 918 meaning-rich excerpts based on participants' language, experiences, and context. This coding process allowed for inductive theme development while maintaining a consistent audit trail through reflexive notes, code definitions, and refinement logs.

After theme refinement was completed, NVivo software was used solely to generate visual representations of the final codes and themes. This included the creation of concept maps and cluster diagrams to illustrate relationships among themes and enhance clarity in the presentation of findings. The researcher remained actively engaged in interpreting and analyzing

all visual outputs to ensure alignment with the study's objectives and research questions. Themes such as "sleep management strategies," "impact of sleep deprivation," and "psychological and social effects of sleep" were developed through this interpretive and reflexive process, providing insights directly connected to the lived experiences of ultra-marathon runners. NVivo supported the final stage of visual organization but did not replace the researcher's central role in data interpretation and meaning-making (Charmaz, 2014; Corbin & Strauss, 2015).

Triangulation, which involves the use of multiple data sources, methods, or investigators to cross-check and validate findings, was employed to ensure the credibility and trustworthiness of the results (Denzin & Lincoln, 2012; Yin, 2018). Information about participants' experience levels, such as whether they were experienced ultra-marathon runners or first-time participants, was gathered during the interview process through questions outlined in Appendix A. For example, Question 3 in Appendix A asked participants, "How long have you been participating in ultra-endurance events?" This information was used during the analysis to compare responses between these groups, helping validate the consistency of emerging themes (Patton, 2015). Additionally, data from interviews were cross-checked with relevant literature on sleep and ultra-endurance sports to enhance the reliability of the findings. Document analysis was utilized when participants were already tracking their sleep through personal logs, diaries, or sleep-tracking devices, adding an additional layer of validation.

Member checking was conducted by sharing preliminary findings and interpretations with a subset of participants to confirm accuracy and resonance with their experiences. Participants were invited to review summaries of their interview data and emerging themes via email and Zoom and provide feedback on whether the researcher's interpretations aligned with

their intended meaning. Any discrepancies were addressed through follow-up discussions to refine the analysis (Birt et al., 2016; Merriam & Tisdell, 2016; Shenton, 2004).

To further enhance the study's objectivity and credibility, bracketing was employed. Bracketing involves the researcher intentionally setting aside personal preconceptions and biases to minimize their impact on the research process (Tufford & Newman, 2012). This approach helped maintain a clear focus on the participants' experiences and perspectives throughout the study. The researcher played an active role in the data analysis process, reflecting on potential biases and ensuring they did not unduly influence the findings. A reflexive journal was maintained throughout the study to document the researcher’s thoughts, decisions, and reflections on the data analysis process, thereby enhancing the transparency and rigor of the research (Berger, 2015). The researcher also remained open to unexpected findings, allowing the data to speak for itself rather than fitting it into preconceived categories.

The data analysis was carefully conducted to ensure that the findings were robust and aligned with the study’s objectives. Using Braun and Clarke’s (2023) reflexive thematic analysis framework, the researcher manually coded and analyzed the data within a structured Excel workbook. This process generated meaningful insights into the role of sleep in the lives of ultra-marathon runners by identifying recurring patterns and themes across participants' narratives. NVivo software was used only after theme development to create visual representations of code relationships and thematic structures. Triangulation, member checking, and a reflexive analytic approach further enhanced the study’s credibility and trustworthiness. These strategies supported a comprehensive understanding of how ultra-marathon runners perceive the impact of sleep on their physical, psychological, and social well-being.

Assumptions

Several assumptions underpinned this qualitative descriptive single-case study's research design, methodology, and analysis. Each was grounded in the study's context and supported by scholarly rationale. Understanding these assumptions is crucial as they form the foundation for the study's credibility and dependability. One fundamental assumption was that participants would be truthful and forthcoming in their interview responses. This assumption was vital because the data's depth and richness depended on the ultra-marathon runners' honesty and openness when discussing their sleep practices, challenges, and perceptions. Given the sensitive nature of discussing personal health and psychological well-being, it was assumed that the confidentiality measures and the rapport established during the interviews would encourage participants to share their experiences candidly (Seidman, 2019).

Another assumption was that the participants selected for the study represented a diverse cross-section of ultra-marathon runners in the United States. This assumption was based on the purposive sampling strategy, which sought to include runners of different ages, genders, and experience levels. The rationale here is that by ensuring a diverse sample, the study captures a wide range of perspectives and experiences, thereby enhancing the transferability of the findings within the context of ultra-marathon running (Patton, 2015).

Additionally, it was assumed that the thematic analysis method used to analyze the data would effectively identify meaningful patterns and themes related to the research questions. This assumption was grounded in the established credibility of reflexive thematic analysis in qualitative research, particularly for exploring complex and multifaceted phenomena such as sleep management among athletes (Braun & Clarke, 2023). It was further assumed that the manual coding process, conducted within a structured Excel workbook, would accurately reflect

participants' experiences and allow the researcher to derive relevant and dependable insights. NVivo software was used only after coding and theme development were complete, serving to visually organize and present the relationships among final themes.

Lastly, it was assumed that the researcher's positionality, including any potential biases, would be managed effectively through reflexive practices, such as bracketing and maintaining a reflexive journal. Bracketing involves the researcher setting aside personal preconceptions and biases to minimize the impact on the research process, thereby enhancing the study's objectivity and credibility (Tufford & Newman, 2012). Alongside bracketing, a reflexive journal was maintained to continuously reflect on the research process and the impact of the researcher's perspectives on the study's findings. The rationale for these practices lies in the importance of reflexivity in qualitative research, which helps ensure that the researcher remains aware of and mitigates any biases that could influence data interpretation (Berger, 2015). These assumptions were critical to the study's design and execution, providing the underlying rationale for the chosen methodology and supporting the credibility and transferability of the study's findings in exploring the role of sleep in the lives of ultra-endurance athletes.

Limitations

While this qualitative descriptive single-case study was designed to provide in-depth insights into the role of sleep in the lives of ultra-marathon runners, several limitations must be acknowledged. These limitations, inherent to the study's design and methodology, may impact the findings and their broader applicability. One significant limitation was the reliance on self-reported data, which is subject to biases such as memory recall and social desirability. Participants may have inadvertently misrepresented their sleep practices or experiences due to lapses in memory or a desire to present themselves in a more favorable light. This limitation is

common in qualitative research and can affect the accuracy and authenticity of the data collected (Maxwell, 2013; Patton, 2015). To mitigate this limitation, strategies were employed, including building rapport during interviews to encourage honesty and conducting member checking, where participants reviewed their transcripts to ensure that their statements were accurately represented (Creswell & Poth, 2018).

Another limitation was the lack of generalizability of the findings. Since this study focused on a small, purposively selected sample of ultra-marathon runners in the United States, the results may not apply to all ultra-marathon runners or athletes in different sports or geographical regions. Qualitative case studies, by nature, are not intended to produce broadly generalizable findings but rather to provide rich, contextualized insights into specific phenomena (Stake, 1995; Yin, 2018). However, the researcher aimed to enhance the transferability of the findings by providing detailed descriptions of the participants, their contexts, and the research process, allowing readers to determine the applicability of the results to other settings (Lincoln & Guba, 1985).

Additionally, researcher bias was a limitation in this qualitative research, where the researcher's perspectives and interpretations could have influenced data collection, analysis, and interpretation. Despite efforts to remain objective, the researcher's background, experiences, and expectations may have shaped how the data were interpreted (Berger, 2015). To address this, the researcher engaged in reflexive practices throughout the study, including maintaining a reflexive journal to document personal reflections and potential biases, and employing bracketing techniques to set aside preconceptions that may have affected the research process (Finlay, 2002; Tufford & Newman, 2012). These approaches helped ensure that the findings are as unbiased and credible as possible.

Finally, the study's design did not account for the potential influence of external factors, such as cultural differences, socioeconomic status, or varying experience levels among participants, which could affect their perceptions of sleep. While the researcher focused on understanding the individual experiences of ultra-marathon runners, these external factors may still shape those experiences (Maxwell, 2013). To address this limitation, demographic and contextual influences that could shape participants' perspectives were explored through interview questions (Appendix A and E). For example, questions such as "What level of experience do you have in ultra-endurance sports?" and "What is your typical training frequency and duration?" provided insight into participants' backgrounds and unique contexts. Additionally, targeted questions related to the study's research questions, such as "How does your sleep schedule impact your social interactions with friends, family, or fellow athletes?" and "What, if any, physical health issues have you experienced that you believe were related to inadequate sleep?" were designed to elicit nuanced responses about external factors that may affect their views on sleep. By including these detailed and exploratory questions, the researcher aimed to account for potential external influences while focusing on understanding participants' experiences. In conclusion, while these limitations are inherent to the study's qualitative design, careful consideration and mitigation strategies were implemented to ensure that the findings remain credible, trustworthy, and valuable in exploring the role of sleep in ultra-marathon running.

Delimitations

In this qualitative descriptive single-case study, several delimitations were intentionally established to focus the research and align it with the study's objectives, problem statement, purpose, and research questions. These delimitations defined the scope of the research, ensuring that the study remained manageable and relevant to the specific phenomena under investigation.

One primary delimitation was the selection of ultra-marathon runners in the United States as the target population. This decision was made to explore a specific group of athletes who face unique sleep management challenges due to their sport's extreme demands. By focusing on this population, the researcher provided insights directly relevant to ultra-marathon runners, as opposed to a broader athletic population. This delimitation is supported by the existing literature, which highlights the distinct physical and psychological stresses experienced by ultra-marathon runners, making them an ideal group for studying the impact of sleep on athletic performance (Kishi et al., 2024; Martin et al., 2018). The study's findings are particularly relevant to the ultra-endurance sports community, contributing to the development of tailored sleep management strategies.

Another delimitation was the qualitative descriptive single-case study design, which was chosen to capture the in-depth experiences and perceptions of a small, purposive sample of ultra-marathon runners. This methodological choice limited the study's generalization of findings to a broader population but allowed for a richer, more nuanced understanding of the factors influencing sleep among ultra-marathon runners. The rationale for this delimitation is grounded in the study's purpose, which was to explore how ultra-marathon runners perceive the role of sleep in their physical, psychological, and social well-being during endurance events. A qualitative approach is particularly suited for this purpose, as it facilitates the exploration of complex, context-dependent experiences that are not easily quantified (Creswell & Poth, 2018; Stake, 1995).

The selection of semi-structured interviews (Appendix A) as the primary data collection method also served as a delimitation. While other methods, such as surveys or physiological measurements, could have been employed, the choice of interviews allowed for a deeper

exploration of participants' subjective experiences and personal narratives related to sleep. This aligns with the study's theoretical framework, which draws on the biopsychosocial model to understand the multifaceted impacts of sleep on ultra-marathon runners' lives (Engel, 1977). The use of interviews is justified by the need to capture the complex interplay between biological, psychological, and social factors that influence sleep, which is central to the study's research questions.

Furthermore, the study was delimited to participants who had completed at least one ultra-marathon within the last year. This criterion ensured that participants had recent and relevant experiences with the challenges of sleep management during ultra-endurance events. By narrowing the focus to this specific timeframe, the researcher aimed to capture current practices and perceptions likely to be influenced by the latest sports trends and developments. This delimitation supports the study's relevance to the current context of ultra-marathon running, as documented in recent literature (Kishi et al., 2024; UltraRunning Magazine, 2023). These delimitations intentionally focused the study on a specific population, methodological approach, and timeframe, ensuring that the research was aligned with its objectives and contributed meaningful insights to the existing body of knowledge on sleep management in ultra-endurance sports. The decisions underlying these delimitations are closely related to the study's theoretical framework, problem statement, purpose, and research questions, ensuring a coherent and targeted exploration of the relevant experiences of ultra-marathon athletes.

Ethical Assurances

This study received approval from National University’s Institutional Review Board (IRB) to ensure compliance with ethical research practices, as required by institutional and federal guidelines, before beginning data collection (Belmont Report, 1979; Creswell & Poth,

2018). The IRB approval confirmed that the study posed no greater than minimal risk to participants, as it involved conducting non-invasive, semi-structured interviews designed to minimize potential harm (Belmont Report, 1979). Participants were informed that their participation was entirely voluntary (Appendix C) and that they had the right to withdraw from the study at any time without any negative consequences, thus respecting their autonomy and ensuring that they were not subjected to undue pressure (Seidman, 2019).

Several measures were implemented to maintain confidentiality in line with ethical research standards. Confidentiality means that while participants' identities were known to the researcher during the interviews, their information remained protected throughout the study (Bloomberg & Volpe, 2016; Creswell & Poth, 2018). Participants' identities were protected by assigning pseudonyms and removing all identifying information from transcripts, reports, and final publications. Recognizing that anonymity cannot be guaranteed due to the interactive nature of interviews, every effort was made to mitigate risks associated with deductive disclosure, particularly in a niche population such as ultra-marathon runners (Lincoln & Guba, 1985; Merriam & Tisdell, 2016). Findings were presented aggregately to avoid identifying individual participants, and organizational or institutional names were replaced with fictitious names unless explicit written permission was obtained as part of site approval.

Data security was prioritized to ensure that all research materials were protected. The following mechanisms were implemented:

- Informed consent forms were stored separately from the interview data to prevent any linkage between participants' names and their responses.

- Digital data, including audio recordings and transcripts, were securely stored on the researcher's password-protected, encrypted laptop, accessible only to the researcher. Files were kept in a dedicated, password-protected folder.
- Any physical documents (e.g., hard copies of transcripts) were stored in a locked file cabinet located in the researcher's private, locked office, with the key retained solely by the researcher.
- All data and research materials will be retained for three years after study completion and then securely destroyed by shredding physical documents and permanently deleting electronic files (APA, 2017).

Informed consent was obtained verbally via Zoom and audio-recorded before each interview began. This process ensured that participants fully understood their role, the study's purpose, and their rights, including the right to withdraw at any time without consequence (Lincoln & Guba, 1985; Merriam & Tisdell, 2016). Participants were also reminded that confidentiality may be breached if they disclosed information that suggested a risk of harm to themselves or others, as required by ethical and legal standards.

The researcher played a critical role in the study, including data collection, analysis, and interpretation (Berger, 2015; Creswell & Poth, 2018). Reflexive practices were actively employed throughout the research process to address potential researcher bias. These included bracketing to consciously set aside preconceptions and maintaining a reflexive journal to document personal reflections, decisions, and interpretations, ensuring transparency and minimizing bias (Berger, 2015; Finlay, 2002; Tufford & Newman, 2012).

Additional strategies to enhance the credibility and trustworthiness of the study included:

- Member checking: Participants had the opportunity to review their interview transcripts to confirm the accuracy and authenticity of the data (Birt et al., 2016; Lincoln & Guba, 1985).
- Peer debriefing: Regular consultations with the dissertation chair and committee members provided external validation of coding and analysis processes, reducing the influence of potential bias (Shenton, 2004).

These ethical considerations aligned with the principles outlined in the Belmont Report (1979), emphasizing respect for persons, beneficence, and justice in research involving human subjects. The researcher remained committed to upholding high standards of integrity, participant protection, and confidentiality throughout the study (Belmont Report, 1979; Creswell & Poth, 2018).

Summary

This chapter outlined the research methodology and design for a qualitative descriptive single-case study that explored how ultra-marathon runners in the United States perceive the role of sleep in relation to their physical health, psychological well-being, and social interactions during endurance events. The researcher addressed the critical issue of inadequate sleep among athletes, particularly those involved in ultra-endurance sports, and examined the nuanced impacts of sleep on these athletes' performance and overall well-being (Fox et al., 2020; Gattoni et al., 2022). The methodology and design were based on a qualitative descriptive single-case study approach, which was chosen for its effectiveness in capturing in-depth and context-specific insights into the experiences of ultra-marathon runners. This approach is well-suited for exploring complex phenomena that are not easily quantified, such as the personal and contextual factors influencing sleep among athletes (Creswell & Poth, 2018; Stake, 1995). By focusing on a

specific group of athletes who face unique sleep challenges due to the extreme demands of their sport, the researcher gathered detailed and meaningful data that contribute to a deeper understanding of the role of sleep in ultra-endurance sports (Kishi et al., 2024).

The target population for this study consisted of ultra-marathon runners in the United States who were 18 to 62 years of age and had participated in at least one ultra-marathon within the last year. This population was highly relevant to the study's purpose, as these athletes frequently experience disrupted sleep patterns and insufficient rest, which can adversely affect their physical health, psychological well-being, and performance (Martin et al., 2018). A sample of 12–18 participants was originally targeted to ensure a diverse representation of experiences and to achieve data saturation, and 15 participants were ultimately included to ensure robust data (Guest et al., 2006). Recruitment occurred through public and private online platforms, including social media groups (Facebook running groups) and ultra-marathon community forums, such as the American Trail Running Association and UltraRunning Magazine forums. Public platforms were accessed directly, while permission was obtained from group administrators prior to posting recruitment flyers on private platforms. All permissions were documented to comply with ethical guidelines (Belmont Report, 1979; Creswell & Poth, 2018). A flyer (Appendix D) was posted on these platforms to invite eligible participants to contact the researcher via email. Interested individuals received a detailed informational email outlining the study's objectives, time commitment, and confidentiality measures. Participants were offered the opportunity to ask questions and clarify expectations before providing verbal consent.

Data collection involved semi-structured interviews (Appendix A) conducted via Zoom, which provided flexibility in accommodating participants' schedules and geographical locations (Creswell & Creswell, 2017; Creswell & Poth, 2018). Each interview lasted approximately 60 to

90 minutes and followed an interview guide designed to ensure consistency while allowing for the exploration of emergent themes. Topics included participants' sleep routines, challenges in achieving adequate sleep, perceived impacts of sleep on physical performance, psychological well-being, and social dynamics, as well as strategies for improving sleep quality (Engel, 1977; Fox et al., 2020; Martin et al., 2018). The interviews were audio-recorded only, transcribed verbatim using Zoom's transcription feature, and verified by the researcher for accuracy. Data were analyzed using reflexive thematic analysis following the framework established by Braun and Clarke (2023). The coding and theme development process was conducted manually using a structured Excel workbook. NVivo software was used only after the analysis was complete to create visual representations of theme clusters and code relationships. Participant confidentiality was ensured by using pseudonyms and removing all identifying information (Bloomberg & Volpe, 2016; Merriam & Tisdell, 2016). The thematic analysis and triangulated findings are presented in Chapter 4.

The researcher acknowledged several assumptions, limitations, and delimitations in the study. Key assumptions included expecting participants to provide honest and accurate accounts of their experiences and that the selected sample would represent a diverse cross-section of ultra-marathon runners in the United States (Patton, 2015). Limitations of the study included reliance on self-reported data, which may be subject to biases such as memory recall and social desirability, and the potential lack of generalizability due to the qualitative nature of the research (Maxwell, 2013; Patton, 2015). Delimitations included focusing on ultra-marathon runners in the United States and using semi-structured interviews as the primary data collection method, aligning with the study's purpose of exploring the complex interplay between sleep and athletic performance (Creswell & Poth, 2018; Engel, 1977).

Ethical assurances for the study included obtaining approval from National University's Institutional Review Board (IRB) before beginning data collection and ensuring that the study complied with ethical research practices as required by institutional and federal guidelines (Belmont Report, 1979; Creswell & Poth, 2018). Confidentiality was maintained by using pseudonyms, securely storing all data, and keeping informed consent forms separate from the data to ensure no link between participants' names and responses (Lincoln & Guba, 1985; Merriam & Tisdell, 2016). The researcher used reflexive practices, including maintaining a reflexive journal to document personal reflections and employing bracketing to minimize potential biases (Berger, 2015; Finlay, 2002; Tufford & Newman, 2012). Further, member checking was conducted to confirm data accuracy, and peer debriefing occurred with the dissertation committee to validate the findings (Birt et al., 2016; Lincoln & Guba, 1985; Shenton, 2004).

This chapter comprehensively overviews the study's research design and methodology. The qualitative descriptive single-case study approach, combined with a purposive sampling strategy and semi-structured interviews, allowed the researcher to explore sleep's complex and multifaceted impacts on ultra-marathon runners. By addressing the study's assumptions, limitations, delimitations, and ethical considerations, the researcher established a solid foundation for this study, contributing valuable insights into sleep's role in ultra-endurance sports. The next chapter presents the findings from the data collected, offering an in-depth analysis of the sleep management practices and experiences of ultra-marathon runners and furthering understanding of how sleep influences athletic performance and well-being (Creswell & Poth, 2018; Fox et al., 2020; Gattoni et al., 2022; Yin, 2018). The thematic analysis, triangulation findings, and results will be discussed in Chapter 4.

Chapter 4: Findings

The problem addressed in this study was the negative impact of inadequate sleep on athletes' physical health, psychological health, and social factors. The Centers for Disease Control (CDC, 2023) highlighted a general shortfall in sleep among adults, with only 72.3% achieving sufficient sleep in 2020, a concern that extends into the athletic realm (Fox et al., 2020; Riegler et al., 2023). The purpose of this qualitative descriptive single-case study was to explore how ultra-marathon runners in the United States perceive the role of sleep in relation to their physical health, psychological health, and social factors during endurance events. Chapter four will begin by addressing the trustworthiness of the data. Next, the researcher will provide a description of the sample demographics. Then, the researcher will present the results of the data analyses in response to each research question. After presenting the results, the researcher will evaluate the findings. Chapter four will conclude with a summary.

Trustworthiness of the Data

Trustworthiness in this qualitative descriptive single-case study was established through multiple strategies aligned with the recommendations of Lincoln and Guba (1985), Shenton (2004), and Nowell et al. (2017). The researcher implemented methodological rigor across credibility, transferability, dependability, and confirmability to ensure analytic transparency and trust in the findings. Credibility was achieved through several means. Triangulation was employed by integrating multiple data sources, including semi-structured interviews, existing literature, and contextual insights gathered from participants' descriptions of their sleep routines and training experiences (Denzin & Lincoln, 2012; Yin, 2018). Member checking was conducted by sharing verbatim transcripts with participants for review and clarification (Birt et al., 2016), ensuring the authenticity of the data. These verification steps occurred prior to formal analysis.

Meanings were then derived through reflexive thematic analysis (Braun & Clarke, 2023), allowing for the identification of nuanced patterns and themes grounded in participants' lived experiences. Peer debriefing with members of the dissertation committee provided additional credibility through external review of analytic decisions and emergent findings (Shenton, 2004).

Reflexivity was maintained throughout the study via a dedicated reflexive journal, where the researcher documented thoughts, interpretive decisions, analytic questions, and theoretical influences at every stage of the process. Bracketing was employed to acknowledge and minimize potential bias by intentionally setting aside personal assumptions during data engagement (Berger, 2015; Tufford & Newman, 2012). These practices align with the principles of reflexive thematic analysis, where researcher subjectivity is recognized as a resource for meaning-making rather than a source of contamination (Braun & Clarke, 2023).

Dependability was supported through a comprehensive audit trail documented in a structured Excel workbook. All stages of the coding process were tracked, including the generation of 144 initial codes, codebook development, iterative code refinement, theme construction, and alignment to research questions and the Biopsychosocial Model. Each code was defined, linked to participant quotes, and accompanied by reflexive commentary. Coding decisions were recorded in a refinement log, which documented whether each code was retained, renamed, merged, or removed, along with rationales for all changes. These procedures followed the auditability standards recommended by Nowell et al. (2017) and Braun and Clarke (2023), ensuring that every interpretive decision could be traced back to the original data.

Confirmability was demonstrated by ensuring that findings were grounded in participants' meanings rather than the researcher's preconceptions. This was achieved by maintaining all 918 original coded data extracts across the final codes, preserving even low-

frequency and initially removed codes for potential nesting under broader themes. Quotes were not summarized or selectively sampled; rather, every coded quote was retained to support later synthesis and ensure completeness. Although NVivo was not used for coding or theme development, it was employed in the final stage to generate visual representations of theme clusters and code relationships to support dissemination and presentation. The analytic process remained entirely manual and interpretive, grounded in the principles of reflexive thematic analysis and guided by theoretical and empirical saturation.

Transferability was supported through thick description of the study context, participant demographics, interview protocol, and methodological steps (Lincoln & Guba, 1985; Nowell et al., 2017; Shenton, 2004). Detailed documentation allows readers to evaluate the relevance of the findings to other populations or settings. Although the findings are not statistically generalizable, they offer rich insight into the lived experiences of ultra-endurance athletes and their complex negotiations with sleep, identity, and training. By employing these layered and rigorous strategies, the researcher established the trustworthiness of the data and ensured a credible, transparent account of ultra-marathon runners' experiences with sleep management in the context of training and performance.

Results

The purpose of this qualitative descriptive single-case study was to explore how ultra-marathon runners in the United States perceive the role of sleep in relation to their physical health, psychological health, and social interactions during endurance events. A total of 15 ultra-marathon athletes participated in semi-structured interviews conducted via Zoom, with each session lasting approximately 60 to 90 minutes. Data saturation was achieved after completing these 15 interviews, demonstrating that no new themes or insights were emerging.

Participant recruitment involved posting a detailed recruitment flyer (Appendix D) on various targeted online platforms, including the American Trail Running Association, UltraRunning Magazine forums, and Facebook running groups. Formal permission was obtained from the administrators of private groups before posting recruitment materials. Interested individuals contacted the researcher via email, where eligibility was confirmed based on established criteria: participants were required to be U.S. residents aged 18 to 62 years and must have completed at least one ultra-marathon in the past year. Participants received a detailed informational email outlining the study's objectives, procedures, and ethical considerations. Verbal informed consent was obtained at the start of each Zoom interview, and pseudonyms were assigned to ensure confidentiality.

The final sample included 15 ultra-marathon runners from various regions throughout the United States. Participants' ages ranged from 25 to 59 years, with an average age of approximately 39.5 years. The group comprised eight females (53%) and seven males (47%), indicating a balanced gender distribution. Participants' experience with ultra-endurance events varied widely, spanning from eight months to 10 years, with an average participation duration of roughly 4.2 years. Participants self-identified their experience levels as novice (n = 4, 27%), intermediate (n = 3, 20%), and seasoned competitors (n = 8, 53%). Table 1 provides detailed demographic data for all 15 participants, encompassing gender identity, age, years of ultra-marathon participation, experience level, and typical weekly training routines. Specific state locations have been withheld from the table to ensure confidentiality, reflecting ethical privacy considerations.

Table 1

Participant Demographic Table

Pseudonym	Gender	Age	Years	Experience	Training Routine
Mark	Male	45	5 years	Intermediate	7 days/week, 0.5-6 hours
Sarah	Female	25	1 year	Intermediate	6 days/week, 1-3 hours
Andrea	Female	33	8 months	Novice	5 days/week, 2-3 hours
Jennifer	Female	38	5 years	Seasoned	6-7 days/week, 1-4 hours
Lisa	Female	59	8 years	Seasoned	7 days/week, 1-6 hours
Justin	Male	29	2 years	Seasoned	5 days/week, varied runs & strength training
Robert	Male	44	6 years	Seasoned	4-6 days/week, varied miles
Michelle	Female	58	7 years	Seasoned	6-7 days/week, long weekend runs
Eric	Male	43	2 years	Novice	6 days/week, 6-8 hours/week
Kelly	Female	40	2 years	Intermediate	6 days/week, running, swimming, biking
Amy	Female	39	3 years	Novice	6 days/week, 1-5 hours
Brian	Male	32	5 years	Seasoned	7 days/week, at least 1 hour daily
Daniel	Male	39	3 years	Intermediate	4-5 days/week, 8 hours total
Emily	Female	33	1 year	Novice	3-4 days/week, 10-60 mile runs
Jason	Male	35	10 years	Seasoned	5-6 days/week, 0.5-3 hours

Data Collection. Following approval from the Institutional Review Board (IRB) at National University, data collection began for this qualitative descriptive single case study exploring ultra-endurance athletes' perceptions of sleep in relation to their physical health, psychological well-being, and social interactions. The data collection process included several structured steps to uphold rigor, accuracy, and ethical considerations. These steps involved participant recruitment, obtaining informed consent, gathering demographic information, and conducting structured yet flexible semi-structured interviews aligned with the interview protocol (Appendix C).

Recruitment involved strategically posting recruitment materials across various online platforms, including ultra-marathon-specific Facebook groups and endurance athlete community forums. Community leaders and administrators were also contacted directly to distribute

recruitment information further. Participants who expressed interest were screened for eligibility through email communication. Eligible individuals received informed consent documents and arranged convenient interview times via Zoom. At the start of each Zoom session, verbal confirmation of informed consent was obtained.

Demographic data collection took place prior to the initiation of the interviews. After participants provided verbal consent to participate in the study via Zoom, a demographic questionnaire (Appendix E) was administered using Zoom's Poll feature, which allowed participants to complete the questions directly. Semi-structured interviews were conducted following the approved interview protocol (Appendix C), which was designed to facilitate consistency while allowing for the emergence of new topics of discussion. The interview questions specifically focused on participants' sleep habits, the perceived impact of inadequate sleep on physical and psychological health, social experiences, and strategies for effectively managing sleep. Each interview was recorded using Zoom's audio recording features, followed by an initial automatic transcription via Zoom's integrated software. The researcher manually reviewed and corrected these transcripts to ensure verbatim accuracy. Participants were then given the opportunity to review and validate their transcripts through member checking, enhancing both accuracy and credibility.

Data Analysis. Guided by Braun and Clarke's (2023) reflexive thematic analysis framework, the interview transcripts underwent a comprehensive, manual coding and theme development process. The researcher first conducted multiple thorough readings of each transcript to become familiar with the data and documented initial reflections in a reflexive journal. Transcripts were then segmented into 918 meaning-rich excerpts, which were systematically coded in a structured Excel workbook. Codes were applied inductively and

descriptively, grounded in participants' verbatim responses, and organized based on semantic meaning. As coding progressed, new codes were created to reflect emerging concepts and patterns related to the research questions. These codes were then grouped into broader conceptual clusters aligned with each research question and the Biopsychosocial Model. Although NVivo software was not used during the analytical stages, it was later employed to visually represent the final themes and code relationships for dissemination purposes. This structured, reflexive approach ensured a transparent audit trail and faithful representation of participants' experiences. A total of nine themes emerged from the reflexive thematic analysis. A full table showing the initial codes grouped under each finalized theme is provided in Appendix G. The themes were organized according to the research questions:

RQ1

How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their physical health during endurance events?

RQ2

How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their psychological health during endurance events?

RQ3

How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their social factors during endurance events?

Table 2 presents a summary of the themes and their alignment with each research question. Some themes addressed multiple domains of the Biopsychosocial Model, and in such cases, they were used to support more than one research question.

Table 2

Alignment of Final Themes With Research Questions

Research Question	Themes Used to Address the Research Question
RQ1: How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their physical health during endurance events?	Theme 1: Strategic Sleep Optimization for Physical and Mental Recovery Theme 2: Bidirectional Sleep Negotiation Across Training and Life Demands Theme 6: Navigating Physical Limits and Health Behaviors in Endurance Training Theme 8: Physiological Consequences and Adaptations Related to Sleep Theme 9: Consequences and Contexts of Sleep Disruption
RQ2: How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their psychological health during endurance events?	Theme 1: Strategic Sleep Optimization for Physical and Mental Recovery Theme 3: Psychological Disruption and Adaptation Across the Ultra-Endurance Journey Theme 5: Lifestyle Trade-Offs and Internal Conflicts in Endurance Commitment Theme 9: Consequences and Contexts of Sleep Disruption
RQ3: How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their social factors during endurance events?	Theme 2: Bidirectional Sleep Negotiation Across Training and Life Demands Theme 4: Identity, Values, and Belonging in the Ultra-Endurance Community Theme 7: Navigating Social Expectations and Sleep Boundaries Theme 9: Consequences and Contexts of Sleep Disruption

Note. This table presents the research questions and the themes that addressed each question. Some themes aligned with more than one question due to their multidimensional relevance across the biopsychosocial spectrum.

Given the volume and complexity of codes generated in this study, presenting the findings in tables provided a clearer and more accessible visualization than concept maps alone. While initial concept maps were created in NVivo to explore thematic relationships, the sheer number of codes and the need to highlight overlaps across biopsychosocial domains made it challenging to represent these connections clearly in a single diagram. As a result, the final analysis and presentation of themes, codes, and supporting participant quotations were organized

in Microsoft Excel tables. This tabular format facilitated easier reading, systematic organization, and enhanced transparency for both researchers and readers (Table 3).

The Excel-based tables allowed for a detailed and replicable audit trail, supporting analytic coherence when organizing findings by research question and biopsychosocial domain. These tables complemented earlier NVivo visualizations and served as the primary means for illustrating how codes, themes, and supporting data were developed. Triangulation was achieved by integrating interview data with existing literature, participant demographics, and reflexive memos, thereby ensuring analytic rigor and theoretical alignment. Each theme was thoroughly defined, supported by direct participant quotations, and systematically categorized according to the relevant research question, providing detailed insight into how ultra-marathon runners experience, interpret, and respond to inadequate sleep across physical, psychological, and social domains.

Table 3

Grouping of Codes into Finalized Themes

Theme	Initial Codes Clustered to Identify Theme	Theme Frequency
Theme 1: Strategic Sleep Optimization for Physical and Mental Recovery	Caffeine sensitivity, Caffeine timing, Consistent sleep schedule, Hydration strategies, Napping strategies, Prioritizing sleep, Sleep tracking via technology, Temperature cues for alertness, Tracking HRV for training, Tracking sleep patterns, Improved sleep during training, Importance of sleep for performance, Sleep for physical recovery, Sleep improves mood, Sleep improves training mindset, Sleep hygiene practices, Sleep monitoring technology, Sleep quality perception, Sleep routine, Enjoyment of ultra training	15
Theme 2: Bidirectional Sleep Negotiation Across Training and Life Demands	Adapting training to sleep quality, Sleep-performance relationship, Structured training, Time commitment of ultra training, Training alone, Training improves mental state,	15

Theme	Initial Codes Clustered to Identify Theme	Theme Frequency
Theme 3: Psychological Disruption and Adaptation Across the Ultra-Endurance Journey	Training improves sleep, Training locations, Training volume adaptation, Balancing work and training demands, Increased work demands, Impact of sleep on work performance, Sleep impacts work performance, Sleep schedule adaptation to work, Afternoon activity preference post-remote work Accepting pre-race sleep loss, Anticipation of sleep impact in longer race, Pre-race mental activity, Recovery delay from poor sleep, Sacrificing sleep for ultra community, Emotional experiences during races, Mental resilience, Motivation after failed ultra, Motivation for ultra-running, Motivation through adversity, Reflection on personal low point	14
Theme 4: Identity, Values, and Belonging in the Ultra-Endurance Community	Community integration, Cultural norms of positivity in ultra-running, Decision to train for ultra, Focus on finishing over speed, Identity as an ultra-runner, Lifestyle changes with training, Supportive ultra environment	12
Theme 5: Lifestyle Trade-Offs and Internal Conflicts in Endurance Commitment	Consequences of deviating from routine, Consequences of personal crisis, Internal negotiation of boundaries, Lifestyle cost of ultra training, Prioritizing active lifestyle over medical treatment, Prioritizing Schedule for Mental Health, Call for ultra research, Reflection on personal low point	9
Theme 6: Navigating Physical Limits and Health Behaviors in Endurance Training	Adaptation to training volume, Benefits of intermittent fasting, Dehydration awareness, Discomfort with treadmill running, Environmental factors affecting sleep, Managing illness during training, No altitude sickness experienced, Proactive physical maintenance, Professional athletes focus on physical optimization	7
Theme 7: Navigating Social Expectations and Sleep Boundaries	Kids as excuse to leave social events, Partner influence, Prioritizing relationships, Scheduling training around family, Self-care for relational health, Sleep affecting social activities, Sleep and romantic relationships, Social life affected by sleep, Ultra community support, Lack of understanding from non-runners	15

Theme	Initial Codes Clustered to Identify Theme	Theme Frequency
Theme 8: Physiological Consequences and Adaptations Related to Sleep	Body adapts to early wake time, Body adjustment to training volume, Elevated heart rate post-ultra, Inability to stay awake during training, Morning routine, Perceived performance despite sleep deprivation	13
Theme 9: Consequences and Contexts of Sleep Disruption	Sleep deprivation from crewing/pacing, Sleep disruption, Sleep disruption due to partner's health, Sleep deprivation in longer races, Sleep deprivation impacts mental resilience, Exhaustion from sleep deprivation, Fatigue from sleep deprivation, Lack of sleep affects concentration, Lack of sleep affects mood, Lack of sleep increases illness, Limited sleep duration, Low sleep score post-ultra, Mental overactivity post-ultra, No correlation of sleep and race emotions, Post-race fatigue	14

Note. Codes were clustered to form finalized themes. Theme frequency refers to the number of unique participant interviews in which each theme was represented.

Research Question 1. How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their physical health during endurance events?

To answer Research Question 1, the interview data was analyzed thematically following Braun and Clarke's (2023) reflexive approach. Codes related to physical health and sleep were assembled, categorized, and grouped into five major themes. The following section presents the first of these themes as supported by direct participant quotes and detailed narrative descriptions. The themes were not mutually exclusive; instead, they reflected the multi-dimensional ways participants perceived sleep's impact on their physical functioning during ultra-endurance training and events.

Strategic Sleep Optimization for Physical and Mental Recovery. This theme reflects the deliberate, performance-oriented approaches ultra-endurance athletes use to enhance sleep for recovery, mood regulation, and training effectiveness. It includes behaviors such as tracking physiological signals, prioritizing rest, and employing sleep hygiene techniques to maximize

both physical and psychological restoration. These practices are embedded within the athletes' routines and represent strategic self-regulation in pursuit of endurance goals.

Ultra-endurance athletes in this study consistently described sleep not as passive rest but as a strategic and essential tool for enhancing recovery, training effectiveness, and psychological regulation. Rather than treating sleep as secondary to performance, participants embedded routines and systems designed to protect and optimize rest. For example, Eric explained, "While you're sleeping, that's when your body heals. If you're not getting good sleep, those little nagging injuries are hard to recover from." Similarly, Michelle noted, "If I do not sleep well, my body is not as forgiving… I believe the importance of sleep is greatly understated." While both emphasized the physical necessity of sleep for recovery, Eric's reflection stemmed from training observations, whereas Michelle spoke from years of personal trial and error, as well as a shift in values following an injury.

In contrast to these physical recovery narratives, other athletes emphasized the impact of sleep on psychological readiness and mood regulation. Lisa stated, "Motivation and sleep are very connected… Good training, positive motivation, and a supportive community help your mental state." Andrea echoed this, noting, "I am a lot less impulsive when I am well-rested. I negotiate with myself a lot better." While Lisa made connections between social factors and sleep-supported mood, Andrea concentrated more narrowly on the emotional regulation that followed quality rest.

Tracking and data monitoring also played a significant role in participants' sleep management strategies. Eric relied on biometric feedback: "I use my Garmin watch to track my HRV status, which I find super valuable for planning training." Justin also utilized wearable technology, noting, "Coros provides basic workout input, run tracking, and gives an efficiency

score after each run." Although both athletes depended on feedback loops for sleep and performance planning, Eric used HRV trends to influence daily readiness, while Justin used efficiency scores to evaluate overall training outcomes. Notably, Lisa and Andrea also used Garmin, though Lisa admitted she rarely checked her data, whereas Andrea expressed frustration with limited sleep tracking due to a faulty secondhand device. These differences highlight a common goal of monitoring recovery, tempered by individual preferences and technological limitations.

Participants also described highly personalized behavioral strategies to support sleep. Michelle described a structured nightly wind-down: "I do a yoga stretching routine every night, faithfully… drink tea, and use an eye mask." In contrast, Mark emphasized what he avoided: "Caffeine drives me nuts if I drink coffee after 10 a.m." While both made deliberate adjustments to protect sleep, Michelle's approach was ritualistic and sensory-based, whereas Mark's focused on eliminating known disruptors. Similarly, Emily and Jennifer emphasized evening routines such as stretching and pre-bed relaxation, but Jennifer, unlike Emily, included naps as a flexible supplement to nighttime sleep, saying, "I am a big proponent of naps… I will take midday, midweek naps for an hour or two."

For many participants, maintaining sleep routines required trade-offs in other life domains. Michelle remarked, "I prioritize sleep over social activities. If invited somewhere, I evaluate whether it fits my schedule. Often, I bow out because by evening, I am ready for bed." Brian described a similar sacrifice, explaining, "We have two young kids, and after they go to bed, we do too." While Michelle framed her decisions as part of a recovery identity, Brian's comments reflected a blend of parenting and training rhythms. In both cases, sleep was positioned as non-negotiable, even at the expense of relational or leisure activities.

To support the multidimensional nature of this theme, a thematic matrix is provided (see Table 4). This table presents the three subthemes: Technological Tracking and Monitoring, Behavioral Sleep Hygiene Strategies, and Performance-Oriented Recovery Practices, along with representative behaviors and participant examples. The matrix offers a visual summary of how ultra-endurance athletes intentionally structure their sleep-related practices to support both physiological and psychological recovery. It complements the narrative analysis by highlighting the strategic layering of tools, habits, and decisions that collectively reinforce sleep optimization as a core pillar of endurance performance.

Taken together, participants described sleep as a deliberately managed component of endurance training. Whether employing technological monitoring, behavioral hygiene strategies, or lifestyle boundaries, athletes constructed routines that enabled sustained performance and mental clarity. Their approaches varied from data-heavy biofeedback loops to low-tech rituals, but each reflected intentional self-regulation aligned with their physical and psychological goals.

Table 4

Participant Strategies for Strategic Sleep Optimization

Subtheme	Description	Key Behaviors or Tools	Illustrative Participants
Technological Tracking & Monitoring	Using wearable devices and apps to track HRV, sleep stages, and recovery metrics	Garmin, Coros, WHOOP, sleep efficiency scores	Eric, Justin, Lisa, Andrea
Behavioral Sleep Hygiene Strategies	Consistent bedtime routines, stimulant management, environmental controls	Yoga, tea, eye masks, magnesium, reduced screen time	Michelle, Lisa, Sarah, Justin
Performance-Oriented Recovery Practices	Adjusting training, travel, and social life to maximize physical recovery	Prioritizing early bedtime, race-week sleep banking, deload weeks	Michelle, Jennifer, Brian, Amy

Note. This table presents the three subthemes associated with Theme 1 and illustrates the specific sleep-related strategies participants used to enhance physical and psychological recovery.

Bidirectional Sleep Negotiation Across Training and Life Demands. This theme captures the dynamic and reciprocal interactions between sleep behavior and external life demands, such as work responsibilities, training schedules, and family routines. Athletes described ongoing negotiation processes to balance these domains, revealing that sleep was not a passive influence but was actively managed in response to shifting pressures. The theme illustrates how life and training reciprocally shaped sleep patterns in ways that were highly individualized and context-dependent.

Ultra-endurance athletes in this study frequently discussed sleep as something that must be adjusted in response to changes in training volume, job demands, or family responsibilities. Michelle reflected on the consequences of inadequate sleep, stating, “If I do not sleep well or have a bad headache, I cut my running by 50% or skip it altogether. I try very hard to sleep well to avoid missing runs and feeling like I cheated myself.” In contrast, Justin maintained his training regardless of how he slept, explaining, “Sleep schedule does not greatly affect whether I run or not. I will not miss a day.” Michelle emphasized recovery and prevention, while Justin prioritized consistency and adherence to his plan, even when it meant compromising rest.

Training could either support or disrupt sleep, depending on individual routines and conditions. Eric shared, “Training and wearing myself out helps my sleep. It also helps calm my mind mentally,” suggesting that physical fatigue induced better rest. Lisa made a similar point, connecting daily physical activity to sleep quality. However, Sarah had a different experience when training during. She stated, “As soon as work was done, I had to take a 30-minute nap. Otherwise, I was just going to be a jerk to everyone I lived with, which is not fair.” While Eric

and Lisa benefited from a training-induced sleep rhythm, Sarah's routine was disrupted by the environment, forcing her to adopt compensatory nap strategies.

Work demands also played a significant role in shaping sleep and training routines. Michelle noted, "After a poor nights sleep, I can complete my morning routine and running, but then I feel like my day is already over and struggle through the rest of the workday." Similarly, Eric stated, "When I don't get enough sleep, I'm a bit more cranky and snippy. It's harder for me to concentrate at work." While both faced cognitively demanding roles, their strategies differed. Michelle occasionally skipped runs to maintain health and clarity, whereas Eric pushed through because he liked to challenge himself as a military veteran. These accounts showed how job-related stress could either restrict recovery options or motivate protective behaviors, depending on perceived flexibility and role expectations.

Several participants described how parenting or domestic responsibilities altered their ability to maintain consistent sleep and training schedules. Mark shared, "People in town that I am with regularly are into fitness, but I am at a different level, so I usually train alone, especially because of my kids' schedules." Robert described how his sleep varied depending on the training load: "When I'm not training, I often will stay up till one or two in the morning." Mark's variation was imposed by training level and family needs, while Robert's reflected self-regulation based on physical demand. In both cases, participants adjusted their sleep and training timing to accommodate shifting personal contexts.

Participants also adapted their training intensity or volume in response to poor sleep. Andrea stated, "A lot of times, I take Thursday off from running or just do a shorter workout... so I can sleep in a little longer." In contrast, Justin was more rigid in his approach: "I am not going to miss a run because I did not sleep well, unless I did not sleep at all. If I am that bad off, I am

probably not going to work either." These differences highlighted a continuum from flexible to inflexible responses to sleep variability, often shaped by individual priorities and beliefs about resilience.

Some participants reported experiencing long-term shifts in their sleep needs after joining the ultra-endurance community. Emily shared, "Before I got into ultra running, six hours was my average, but after starting, I craved more sleep, getting about eight hours." In comparison, Jennifer noted that her sleep did not change much, but that "the pressure to perform before big races is more intense now, so I have to be serious about sleep." Emily described a physiological shift in sleep needs, while Jennifer emphasized a more strategic and time-bound approach based on competition demands. Both acknowledged a connection between sleep and performance, but from different angles—one biological, the other situational.

Overall, ultra-endurance athletes described sleep as something to be negotiated rather than scheduled. A range of external variables, including professional obligations, parenting responsibilities, training sessions, and environmental conditions, influenced sleep patterns. Participants described trade-offs, such as skipping workouts, delaying runs, rearranging their nap schedules, or adjusting their sleep hygiene practices, to protect their recovery. While some responses prioritized flexibility and self-care, others reflected a stronger emphasis on consistency and achieving goals. Across these narratives, sleep emerged not as a passive background process, but as an active and adaptive component of ultra-endurance life.

To further illustrate the dynamic interplay between external demands and sleep behavior, a domain-level interaction matrix is included (Table 5). This table presents four primary areas of influence: training load, work responsibilities, family obligations, and environmental or seasonal factors, along with how each shapes and is shaped by sleep behavior. The matrix highlights the

bidirectional nature of this theme, demonstrating how ultra-endurance athletes adjust their sleep in response to social, biological, and environmental contexts. It supplements the narrative analysis by clarifying the distinct ways these life domains interact with recovery-related decision-making.

Table 5

Bidirectional Influences Between Life Domains and Sleep Behavior

Domain of Life Demand	Influence on Sleep Behavior	How Sleep Influences This Domain	Illustrative Participants
Training Load	Increased volume or intensity raised sleep needs; training time altered bedtime	Poor sleep reduced endurance, slowed paces, or led to skipped/reduced workouts	Michelle, Andrea, Emily, Justin
Work Responsibilities	Long hours or emotional labor led to late nights or fragmented sleep	Fatigue impaired concentration, decision-making, and emotional regulation at work	Brian, Michelle, Sarah, Eric
Family Obligations	Children's sleep patterns disrupted consistency; caregiving cut into rest or training windows	Sleep loss affected patience and forced adaptations in training time or social routines	Jason, Mark, Robert
Environmental/Seasonal Factors	Hot climates or work-from-home schedules pushed training into odd hours, reducing sleep	Fatigue led to increased reliance on naps or reduced training motivation	Andrea, Sarah, Brian, Robert

Note. This table summarizes how four key external domains influenced, and were influenced by, participants' sleep behaviors as part of the negotiation process described in Theme 2.

Navigating Physical Limits and Health Behaviors in Endurance Training. This theme explores how ultra-endurance athletes managed their physical health in response to sleep-related challenges, highlighting hydration, strength training, illness recovery, and environmental adaptation. Unlike themes that addressed social or psychological pressures, these accounts

focused on bodily cues, physical maintenance, and recovery rituals as crucial components of endurance sustainability. Athletes demonstrated awareness of how disrupted sleep or environmental stress could compromise performance and described various strategies to proactively address these risks. The codes in this theme clustered around dehydration awareness, proactive physical maintenance, physiological adaptation, and adjustments related to environmental or equipment factors. These behaviors reflected a distinctly biological orientation, aligning this theme with Research Question 1.

Hydration emerged as a particularly prominent concern. Jason explained, “I try not to do big races in the summertime... I had heat exhaustion when I was younger.” He also described a mixture of internal and external accountability: “During races, my wife is usually my crew and makes sure I am drinking... Even if she is not there, it is in the back of my mind to stay hydrated.” For Jason, hydration was not only a physiological safeguard but also a habitual part of racing routine. Andrea recalled, “I struggled. I think I got dehydrated around mile four... it ended up being about 90 degrees that day,” illustrating the limits of anticipatory planning and the challenge of recognizing symptoms in real-time. Justin linked hydration directly to sleep recovery, stating, “You will not sleep well if you are dehydrated. Dehydration can cause night sweats... because the body lacks hydration.” These accounts emphasized both the short-term risks of dehydration and its downstream effects on overnight recovery.

Participants also adopted maintenance behaviors that prioritized physical resilience. Andrea described her experience with ice baths: “I froze but it felt so good... I sat there until there was no ice left—mostly because I could not figure out how to get up.” This humorous account underscored her willingness to endure discomfort in pursuit of long-term recovery. She later added, “If that is what an ice bath does, I should do it more often,” though acknowledged

she only returned to the practice when pain justified it. In terms of gear, Andrea chose function over aesthetics, saying, “My trail shoes have a wider toe base, and they look goofy but are very comfortable,” signaling a shift toward physical prioritization in decision-making. These reflections reveal how athletes learned to interpret bodily feedback and adjust tools, strategies, and behaviors accordingly.

Strength training and biomechanics were also foregrounded. Andrea noted, “Strength training is just as important as running when training. So many runners just want to get their miles in and forget about strength training.” She elaborated on the rationale, explaining, “Running is a lot of single-leg movement... so you should work each leg individually and focus on balance.” These insights reframed strength work not as supplementary, but as essential to core running function. Her emphasis on balance and isolated movement quality suggested a deeper understanding of how physical mechanics support endurance and reduce injury risk—especially when sleep deficits might make athletes more vulnerable to biomechanical breakdown.

Environmental and nutritional adjustments were also described. Brian shared how traveling for work disrupted his sleep, and he needed to make adjustments. “When traveling, avoid late flights to prioritize sleep. I plan travel to allow better rest and performance,” pointing to how environmental changes could interfere with rest. Daniel noted, “I’ve never experienced altitude sickness,” a statement that contrasts with common endurance narratives and reinforces the individuality of physical responses. Mark offered an enthusiastic endorsement of intermittent fasting: “I have tons of energy working out without having a stomach full of food; it is the best thing ever,” highlighting how nutrition strategies were integrated into energy management and potentially impacted sleep quality.

Across these narratives, athletes consistently described an orientation toward protecting and sustaining physical function. Whether adjusting for temperature, training volume, nutritional intake, or gear selection, participants demonstrated a biologically grounded awareness of how sleep and recovery influence performance longevity. These behaviors were not framed as motivational or emotionally driven, but as calculated, often habitual responses to the physiological realities of training. This theme offers insight into how ultra-endurance athletes respond to sleep challenges by fine-tuning their physical practices to reduce strain and optimize bodily resilience.

Physiological Consequences and Adaptations Related to Sleep. This theme highlights the physical toll of disrupted or insufficient sleep and the ways in which ultra-endurance athletes' bodies adapt, or struggle to adapt, within the high-demand context of training and competition. Unlike themes centered on emotion, motivation, or social context, this theme is rooted in biological feedback: elevated heart rate, disrupted circadian rhythms, accumulated fatigue, and changes in performance efficiency. Participants described how their sleep, or lack thereof, directly influenced heart rate regulation, physical output, and perceived performance capacity. The narrative emphasized sleep's impact on recovery and physiological readiness, clearly placing this theme in the biological domain and aligning with Research Question 1.

Participants frequently discussed how sleep impacted their body's ability to recover. Eric explained, "After an ultra, my heart rate is noticeably different. I'll probably have a naturally higher heart rate, which makes sleeping difficult," illustrating how post-race sympathetic activation disrupts rest. Similarly, Daniel described parasympathetic dysregulation during training cycles: "My heart rate is higher, and sleep is lighter." Amy echoed this experience, stating, "The biggest thing I notice is my heart rate is elevated when I have less sleep, which

means the body fatigues sooner." These accounts connect inadequate sleep to clear physiological markers, especially autonomic regulation and fatigue onset.

Training volume also shaped sleep needs and patterns over time. Emily noted, "Before I got into ultra running, six hours was my average, but after starting ultra running, I craved more sleep, getting about eight hours." Mark described a similar phenomenon from the other end of the spectrum: "When training volume is high, I cannot stay awake even if I am watching an engaging show or movie." In both cases, the body demanded more rest in response to the increased workload. Participants like Justin tracked their output closely: "My cadence was lower than normal—usually in the 170s, but it dropped to 166—indicating fatigue," and "My average pace during training was about 35 seconds slower than it should have been, showing a real decline in performance due to poor sleep." These examples demonstrate how athletes monitored subtle performance shifts to assess the biological effects of sleep loss.

Routine also factored into physiological adaptation. Sarah shared, "I used to be an abrupt wake-up person. I just cannot do it anymore at the times I have to wake up," and noted how sleeping until 5 a.m. now felt like "sleeping in." Andrea and Mark detailed early rising routines layered around 4:00 a.m. training starts, while Michelle stated, "My goal is eight hours, though it does not always happen... Before races, even if I do not sleep well the night before, as long as I sleep well the week leading up to it, I perform better." These comments reflected athletes' efforts to manage long-term sleep quality, often prioritizing cumulative rest over single-night recovery. Despite best efforts, fatigue still accumulated. As Justin described, "Poor sleep left me unable to push into threshold heart rate zones properly or recover between sprints... My efficiency dropped, and I had to deload."

For many, sleep was viewed not just as a passive biological need but as a dynamic performance tool. Robert noted, “Even during races, short periods of lying down with eyes closed can reset the brain and significantly boost performance.” Similarly, Justin described using HRV data to monitor recovery: “When HRV drops but sleep stays the same, it shows I am absorbing fatigue my body cannot handle yet.” Sarah and others maintained detailed routines, such as bedtime wind-down rituals or fixed early training schedules, to reinforce circadian regularity and physical preparedness. These strategies reflected a high level of body literacy, as athletes translated biological feedback into concrete training decisions.

Across these accounts, participants portrayed the body as both an indicator and regulator of sleep adequacy. Elevated heart rate, disrupted rhythms, reduced cadence, and sluggish pace all served as signals that recovery had been compromised. Yet, these physiological responses also triggered adaptation, including modified sleep windows, intentional rest periods, and metrics-based monitoring. This theme demonstrates how ultra-endurance athletes experience and respond to the biological consequences of inadequate sleep, shaping their physical routines to sustain performance and mitigate breakdown. The emphasis on measurable, bodily feedback places this theme firmly within the biological domain, offering direct insight into how athletes perceive and manage the physical realities of recovery.

Consequences and Contexts of Sleep Disruption. This integrative theme captures the widespread impact of disrupted sleep on the biological, psychological, and social functioning of ultra-endurance athletes. While the scope of this theme spans all three biopsychosocial domains and aligns with Research Questions 1, 2, and 3, the focus here is on the physical health consequences associated with inadequate or disrupted sleep, directly addressing Research Question 1. Participants described how sleep deprivation, irregular sleep duration, and post-race

sleep disruption influenced fatigue, illness vulnerability, physical recovery, and performance decline. These outcomes were not limited to isolated incidents but appeared repeatedly in the training and racing cycles, highlighting sleep disruption as a chronic, embodied reality of ultra-endurance life.

Post-race physical exhaustion was a common narrative. Emily reflected, “After the race, I felt much more tired and slower to recover compared to after my 100k,” emphasizing the nonlinear toll of longer distances. Sarah described a predictable end-of-week crash, stating, “I would always start the week feeling strong, and by the end of the week, I felt dead with nothing left in the tank, but I still needed to get my miles in.” Similarly, Andrea noted, “On Fridays, after a full week of work and running, I was exhausted... you were just struggling to get your miles done.” These accounts illustrate how the cumulative effects of sleep loss and physical exertion lead to a biological cost, resulting in depleted energy and compromised endurance.

Participants also linked poor sleep with increased illness and immune vulnerability. Eric observed, “When you’re not sleeping and you're training a lot, you become more susceptible to illness.” Sarah echoed this risk, explaining, “I gave myself mono and a kidney infection” after prolonged sleep and nutrition neglect. Amy affirmed this connection succinctly: “Sleep deprivation contributes to immune issues.” While some participants, like Michelle, had not directly linked poor sleep to specific illnesses, they still acknowledged its physiological consequences: “If I get run down and do not address it quickly, it can develop into something worse.” These reflections reveal how even subclinical fatigue can degrade recovery capacity and elevate health risks.

Many athletes also described impaired physical functioning during or after races as a direct result of sleep deprivation. Lisa shared, “After big races, muscles are sore and it is hard to

sleep... After a three-day training in Phoenix, I did a night 50K... I flew home the next morning with no sleep." She added that post-race soreness and disrupted circadian rhythms often delayed recovery for days. Emily described beginning a race already depleted: "I felt physically and mentally like I had already run 100 miles before the race even began." This pre-existing exhaustion, exacerbated by poor sleep quality, led to performance struggles, including slower pacing, heavier limbs, and impaired concentration.

Disrupted sleep also undermined participants' ability to sustain high-effort physical performance. Mark noted, "During that first week [post-race], I hardly do any exercise... it's definitely fatigue from the event." Others, like Sarah, described how insufficient sleep made long runs feel unbearable: "I feel hungover, my head hurts, and I feel nauseous. Getting out the door becomes the hardest activity." These physical symptoms—nausea, pain, and general depletion—were treated not as exceptions but as expected outcomes of endurance life under sleep strain. Kelly stated bluntly, "Lack of sleep makes you exhausted," underscoring the inescapable energy deficit athletes face when rest is compromised.

Some participants used biometric feedback to validate their recovery patterns and better understand sleep disruption. Eric shared, "The day after my ultra race, my Garmin sleep score was 36 out of 100. Normally, I run between 70 to 90 for my sleep score," revealing how performance metrics were used to monitor the body's physiological recovery. Lisa similarly reviewed her sleep data: "The night of my hundred, I ran for 28 hours, so there was no sleep recorded that night. It just showed a blank. The next night, it recorded only three hours of sleep." Her experience illustrates both the lack of recovery during extreme efforts and the delayed restoration window that can occur even after the event. Lisa also noted unusual physical symptoms interfering with sleep: "Usually the night after my run, I'm kicking limbs or my feet

are moving." These accounts demonstrate how athletes utilize quantified feedback in conjunction with bodily signals—such as limb movement, soreness, or disrupted sleep patterns—to monitor their recovery and adjust their expectations. These physiological markers of strain reinforced the role of sleep-tracking devices as both motivational tools and indicators of biological stress.

Finally, participants described how external factors, such as travel, crewing, or environmental mismatches, further impaired their physical recovery. Lisa described the danger of prolonged wakefulness during a Grand Canyon ultra: "People were worried about missing curves... it became dangerous." Emily noted that staying with family before a race resulted in wildly inconsistent sleep, ranging from "one or two hours" to "ten or eleven." Jason added that having young children meant "sleep is really random right now... sometimes it's three or four hours." These disruptions often meant entering races already fatigued, raising the risk of physical breakdown and diminishing performance capacity.

In summary, participants consistently linked disrupted sleep with physical fatigue, immune vulnerability, slow recovery, and performance deterioration. These effects were rarely described in isolation and often compounded by life responsibilities, environmental factors, or post-race strain. While the full scope of this theme spans psychological and social consequences as well, its biological dimension aligns directly with Research Question 1, illustrating how disrupted sleep manifests in the body and affects training, competition, and overall health in ultra-endurance athletes.

Research Question 2. How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their psychological health during endurance events?

To answer Research Question 2, a reflexive thematic analysis was conducted following Braun and Clarke's (2023) approach. Codes related to mood regulation, emotional strain,

cognitive functioning, motivational dynamics, and psychological recovery were examined across the dataset. Four primary themes were identified that reflect the complex psychological toll of sleep disruption in the context of ultra-endurance participation. Two of these themes—Strategic Sleep Optimization for Physical and Mental Recovery and Consequences and Contexts of Sleep Disruption—were previously introduced under Research Question 1 due to their relevance to physical health. However, they are revisited here with a specific focus on their psychological dimensions, including how intentional recovery behaviors and inadequate sleep impact emotional stability, mental resilience, and cognitive clarity. Two additional themes—Psychological Disruption and Adaptation Across the Ultra-Endurance Journey and Lifestyle Trade-Offs and Internal Conflicts in Endurance Commitment—emerged uniquely in response to RQ2. These themes capture athletes' lived experiences of anxiety, mental fatigue, intrapersonal negotiation, and emotional recalibration under sleep strain. The following sections present each theme with direct participant quotes and interpretive commentary, illustrating how ultra-runners navigate the psychological consequences of insufficient sleep throughout their training, competition, and recovery timelines.

Strategic Sleep Optimization for Physical and Mental Recovery. This theme was previously introduced under Research Question 1 to illustrate how ultra-endurance athletes strategically manage sleep to support physical recovery. However, the same behaviors, such as biofeedback tracking, behavioral sleep hygiene, and intentional rest, were also consistently described as essential for preserving psychological health. The following discussion revisits this theme through the lens of emotional regulation, mental resilience, and cognitive functioning, addressing its specific relevance to Research Question 2.

This theme reflects the deliberate and performance-oriented approaches that ultra-endurance athletes use to enhance sleep and foster psychological resilience and mental recovery. Participants described sleep not as passive rest but as an intentional tool for regulating mood, maintaining emotional stability, and preserving cognitive clarity during training and competition. While the physical benefits of sleep were acknowledged, athletes emphasized that psychological readiness—feeling calm, motivated, and emotionally balanced—was equally dependent on strategic rest practices.

Many athletes reported that adequate sleep contributed to improved mood and mindset, with Lisa stating, “Motivation and sleep are very connected… good training, positive motivation, and a supportive community help your mental state.” Andrea noted how rest affected her emotional self-regulation: “I am a lot less impulsive when I am well-rested. I negotiate with myself a lot better.” These reflections highlight how emotional resilience and psychological clarity are enhanced through consistent, quality sleep.

Participants also described how biofeedback from wearable technology shaped their mental outlook and decision-making. Eric used heart rate variability (HRV) data to assess recovery readiness, saying, “I use my Garmin watch to track my HRV status, which I find super valuable for planning training.” Justin echoed this, explaining that Coros metrics guided his workout choices: “Coros provides basic workout input, run tracking, and gives an efficiency score after each run.” For these runners, data not only tracked physical output but also offered psychological reassurance and helped manage expectations.

Behavioral routines also played a central role in supporting sleep quality and mental well-being. Michelle followed a ritualistic evening routine that included yoga, tea, and sensory cues like an eye mask, explaining, “If I do not do my stretching routine, I do not sleep well, and it

affects everything the next day." Others, like Mark, emphasized stimulant control and routine protection: "Caffeine drives me nuts if I drink coffee after 10 a.m." These routines were not only about falling asleep, but also about creating calm and consistent environments that supported emotional recovery and psychological stability.

Participants commonly made lifestyle sacrifices to preserve mental sharpness and psychological consistency. For instance, Brian noted, "After the kids go to bed, we do too," aligning family rhythms with rest. Michelle shared, "I prioritize sleep over social activities. If invited somewhere, I evaluate whether it fits my schedule." These decisions reflect more than physical recovery as they demonstrate boundary-setting that protects emotional energy and self-regulation in a sport that demands prolonged mental endurance.

Taken together, this theme reveals that psychological optimization through sleep was as critical as physical restoration. Whether through tracking tools, bedtime rituals, or disciplined boundaries, participants constructed recovery systems that allowed them to train and compete with emotional clarity and mental resilience. These strategies were embedded in their routines not just to improve performance, but to sustain a stable, well-regulated mental state capable of enduring the extreme demands of ultra-endurance training and events.

Psychological Disruption and Adaptation Across the Ultra-Endurance Journey. This theme reflects the emotional and cognitive fluctuations ultra-endurance athletes experience throughout training, racing, and recovery. Participants described disrupted sleep as both a trigger and consequence of psychological strain, manifesting in anticipatory anxiety, mood instability, emotional exhaustion, and post-race mental recalibration. Rather than viewing sleep deprivation as an isolated challenge, athletes framed it as embedded within a broader psychological umbrella that demanded mental endurance, self-regulation, and adaptive coping.

Many participants discussed disrupted sleep prior to events, often shaped by anticipatory anxiety or unresolved mental activity. Mark reflected, “Even though I would not say I am nervous, something in my brain is definitely active the night before a race,” describing a persistent alertness that interfered with rest. Jennifer acknowledged she hadn’t yet raced beyond 100 miles. Still, she anticipated that “I would have to implement mid-race napping” if she ever did, already mentally rehearsing how she would manage psychological fatigue under future sleep constraints. Sarah, preparing for her first 100-miler, tried to mitigate these stressors by practicing on the racecourse, explaining, “I am a little nervous, but the course is close to my house, so I have been practicing there to feel less nervous.” While their approaches varied, each participant engaged sleep disruption as an expected part of psychological preparation.

Once racing began, sleep loss frequently magnified emotional distress. Michelle described how it undermined her mental composure: “Lack of sleep affects my motivation and confidence. Mentally, I can derail myself during races if I am not rested.” For Sarah, disrupted sleep contributed to self-critique and emotional overload: “I almost wish I were actually hungover because then I could blame a third party, but it is just me making bad choices and not sleeping enough, leading to a hard crash.” Her description highlights how emotional regulation deteriorated under the weight of poor sleep and personal expectations. These disruptions also extended into community norms. Sarah remarked, “My community is fabulous… but they do not always encourage me to sleep,” pointing to subtle social pressures that complicated recovery behaviors even in supportive environments.

Despite these challenges, many athletes revealed that they had developed psychological resilience through reframing, ritual, and determination. Eric described missing a race cutoff: “I didn’t finish, which was disappointing, but it also motivated me to do more ultras.” Andrea, after

dropping out of a 34-mile race, said, “Now that I started and got a taste of it, I know I cannot be a quitter.” Her resolve was mirrored by others who used symbolic milestones to maintain focus. During a difficult event, Andrea recalled, “I thought, ‘At least a mile for every year I am old, plus an extra.’ I was determined not to give up there.” These moments illustrate how emotional recovery from disrupted performance often became a source of renewed commitment.

Mental toughness also emerged in the ways participants structured their internal narratives mid-race. Lisa shared that she writes the names of fallen soldiers on her arm while running: “It really motivates me. She talks about doing hard things and staying strong, and ultras feel easy compared to what they’ve been through.” Andrea employed a gritty form of self-talk, describing how she choked down pickle juice during a race: “I treated it like a shot—down the hatch, do not let it touch your mouth.” In both examples, participants employed psychological strategies to override discomfort and maintain momentum, even in sleep-deprived, emotionally taxing states.

Social dynamics also played a role in how sleep loss was managed or neglected. Michelle noted, “I occasionally volunteer at aid stations… even though it often involves sacrificing sleep.” Justin commented more broadly, “You will begin to find ways to sacrifice sleep to achieve training goals. That is what everybody ends up doing.” While these comments underscore the communal normalization of exhaustion, participants also expressed awareness of its costs. Justin later admitted, “Once you start sacrificing your own needs constantly, you become drained, resentful, and lose the ability to show up fully for others.” This sentiment reflected a growing recognition among several runners that endurance culture’s badge-of-honor attitude toward fatigue can contribute to psychological burnout.

For others, disrupted sleep was nested within larger life transitions and identity reconstructions. Mark described racing as a stabilizing force after emotional crisis: “In late 2018, I realized I was definitely in the biggest hole that I think a person could be in.” Similarly, Brian explained that a life-threatening health warning transformed his commitment to training and recovery: “A doctor told me I would die before 30… That motivated me to take fitness seriously, learn about nutrition, and prioritize sleep.” These statements highlight how sleep management becomes entangled not only with race outcomes but with broader efforts to reestablish control, purpose, and well-being.

This theme illustrates how ultra-endurance athletes experience psychological disruption in tandem with sleep loss, and how they adapt through anticipatory planning, emotional regulation, and meaning-making. Whether managing the impact of poor rest before a race, responding to emotional fatigue during competition, or reframing post-race disappointment into future goals, participants revealed a rich tapestry of psychological strategies. These responses do not erase the costs of sleep disruption, but they reflect an evolving relationship with mental endurance. To further clarify the multidimensional nature of this theme, Table 6 summarizes the two subthemes—Pre-Race Anxiety and Anticipation and Post-Race Emotional Processing—along with representative behaviors and illustrative participants. This table complements the narrative analysis by visually organizing how psychological disruptions and adaptations unfold across different phases of the ultra-endurance timeline.

Table 6

Participant Reflections on Psychological Disruption and Adaptation

Subtheme	Description	Representative Behaviors or Thoughts	Illustrative Participants
Pre-Race Anxiety and Anticipation	Psychological tension, worry, or planning related to disrupted sleep before events	Mental rehearsal, nervous arousal, familiarity tactics, anticipation of fatigue	Mark, Sarah, Jennifer, Daniel
Post-Race Emotional Processing	Mental recovery and reframing following disrupted races or emotional fatigue	Reframing DNFs ("did not finish"), meaning-making, motivational redirection	Andrea, Eric, Michelle, Brian

Lifestyle Trade-Offs and Internal Conflicts in Endurance Commitment. This theme captures the internal negotiations, and cognitive reframing ultra-endurance athletes engage in as they manage the psychological cost of sustaining high-volume training alongside other life demands. Rather than describing external conflicts or interpersonal obligations, participants reflected on personal choices of when to push, when to pause, and how to protect their sense of balance while remaining committed to training. Inadequate sleep, disrupted routines, and personal crises often prompted these reflections, leading athletes to reassess limits, adjust expectations, or establish firmer boundaries to protect their well-being.

Many of these trade-offs originated from conflicts between daily structure and competing priorities. Emily explained that when staying with family, "I had to stop eating with them because it was affecting my sleep schedule and making me stay up later than I wanted." Without control over her environment or mealtimes, she added, "I did not have blackout curtains… which disrupted my sleep." Her account revealed how even minor disruptions could erode carefully maintained sleep routines. Mark, reflecting on similar experiences, said, "When I stay out late, I feel like the next day is half wasted," adding that it reminded him to avoid late nights so he could

preserve his normal routine. While Emily adjusted proactively, Mark's insight came after repeated disruptions, illustrating how internal boundaries sometimes form only after trial and error.

Amy also described the consequences of poor regulation during fatigue: "When tired, I do not think about fueling enough. I tend to underfuel, which worsens performance." Her comment highlighted how disrupted sleep or physical depletion can lead to additional challenges, such as poor decision-making regarding nutrition. Justin similarly reflected, "After a low sleep night… I had a hard tempo run late in the day, which worsened recovery." His use of data to track these patterns demonstrated a more analytical form of internal negotiation, showing how some athletes used feedback loops to recalibrate their routines.

Participants often confronted situations where physical discipline did not shield them from illness or stress, intensifying the emotional toll. Sarah remarked, "I have done everything right, and I still have a kidney infection… This is so dumb," capturing a deep frustration when outcomes seemed disconnected from effort. Mark described a particularly dark period: "I realized I was definitely in the biggest hole that I think a person could be in." He turned to training as something he could control and "win," using endurance to anchor himself when other aspects of life felt unstable. Robert echoed this use of running as both escape and overextension: "Running became a coping mechanism… but I overdid it." He recounted physical breakdowns during a traumatic divorce, stating, "My immune system was extremely low… There is a big cycle where going through something stressful in life impacts your sleep and therefore your performance."

While these narratives highlight moments of crisis, others reflected long-term patterns of sacrificing medical care for continuity in training. Brian shared, "I have a torn ACL and MCL

but delay surgery because it would disrupt my active lifestyle for too long." In contrast, Amy emphasized that activity supported her medical stability: "With PCOS, I must stay active to manage my weight and health." Whereas Brian prioritized athletic identity over clinical recovery, Amy framed training as a necessity for managing a chronic condition. Both decisions showed calculated compromises but with different motivations.

Others spoke more explicitly about guarding emotional stability through structured routines. Andrea explained, "It is all about time management and shifting my schedule to make sure I get enough sleep." Justin offered a similar view: "I will adjust small things like going for a drink, but I will not overhaul my whole training week because that would derail my mood and focus." His comment, "Letting others control your schedule leads to resentment," highlighted how schedule protection was not just about logistics but also emotional health. While Andrea leaned on planning as a strategy to balance responsibilities, Justin treated his calendar as a boundary that supported mood regulation.

Some participants reflected on formative experiences that had reshaped their approach to health and training. Brian remembered, "A doctor told me I would die before 30… That motivated me to take fitness seriously." This encounter marked a turning point in his life, one that he later connected to his work with injured clients: "I view life through the lens of appreciating physical health." For Brian, training was not just a physical pursuit but a safeguard against the vulnerability he once faced.

Altogether, participants described internal conflict not as a sign of ambivalence but as part of the cognitive and emotional work of endurance commitment. Whether managing disrupted routines, processing the impact of illness, or drawing firm boundaries around recovery, athletes engaged in ongoing self-evaluation. These trade-offs were rarely perfect or final.

Instead, they reflected the endurance mindset of being flexible, responsive, and deeply invested in sustaining both performance and well-being. To further highlight the cognitive and emotional mechanisms underlying these personal trade-offs, Table 7 outlines the two subthemes—Cognitive Reframing of Sacrifice and Internal Boundary Negotiation—alongside representative decisions and illustrative participants. This table complements the narrative analysis by mapping how internal dialogues and structured routines support athletes' psychological adjustment.

Table 7

Participant Strategies for Lifestyle Trade-Offs and Internal Conflicts

Subtheme	Description	Representative Decisions or Strategies	Illustrative Participants
Cognitive Reframing of Sacrifice	Emotional processing of trade-offs related to health, identity, or crisis	Training through illness, delaying medical care, reframing emotional lows	Brian, Robert, Sarah, Mark
Internal Boundary Negotiation	Psychological strategies used to protect routines and emotional health	Adjusting sleep schedules, resisting social pressure, structured time management	Andrea, Justin, Emily, Amy

Consequences and Contexts of Sleep Disruption. This theme was previously introduced under Research Question 1 to highlight the biological consequences of disrupted sleep among ultra-endurance athletes. However, participants also described pervasive psychological effects, aligning this theme with Research Question 2. From emotional volatility and mental fatigue to impaired concentration and decision-making, disrupted sleep contributed to psychological dysregulation in training, racing, and daily functioning. This section revisits the theme through the lens of psychological resilience, emotional strain, and cognitive endurance.

Participants described how inadequate sleep compromised focus and mental clarity. Sarah explained, "On tired days I call them my busy work days because I know I will not be able to do any deep thinking work. It will not work. I cannot do it. It will be bad. I will be unhappy.

Everyone will be unhappy." Similarly, Andrea noted, "When I do not get enough sleep, I definitely have trouble focusing. I tend to multitask more, jump around from thing to thing, and struggle to sit and complete something when I am sleep-deprived." These statements capture not just attention deficits but also the frustration and fragmentation that accompany mental fatigue. Amy echoed this with, "When tired, the brain is not functioning fully. It is easier for negative thoughts to creep in," describing how exhaustion lowers cognitive defenses.

Sleep deprivation also affected participants' ability to manage emotions. Jennifer explained, "When I do not get enough sleep, I experience irritability and a lower threshold for frustration and overwhelm," and added, "Lack of sleep affects my emotional responses more than my cognitive function. Everything seems like a bigger problem." For Andrea, emotional volatility was also a key indicator: "One of my big trigger moments is when I randomly start crying about things that should not bother me… it is a clear sign that I need sleep." Kelly was more blunt: "I am a raging bitch if I do not get enough sleep… lack of sleep makes everything worse." These reflections show a consistent pattern of lowered emotional tolerance and increased reactivity in sleep-deprived states.

Some athletes described how lack of sleep altered their mood and distorted mental framing. Amy explained, "Absolutely. Lack of sleep heightens my anxiety and depression. It causes spiraling thoughts, amplifies my imposter syndrome, and increases negative self-talk." Jason offered a broader emotional pattern: "Motivation is definitely a rollercoaster. Some weeks, if I am really tired, I do not want to do anything at all. Confidence can be affected too." He also acknowledged the downstream social impact of sleep loss: "If the running or lack of sleep affects my mood, like getting angry at my kids, I need to remember that running is not the main thing." In contrast, Brian shared a coping approach: "Lack of sleep does affect my mood and cognitive

performance, but working out helps manage stress and anxiety." This contrast highlights the variation in participants' responses, with some struggling to maintain emotional control while others adapted through compensatory routines.

Disrupted sleep also intensified impulsivity and cognitive overload. Sarah described, "When I do not sleep enough, I tend to be more trigger-happy with my decisions. I do not think it through as much because I do not have the brain space it deserves." Daniel explained how sleep loss distorted his experience of effort: "If the brain can't process daily thoughts and emotions under normal circumstances, and then you throw in an ultra when you're only at 70% capacity, everything will be perceived as pain and effort, and that will be magnified." Amy added, "When your brain is already tired, it starts playing games earlier. Instead of at mile 10, it might start at mile three with procrastination and excuses." These quotes reflect the mental exhaustion and distorted processing that accompany prolonged sleep deprivation.

Participants also described sleep deprivation as interfering with their routines, increasing emotional exhaustion. Justin shared, "When I do not get up and run or stick to my routines, even my students can tell my energy is off and that I am upset," and later noted, "If I adjust my whole week for someone else, I become very angry and stressed, even though I am usually a very chill person." Michelle, who works in a high-stakes care role, reflected, "Sleep is essential to my mental state. If I do not sleep well, I do not function well, and my mood is uneven." This emphasis on daily structure and mood regulation illustrates how participants used routine and recovery as tools to buffer psychological decline.

In summary, ultra-endurance athletes in this study consistently reported that disrupted sleep served as a catalyst for psychological strain. Their experiences reveal a clear pattern of impaired concentration, emotional volatility, reduced decision-making capacity, and diminished

motivation. Whether through tears, reactivity, or reframing strategies, participants were acutely aware of how insufficient rest undermined their psychological stability. These consequences were not isolated to race events but permeated daily life, work roles, relationships, and training engagement. Theme 9, when viewed through the lens of Research Question 2, illustrates that psychological resilience in ultra-endurance contexts depends as much on quality sleep as it does on discipline, mindset, or physical preparedness.

Research Question 3. How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their social factors during endurance events?

To answer Research Question 3, a reflexive thematic analysis was conducted using Braun and Clarke's (2023) approach. Codes relating to social interactions, family dynamics, community belonging, and the broader social consequences of sleep disruption were systematically examined within the dataset. Four primary themes were identified that reflect the nuanced and multifaceted ways inadequate sleep shapes social experiences and relationships among ultra-marathon runners.

Two of these themes connect to earlier analyses. Bidirectional Sleep Negotiation Across Training and Life Demands, originally introduced under Research Question 1, is revisited here with a focus on how sleep and social obligations are actively balanced within daily life. Consequences and Contexts of Sleep Disruption, previously discussed under both Research Questions 1 and 2, is further explored here to highlight the pervasive social impact of disrupted sleep, including challenges in family roles, social participation, and relational functioning. The remaining two themes—Identity, Values, and Belonging in the Ultra-Endurance Community and Navigating Social Expectations and Sleep Boundaries—emerged uniquely in response to Research Question 3. These themes illustrate how athletes build social identities, negotiate

cultural and community norms, and manage relational expectations that both support and complicate their sleep practices. The following sections present each theme in detail, featuring direct participant quotes and interpretive commentary, which illustrate how ultra-marathon runners navigate the social ramifications of inadequate sleep throughout their endurance journeys.

Bidirectional Sleep Negotiation Across Training and Life Demands. This theme was previously introduced under Research Question 1 to illustrate how ultra-endurance athletes navigate the reciprocal relationship between sleep and physical training demands. However, these bidirectional negotiations were also consistently described as essential for managing social responsibilities, family roles, and daily life pressures. The following analysis revisits this theme from a social perspective, focusing on how athletes actively balance sleep, training, and external obligations within their broader social context.

Ultra-endurance athletes described sleep as an ongoing negotiation process, constantly balanced against the shifting demands of training, work, family, and other life responsibilities. Rather than treating sleep as a fixed routine, participants depicted it as something that required continual adjustment in response to the dynamic pressures of life. Several participants described how work and professional obligations required active management of sleep and training. For example, Eric, a nurse practitioner, noted, “As a nurse practitioner, I need to be fully present with patients, and lack of sleep makes that challenging.” This sense of heightened professional responsibility was echoed by Brian, who stated, “In my work—civil and criminal law—decision-making has massive consequences… Clear thinking is essential.” While both Eric and Brian emphasized the cognitive demands of their roles, their adaptation strategies diverged. Eric emphasized the importance of being well-rested for direct patient care. In contrast, Brian

highlighted the broader implications of professional decision-making and described paying extra for travel accommodations to protect his sleep when necessary.

By contrast, some athletes found that training routines directly shaped their sleep quality. Eric reflected, “For me, training and wearing myself out helps my sleep. It also helps calm my mind mentally,” suggesting a symbiotic relationship where physical fatigue led to better sleep and mental calm. Lisa, too, connected consistent activity to successful rest, stating, “I don’t usually have trouble sleeping. I’m tired at night, probably because I work out in the morning. On days I do not work out, I do not feel as tired.” However, not all participants experienced this positive effect. Andrea’s routine was disrupted by environmental factors, noting, “I was not getting to bed until around 10:30. In order to get my six to eight hours of sleep, I had to take that nap in the afternoon because there were not enough hours later in the day.” While Eric and Lisa benefitted from training-induced sleep rhythms, Andrea’s environment forced her to improvise with daytime naps to compensate for lost nighttime sleep.

Parenting and family responsibilities emerged as another significant influence on sleep and training schedules. Jason described frequent adaptations based on his children’s needs: “Sometimes, I put a kid back to sleep at three or four in the morning. If I am halfway awake, I just go do my run then, instead of at six or seven like planned. Sometimes I am completely tired, so I will run in the afternoon or not do anything that day.” This flexibility contrasted with Robert’s self-regulation, who explained, “When I’m not training, I often will stay up till one or two in the morning,” suggesting that his sleep variability was primarily influenced by his own activity choices rather than external pressures. Jason’s approach was reactive, shaped by immediate family demands, while Robert’s was proactive, structured around his training cycles.

Athletes also differed in how they responded to poor sleep in their training decisions. Michelle adopted a flexible approach, stating, “If I do not sleep well or have a bad headache, I cut my running by 50% or skip it altogether. I try very hard to sleep well to avoid missing runs and feeling like I cheated myself.” Andrea echoed this willingness to adjust, stating, “A lot of times, I take Thursday off from running or just do a shorter workout or strength training so I can sleep in a little longer, until 4:30.” In contrast, Justin described a more rigid mindset by expressing, “Not missing a day is better than missing it because you can take other things out.” For Justin, adherence to training plans took precedence, even if it meant compromising on rest. This approach stood in contrast to Michelle and Andrea’s prioritization of recovery and self-care.

Participants also reported long-term shifts in sleep needs as their training loads increased. Emily observed, “Before I got into ultra running, six hours was my average, but after starting ultra running, I craved more sleep, getting about eight hours.” For Emily, sleep needs rose as a result of her body’s adaptation to higher training volumes. Conversely, Jennifer did not see a dramatic change in her overall sleep duration. Still, she did notice increased pressure to maximize sleep quality before major events by observing, “The pressure to perform before big races is more intense now, so I have to be serious about sleep. As I have gotten older, with kids and working more, it is harder to fit in extra sleep.” While Emily experienced a biological shift in her baseline sleep requirement, Jennifer’s adaptation was more situational, driven by the temporal demands of competition and family responsibilities.

Environmental and work-related factors further complicated the negotiation of sleep training. Mark described the pressure of holding multiple jobs during the pandemic, “I was working from home starting in March 2020, and I basically got dumped two full-time jobs on me… Eventually, I would get up at 4 a.m., sit down with a cup of coffee, and just start working,

usually until about 6 p.m. every day." These long, inflexible work hours left little room for rest or consistent training, demonstrating how external stressors could push sleep and recovery to the margins. Despite these challenges, many athletes remained highly attuned to the relationship between sleep, performance, and well-being. Amy explained, "If I have a good night's sleep, my zone two pace might be between a 9:30 and 10-minute mile. If I do not have good sleep, it might be an 11.5-minute mile because my heart rate is already elevated." Brian added, "I know the difference between being optimally rested and being suboptimal and adjust accordingly." These accounts highlight a high degree of self-monitoring and a willingness to recalibrate routines in pursuit of both social and performance goals. To further illustrate the dynamic interplay between external demands and sleep behavior as it relates to social functioning, the domain-level interaction matrix provided under Research Question 1 (Table 5) remains applicable here. The same bidirectional processes described previously continue to shape athletes' experiences as they negotiate social, familial, and occupational obligations in relation to sleep and recovery needs.

Overall, participants depicted sleep as an active, adaptive component of ultra-endurance life, viewing it as a resource to be protected, adjusted, or, at times, sacrificed in response to the ever-shifting balance of training, work, family, and environmental pressures. The ongoing negotiation of sleep reflected not only individual priorities but also the wider social and contextual realities facing ultra-endurance athletes. By actively managing sleep in relation to social roles and external demands, participants demonstrated the complexity of balancing high achievement with sustainable health and meaningful relationships. These findings underscore that sleep, far from being a passive background variable, is instead a central factor negotiated at the intersection of athletes' physical, social, and emotional worlds.

Identity, Values, and Belonging in the Ultra-Endurance Community. This theme explores how ultra-endurance athletes construct their identities, foster social belonging, and align themselves with the cultural values of the ultra-running community. Unlike themes focused on adaptation or strain, this theme was developed to capture the nuanced ways that participants made sense of their commitment to the sport through shared meaning, community integration, and group norms. This theme is introduced here for the first time, as it did not emerge in connection with the physical or psychological dimensions of sleep but is central to the social domain explored in Research Question 3.

Several participants described their goals as being about finishing rather than competing for time or placement. Eric summed it up with, "My primary goal is always just to complete the race." This statement aligns with Brian's mindset: "I am not competing to win; I just do it for fun." While Eric spoke about endurance for its own sake, Brian mentioned enjoying the process, even though he often finished near the top. Both participants reflected a value system in ultra-running that emphasizes personal satisfaction over external rewards.

The theme of support arose frequently. Lisa explained, "Most of my ultra races, I have had someone there with me, either running or crewing. Even people who are alone don't feel alone because the ultra community is so supportive. It's a positive domino effect—positive motivation, positive training, better mental state, better sleep." Jennifer offered a different view, describing how her running friends became her main social group: "Our 'happy hour' is at 5:00 AM." While Lisa described the support she received during races, Jennifer talked about regular training as her main way of connecting socially.

Some participants compared the ultra community to other athletic groups. Brian said, "The endurance community is very supportive and welcoming, similar to the CrossFit

community." In a related way, Kelly talked about her first ultra, saying, "During my first ultra, everyone was welcoming and supportive. It made me feel like I belonged." Brian focused on how this attitude sets ultras apart from other sports, while Kelly described the immediate sense of inclusion as a newcomer.

There were also comments about the community's overall attitude. Sarah described ultra-running as, "one place that toxic positivity loves to live and it lives there happily. No one says, oh my gosh, you are too positive. Everyone says, oh my gosh, yay." In contrast, Jason explained, "I have had some friends and cousins who say I am crazy for doing this. They say it in a friendly, respectful way, not rude. No one has ever straight-up told me I am stupid or dumb for doing it, at least not to my face. Maybe they have behind my back, but I do not know about it." Sarah critiqued the expectation to always be positive, while Jason focused on how social judgments were usually good-natured.

Some explanations highlighted how identity changes over time. Lisa described being encouraged by friends to move from shorter races to ultras, saying, "A group of ladies encouraged me to join a relay at a marathon event. I volunteered to run the longest segment, then moved to 10Ks, marathons, 50Ks, and up from there." Meanwhile, Andrea's path felt more surprising, stating, "It turns out I am kind of in the running community now. A year ago, if you had told me that, I would have said you were crazy. But here I am, fully in the loop with running people." Lisa showed a step-by-step progression, while Andrea noticed the shift after it had happened.

The sense of community went beyond group runs and included more distant connections. Mark said, "Most of my close social circle does not share the same level of interest in ultra-endurance events. Most of the people I do events with live in different towns, and we

communicate over social media or text." Amy added, "Most of my current friends are athletes, and we often train early together," illustrating how involvement in ultra-running can often reshape social circles over time.

Overall, this theme suggests that ultra-endurance athletes often perceive themselves as part of a group that values mutual support, completing what they start, and connecting through shared experiences. These athletes described finding a sense of belonging and identity that is unique to the ultra community and distinct from the physical and psychological themes discussed earlier. This focus on group values and identity is central to how many participants described their experience with sleep, training, and life as ultra-endurance athletes.

Navigating Social Expectations and Sleep Boundaries. This theme explores how social roles, family dynamics, and interpersonal expectations impact the prioritization and quality of sleep. Athletes describe the tension between relational obligations and training goals, revealing the need to set or negotiate boundaries that protect the recovery. The theme underscores the relational complexities that shape sleep behaviors in social contexts.

Athletes frequently described creative negotiations to balance training and sleep within family contexts. Eric illustrated this by stating, "I try to schedule my training when others are sleeping or during times like when I take my kids to their sports practices and can run simultaneously." Similarly, Lisa recounted family humor around her structured schedule, noting, "When we go to the lake house, they joke that it's Mom's bootcamp because everyone has to sleep earlier and get up earlier." Mark shared a comparable experience of extreme schedule adjustments, remarking, "I often have to squeeze workouts around my kids' activities, like getting up at 3 a.m. for a run before a softball tournament." Robert added further nuance, explaining how his child custody schedule directly shaped his sleep routine: "When she's here, I

tend to go to bed really early, right after her at like eight or nine o'clock. So it varies, oddly enough. I don't have a set routine." While Eric and Lisa managed to integrate training and sleep schedules more seamlessly into family life, Robert's reflection suggests greater variability and negotiation due to his custody arrangement.

Participants also navigated boundaries within romantic relationships, where sleep schedules sometimes created relational tension or required intentional negotiation. Eric highlighted relational understanding when prioritizing early bedtimes, remarking, "With friends and family, I'm less likely to go out late because I always have to consider getting enough sleep. It's nice that my relationship understands this." In contrast, Lisa revealed some subtle friction, admitting, "I usually go to bed before my husband, and he stays up later. We don't have the same sleep patterns at all." Jason further expanded this complexity by explicitly framing running as secondary to family roles, stating, "I am a husband first, a father, and I have to work. If the running or lack of sleep affects my mood, like getting angry at my kids, I need to remember that running is not the main thing." Eric's experience emphasized mutual understanding, whereas Lisa's and Jason's comments indicated a more active negotiation of relational boundaries influenced by sleep needs.

Social connections outside immediate family similarly required careful management of sleep schedules, which occasionally led to reduced social participation. Sarah explicitly described her disengagement from evening social activities, stating, "I very rarely go to events because they are in the evening…I would rather sleep, eat snacks, or do other things." She further detailed how choir rehearsals specifically conflicted with her sleep routine, noting, "I always leave at the halfway point because I physically cannot stay longer." Daniel, however, emphasized a more strategic balancing act, reflecting, "You can't say no to social invitations all

the time, or you'll stop getting invited. It's about finding a balance." Mark humorously added another angle by using parenting responsibilities as a socially acceptable excuse: "Having kids sometimes provides a natural excuse to leave early." While Sarah demonstrated more rigid boundaries around sleep needs, Daniel and Mark both revealed more flexible strategies for maintaining social relationships.

Participants also expressed that being part of the ultra-endurance community alleviated some relational strain caused by prioritizing sleep. Lisa captured this clearly by emphasizing the positive influence of community support: "It's a positive domino effect—positive motivation, positive training, better mental state, better sleep." Emily echoed a similar appreciation, explicitly recommending specific events, such as, "The Shippey Endurance Run in St. Louis fosters a strong, supportive community and rewards inspirational efforts." Andrea reinforced the depth of community connection, stating, "Everybody is so supportive and understanding because they have all been there at some point." While Lisa and Emily highlighted community support broadly and event-specific, Andrea underscored empathy as particularly valuable in managing sleep and social tensions.

Nevertheless, these athletes also recognized ongoing tensions with non-running acquaintances who struggled to understand their sleep-focused lifestyles. Lisa described isolation clearly, stating, "I do not think many people really understand the sleep and training needs. I don't have a lot of people around me who do." Jason added complexity by distinguishing between friend groups, noting, "I definitely have my running friends and my non-running friends…very few do the long, long distance stuff. Everyone kind of has their own goals." Amy further emphasized this shift, reporting explicitly, "My non-athlete social circle has shrunk

because my lifestyle is different." While Lisa felt generally misunderstood, Jason and Amy highlighted how lifestyle differences distinctly segmented their social relationships.

Overall, this thematic analysis demonstrates the nuanced and sometimes challenging social negotiations ultra-endurance athletes face as they protect sleep for optimal performance. Participants managed these negotiations through creative boundary-setting, clear communication, and strategic relational investments, illustrating the importance of sleep within their social lives. To further clarify how these interpersonal dynamics shaped sleep behaviors, Table 8 provides a structured overview of the two subthemes—Family and Relational Pressures and Social Scheduling and Sleep Intrusion—highlighting representative behaviors and illustrative participants. This summary complements the narrative, providing an organized depiction of the complex social dynamics that athletes navigate to sustain both their relationships and recovery priorities.

Table 8

Participant Reflections on Navigating Social Expectations and Sleep Boundaries

Subtheme	**Description**	**Representative Behaviors or Thoughts**	**Illustrative Participants**
Family and Relational Pressures	Negotiating sleep boundaries within family and intimate relationships	Early bedtimes, adjusted training schedules, communication of needs	Eric, Lisa, Jason, Mark, Robert, Justin, Brian
Social Scheduling and Sleep Intrusion	Managing social life and external expectations in relation to sleep needs	Declining invitations, limited evening engagement, prioritizing meaningful interactions	Sarah, Daniel, Michelle, Amy, Andrea, Kelly

Consequences and Contexts of Sleep Disruption. This theme was previously explored under Research Questions 1 and 2, focusing on biological and psychological impacts, respectively. Here, attention shifts to the social consequences, specifically exploring how

disrupted sleep influences the interactions, responsibilities, and roles of ultra-endurance athletes within their families, work environments, and social communities. Participants consistently described sleep disruption not only as a personal issue but as a factor significantly impacting their relational dynamics and social obligations.

Disrupted sleep notably affected participants' roles and relationships within their family structures. Jason detailed the complex interaction between parenting duties and his ultra training, stating, "Right now, my sleep is very inconsistent… my youngest wakes up twice during the night… Sleep is really random right now." He explicitly connected disrupted sleep with increased tension, recognizing the importance of balancing family commitments: "If the running or lack of sleep affects my mood, like getting angry at my kids, I need to remember that running is not the main thing." Kelly similarly discussed relational strain caused by disrupted sleep due to her husband's health condition, remarking, "My husband has sleep apnea, which makes sleep harder," highlighting how a partner's health directly compounds personal recovery issues.

Social responsibilities, including caregiving and professional roles, were also affected by sleep disruption. Sarah described sleep-related cognitive impairment impacting her job, explaining, " When it comes to concentration, on tired days I call them my busy work days because I know I will not be able to do any deep thinking work. It will not work. I cannot do it." Michelle echoed this sentiment from a caregiving perspective, stating, "Sleep is essential to my mental state… Dealing with other people's issues as a nurse makes sleep even more important for maintaining emotional balance." These reflections underscore the heightened stakes of disrupted sleep in professional caregiving roles, where cognitive clarity and emotional stability are crucial.

Participants also discussed the communal aspects of ultra-running itself, highlighting how disrupted sleep related to supporting roles such as crewing and pacing. Daniel explained the demanding reality of crewing, noting, "You're awake the entire time, even though you're not running… then you might pace someone 18 or 20 hours later after being up the entire time." Lisa similarly highlighted logistical and safety concerns arising from sleep deprivation during group activities, recounting, "During my overnight run in Phoenix… It's really important to have a crew because mentally it's hard to manage everything like packing, driving, and getting to the airport." These insights highlight the inherent social fabric of ultra-endurance athletics, where mutual support obligations frequently involve substantial personal sleep deprivation.

Participants articulated that sleep disruption was not merely a personal inconvenience but a catalyst for broader social and interpersonal difficulties. Andrea captured the cumulative toll of disrupted sleep on group interactions, stating, "On Fridays, after a full week of work and running, I was exhausted… even with the group camaraderie, you were just struggling." This struggle extended into domestic life, as Sarah noted, "As soon as work was done, I had to take a 30-minute nap… otherwise, I was just going to be a jerk to everyone I lived with." These examples illustrate how the interpersonal strain resulting from disrupted sleep permeates both public and private spheres, influencing social interactions and emotional availability.

In summary, participants emphasized that disrupted sleep significantly undermines their capacity to fulfill relational, professional, and communal roles. From caregiving responsibilities and professional interactions to family dynamics and athletic support roles, disrupted sleep emerges as a significant factor in determining social functioning. Theme 9, viewed through the lens of Research Question 3, thus illustrates how compromised sleep reverberates beyond

individual boundaries, profoundly impacting social relationships, community interactions, and family life among ultra-endurance athletes.

Summary of Cross-Question and Cross-Domain Themes. While individual research questions organized the results in this chapter, several themes emerged that spanned multiple research questions and biopsychosocial domains. These integrative themes reflect the layered and interconnected ways ultra-endurance athletes experience the effects of sleep—biologically, psychologically, and socially. To provide transparency and coherence in reporting, table 9 below summarizes each overlapping theme, including its subthemes, associated research questions, biopsychosocial domains, and the key codes that contributed to its development. This synthesis highlights the complexity of sleep disruption and regulation within the ultra-endurance lifestyle, supporting the theoretical orientation of the Biopsychosocial Model.

Table 9

Overview of Overlapping Themes by RQ and Domain

Theme Name	Subthemes	RQ Alignment	Biopsychosocial Domain	Codes
Strategic Sleep Optimization for Physical and Mental Recovery	Technological Tracking & Monitoring, Behavioral Sleep Hygiene Strategies, Performance-Oriented Recovery Practices	RQ1, RQ2	Biological, Psychological	Caffeine sensitivity, Caffeine timing, Consistent sleep schedule, Hydration strategies, Napping strategies, Prioritizing sleep, Sleep tracking via technology, Temperature cues for alertness, Tracking HRV for training, Tracking sleep patterns, Improved sleep during training, Importance of sleep for performance, Sleep for physical recovery, Sleep improves mood, Sleep improves training mindset, Sleep hygiene practices, Sleep monitoring

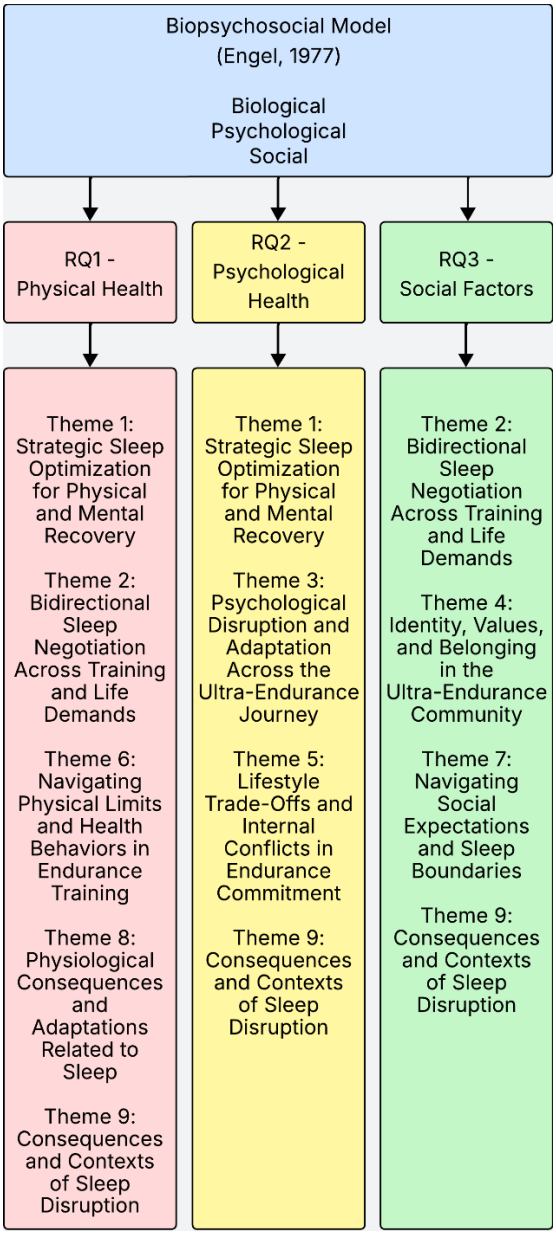
Theme Name	Subthemes	RQ Alignment	Biopsychosocial Domain	Codes
				technology, Sleep quality perception, Sleep routine, Enjoyment of ultra training
Bidirectional Sleep Negotiation Across Training and Life Demands	Training-Driven Sleep Adjustments, Work-Life Sleep Interference	RQ1, RQ3	Biological, Social	Adapting training to sleep quality, Sleep-performance relationship, Structured training, Time commitment of ultra training, Training alone, Training improves mental state, Training improves sleep, Training locations, Training volume adaptation, Balancing work and training demands, Increased work demands, Impact of sleep on work performance, Sleep impacts work performance, Sleep schedule adaptation to work, Afternoon activity preference post-remote work
Consequences and Contexts of Sleep Disruption	Biological Consequences, Psychological Consequences, Social Disruptions	RQ1, RQ2, RQ3	Biological, Psychological, Social	Sleep deprivation from crewing/pacing, Sleep disruption, Sleep disruption due to partner's health, Sleep deprivation in longer races, Sleep deprivation impacts mental resilience, Exhaustion from sleep deprivation, Fatigue from sleep deprivation, Lack of sleep affects concentration, Lack of sleep affects mood, Lack of sleep increases illness, Limited sleep duration, Low sleep score post-ultra, Mental overactivity post-ultra, No correlation of sleep and race emotions, Post-race fatigue

Evaluation of the Findings

This section interprets the study's findings through the lens of the Biopsychosocial Model (Engel, 1977) and in relation to the literature discussed in Chapters 1 and 2. The findings offer a multidimensional portrait of how ultra-marathon runners experience and manage inadequate sleep across physical, psychological, and social domains. The themes identified through reflexive thematic analysis represent a coherent, layered response to the study's three research questions. As illustrated in Figure 1, several themes aligned primarily with a single domain, while others—including Strategic Sleep Optimization for Physical and Mental Recovery (Theme 1), Bidirectional Sleep Negotiation Across Training and Life Demands (Theme 2), and Consequences and Contexts of Sleep Disruption (Theme 9)—spanned multiple biopsychosocial domains and research questions. This conceptual overlap highlights the interrelated nature of physical health, psychological health, and social well-being in the context of ultra-endurance. Across all dimensions, the findings align with existing research while also extending the conversation in important and novel ways.

Figure 1

Thematic Distribution Across Research Questions and Biopsychosocial Domains



For Research Question 1, five themes demonstrated that participants viewed sleep as essential for physical performance, recovery, and adaptation to training demands. These findings confirm previous research on the physiological consequences of inadequate sleep, including impaired muscle repair, an increased risk of injury, and delayed adaptation to increased training

loads (Fullagar et al., 2015; Riegler et al., 2023). Notably, this study extends the existing literature by revealing how athletes adopt individualized sleep routines and use both behavioral and technological strategies to enhance their recovery and resilience. Participants described using wearable technology, making routine adjustments, and prioritizing recovery to protect their physical health during demanding training cycles. These proactive approaches suggest a growing awareness of the long-term benefits of sleep management among ultra-endurance athletes.

Regarding Research Question 2, four themes emerged that captured the cognitive and emotional consequences of sleep disruption, including reduced focus, emotional volatility, and motivation challenges. These outcomes are consistent with established research documenting the psychological effects of inadequate sleep in both general and athletic populations (Brace et al., 2024; Montero et al., 2022). The results also demonstrate that athletes employ a range of deliberate strategies to support psychological recovery, including ritualized routines, boundary setting, and cognitive reframing of setbacks. Participants highlighted how quality sleep contributes to improved mood, emotional regulation, and sustained engagement in both training and competition. The ability to adapt and maintain motivation despite disrupted sleep was frequently described as a critical component of mental resilience.

For Research Question 3, four themes were identified that describe the social consequences of insufficient sleep, including the negotiation of family routines, challenges to social participation, and changes in norms within endurance sports communities. These findings support the existing literature on the social context of athlete health, highlighting that relational demands and cultural expectations can complicate sleep prioritization and recovery practices (Smith et al., 2023). Notably, some participants expressed a growing resistance to endurance culture’s tendency to glorify sleep sacrifice, suggesting that attitudes toward recovery may be

evolving. The study highlights that successful sleep management often depends on both individual boundary-setting and the willingness of family, peers, and communities to support new norms. In this way, sleep health is positioned as both a social and a personal or biological issue.

In conclusion, this study's findings are consistent with the Biopsychosocial Model and reinforce previous research while also offering new insight into how ultra-endurance athletes navigate the multifaceted impact of inadequate sleep. This study supports prior evidence that sleep deprivation impairs physical function (Riegler et al., 2023), emotional regulation (Brace et al., 2024), and social relationships (Smith et al., 2023). The study advances the understanding of sleep as a critical, multidimensional factor in endurance sports, highlighting the importance of integrated approaches to athlete well-being. By clarifying the interplay between physical, psychological, and social dimensions, these results lay a foundation for further discussion of theoretical implications, practical recommendations, and future research directions in Chapter 5.

Summary

Chapter 4 of this dissertation presents comprehensive findings from a qualitative, descriptive, single-case study that explored how ultra-marathon runners perceive the role of sleep in their physical, psychological, and social well-being during endurance events. By conducting semi-structured interviews with 15 ultra-marathon runners from various regions of the United States, the study explored the complex relationships between sleep, athletic performance, and personal well-being. The study identified patterns and themes that clarified the multidimensional impact of sleep disruption on ultra-endurance athletes, providing critical insights into their biopsychosocial experiences.

The trustworthiness of the data was ensured through rigorous methodological approaches addressing credibility, transferability, dependability, and confirmability. Credibility was established through triangulation of data sources, including semi-structured interviews, existing literature, and contextual insights. Member checking was conducted by sending participants their verbatim transcripts for review, while peer debriefing with dissertation committee members provided external validation of analytic decisions. Transferability was supported through detailed documentation of the study context, participant demographics, and methodological steps, enabling readers to assess the relevance of the findings to other populations.

Nine distinct themes were identified across three primary research questions. For physical health, participants demonstrated strategic sleep optimization techniques, including the use of technological tracking, behavioral sleep hygiene practices, and adaptive training approaches. The physiological consequences of sleep disruption have been documented, highlighting its impacts on heart rate regulation, performance efficiency, and recovery processes. Psychological findings unveiled complex emotional and cognitive responses to sleep challenges, including anticipatory anxiety, mental resilience strategies, and the development of adaptive coping mechanisms. Social factors emerged as equally significant, with participants navigating intricate relationships between athletic commitments and personal life demands. The research highlighted how ultra-marathon runners construct their identity within a supportive community, manage social expectations, and establish boundaries to protect their sleep and recovery needs. Themes of community belonging, social negotiation, and the impact of sleep disruption on interpersonal relationships were explored.

The findings align with the Biopsychosocial Model, demonstrating that sleep experiences are not isolated phenomena but rather interconnected experiences that span biological,

psychological, and social domains. The findings extend existing literature by providing nuanced insights into how ultra-endurance athletes understand, manage, and respond to sleep challenges. Practically, the study highlights the need for integrated approaches to sleep management in endurance sports. The findings suggest that effective support for athletes must consider the complex interplay between physical recovery, psychological well-being, and social dynamics. By revealing the multifaceted nature of sleep in ultra-marathon running, the research provides a foundation for more comprehensive athlete support strategies, which may potentially improve performance, health, and the overall athletic experience.

Chapter 5: Implications, Recommendations, and Conclusions

The problem addressed in this study was the negative impact of inadequate sleep on athletes' physical health, psychological health, and social factors. The Centers for Disease Control (CDC, 2023) highlighted a general shortfall in sleep among adults, noting that 72.3% got sufficient sleep in 2020, a concern that extended into the athletic domain (Fox et al., 2020; Riegler et al., 2023). Ultra-marathon runners, in particular, have been significantly affected by the problem due to the extreme physical and psychological stresses they endure during their intense training and racing schedules. However, what had not been fully understood was the efficacy of sleep interventions specifically tailored to meet the unique needs of ultra-marathon athletes (Miller et al., 2022). The purpose of this qualitative, descriptive, single-case study was to explore how ultra-marathon runners in the United States perceive the role of sleep in relation to their physical health, psychological health, and social factors during endurance events. This research provided insights into effective sleep management practices tailored to the extreme demands of ultra-marathon participation, which are often characterized by prolonged physical exertion and disrupted sleep patterns (Fox et al., 2020; Miller et al., 2022; Riegler et al., 2023).

The study utilized a qualitative descriptive single-case study approach to investigate the perceptions of ultra-marathon runners regarding the impact of sleep on health and performance. Data were collected through in-depth, semi-structured interviews with 15 participants recruited from across the United States. The reflexive thematic analysis framework developed by Braun and Clarke (2023) guided the systematic coding and interpretation of the interview data. This approach facilitated a rigorous and transparent analysis of participants’ narratives regarding their sleep strategies, challenges, and adaptations.

Thematic analysis identified nine themes reflecting the multifaceted ways inadequate sleep influences the physical, psychological, and social domains of ultra-marathon runners' experiences. These themes, aligned with the study's three research questions, revealed a complex interplay between biological recovery, psychological adaptation, and social negotiation. Key findings demonstrated that ultra-endurance athletes employ a variety of deliberate strategies for optimizing sleep, navigate ongoing tensions between training and life demands, and experience significant biopsychosocial consequences from disrupted sleep. Subthemes further illustrated the depth of adaptation and the individualized responses to sleep challenges. Limitations of this study included a relatively small sample size of 15 participants, potential self-selection bias due to the recruitment methods used, and reliance on self-reported data. While the qualitative approach enabled rich exploration of lived experiences, generalizability to all ultra-marathon runners may be limited. Additionally, interviews were conducted virtually, which could have influenced participants' responses due to environmental distractions or technological issues.

This chapter presents a comprehensive discussion of the study's findings, organized by research question and subtheme, and framed within the existing literature and theoretical framework. The implications section outlines how the results contribute to the understanding of sleep's role in ultra-endurance athletics, as well as the factors that may have influenced the interpretation of the results and the areas of consistency or divergence from previous research. Following this, the chapter presents recommendations for practice and theory based on the study's findings. The chapter concludes with suggestions for future research and a summary of the study's significance and key takeaways.

Implications

Research Question 1. How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their physical health during endurance events?

Theme 1: Strategic Sleep Optimization for Physical and Mental Recovery. Ultra-marathon runners in this study consistently reported that sleep is not just a passive recovery state but an active and essential tool for enhancing both physical recovery and training effectiveness. Many athletes described incorporating wearable technology, such as Garmin or WHOOP devices, into their daily routines to track metrics like heart rate variability and sleep stages. As Eric shared, "I use my Garmin watch to track my HRV status, which I find super valuable for planning training." This technological feedback loop enabled participants to make data-informed adjustments to their training load and rest, embodying the performance-driven approach advocated in contemporary sports science research (Fullagar et al., 2015; Roberts et al., 2022). Importantly, the use of technology also introduced new challenges, such as reliance on device accuracy or frustrations with equipment, highlighting the need for personalized approaches to sleep monitoring.

Alongside technological strategies, participants emphasized the importance of behavioral sleep hygiene practices. Many reported maintaining structured routines before bedtime, including yoga, stretching, reducing caffeine intake after morning hours, and controlling environmental factors such as light and noise. Michelle described her routine: "I do a yoga stretching routine every night, faithfully… drink tea, and use an eye mask." This dedication to sleep rituals is strongly supported in the literature as a way to promote recovery and minimize the negative effects of sleep deprivation in endurance athletes (Doherty et al., 2021; Fullagar et al., 2023). However, the real-world implementation of these strategies was sometimes influenced by factors

outside the athlete's control, such as family demands, travel for races, or changes in home environment, demonstrating how social and environmental variables can complicate even the most well-designed routines.

Another aspect of this theme centered on how runners deliberately adjusted training and lifestyle to optimize physical recovery. For example, Andrea explained, "A lot of times, I take Thursday off from running or just do a shorter workout… so I can sleep in a little longer." Such intentional rest planning, including the strategic use of naps or modifications to training volume, aligns with research advocating for periodized rest as a core element of injury prevention and performance gains (Bender & Lambing, 2024; Charest & Grandner, 2022). For these athletes, sleep was seen not as optional, but as an integral part of the endurance toolkit—a resource to be managed and protected as carefully as nutrition or hydration.

The implication of these findings is that effective physical recovery for ultra-endurance athletes relies on a dynamic combination of biological, psychological, and social strategies. The biopsychosocial model (Engel, 1977) is thus fully supported by the evidence here, as participants' approaches to sleep optimization were influenced by their bodily needs, mental routines, and social environments. These results reinforce the need for highly individualized, technologically supported, and context-sensitive interventions to enhance sleep and recovery, aligning with the growing consensus in the literature.

Interpretation of these findings should consider that the COVID-19 pandemic, changes in work structure, and family roles may have influenced participants' ability to implement sleep optimization strategies during data collection. Additionally, access to technology or a supportive environment was not equal for all athletes, and those with greater resources may have experienced more consistent improvements in recovery. Participants with access to wearable

sleep trackers may have had greater awareness of sleep deficits, which could have biased them toward more structured interventions than athletes without such tools. It should also be noted that athletes with greater access to wearable technology or flexible work schedules may have reported more success with implementing sleep optimization strategies, potentially skewing results toward higher adaptability.

Theme 2: Bidirectional Sleep Negotiation Across Training and Life Demands. Participants described an ongoing process of negotiating between the demands of their training and the realities of their personal and professional lives. Sleep was rarely a fixed routine; instead, it adjusted in response to increases in training intensity, changes in work schedules, or unexpected family needs. Justin reflected on this balancing act, noting, "I base my sleep needs on training intensity. After a very hard training week nearing my peak, I adjust for a deload week." This flexible approach aligns with the literature advocating for individualized rest protocols and the concept of "sleep periodization" in athlete recovery plans (Fullagar et al., 2015; Kishi et al., 2024). The ability to self-monitor and adjust both sleep and training demonstrates high self-awareness while also highlighting the vulnerability of even the best-laid plans to outside pressures.

Work and family obligations were the most frequently cited barriers to optimal sleep patterns. Michelle shared, "If I do not sleep well or have a bad headache, I cut my running by 50% or skip it altogether. I try very hard to sleep well to avoid missing runs and feeling like I cheated myself." This sentiment was echoed throughout the sample, with participants often expressing feelings of guilt or frustration when external factors, such as late-night work, travel, or childcare, forced them to compromise on sleep or skip workouts. These patterns are strongly supported by research indicating that social and environmental demands are among the most

significant barriers to adequate recovery for athletes (Bender & Lambing, 2024; Walsh et al., 2020). The implication is that effective sleep and training management for ultra-endurance athletes must recognize and accommodate these external realities, rather than prescribing rigid, one-size-fits-all routines. The data also suggest that societal changes, such as the rise of remote work during the pandemic, may have had both positive and negative impacts on athletes' sleep and training schedules. For some, flexible hours enabled more rest and self-care; for others, the blurring of boundaries between work, training, and family created additional strain. This complexity underscores the need for coaches, mental performance coaches, and other health professionals to adopt a holistic approach to athlete well-being, providing support that addresses both the physical and social aspects.

Theme 6: Navigating Physical Limits and Health Behaviors in Endurance Training. Managing hydration, nutrition, and physical health behaviors emerged as a central strategy for minimizing the negative physical effects of sleep deprivation. Mark described the challenge: "Staying hydrated is sometimes a challenge, especially at work. You get busy doing stuff and end up not drinking enough water all day, and it snowballs." Runners frequently reported adopting proactive approaches to fueling, hydrating, and monitoring their bodies for signs of overtraining or illness. These strategies align with findings from Simim et al. (2020) and Vitale et al. (2019), who demonstrated that well-managed nutrition and hydration can buffer the physiological impacts of inadequate sleep.

Despite high health literacy, participants acknowledged that workplace constraints, travel, and illness could easily disrupt these routines, leading to fatigue or injury. The data highlight that even the most committed athletes cannot always control every variable affecting their recovery, reinforcing the need for flexible and realistic self-management strategies. The implication here is

that interventions targeting the physical health of ultra-marathon runners should incorporate education on adaptable hydration, fueling, and rest protocols, emphasizing that perfection is less important than consistency and resilience. As many participants self-identified as seasoned or experienced runners, their insights may reflect post-hoc rationalizations of behavior that evolved over time, rather than real-time responses to sleep loss. The absence of strong correlations between sleep loss and reported injury for some may be due to individual genetic differences in sleep need or pain tolerance—factors not measured in this study but noted in sleep literature. These findings align with the biopsychosocial perspective, which recognizes that physical, psychological, and social dimensions are all essential for sustained health and performance (Engel, 1977).

Theme 8: Physiological Consequences and Adaptations Related to Sleep. Participants vividly described the physical consequences of inadequate sleep, noting increased heart rate, persistent fatigue, and a greater struggle to maintain performance during and after ultra events. Eric stated, “After an ultra, my heart rate is noticeably different. I'll probably have a naturally higher heart rate, which makes sleeping difficult.” The experience of chronic tiredness, disruptions in circadian rhythm, and reduced recovery capacity is reflected throughout the literature on sleep and endurance performance (Benchetrit et al., 2024; Riegler et al., 2023). Surprisingly, not all participants linked chronic sleep loss to noticeable injury, diverging from the majority of physiological literature. This may reflect sample-specific resilience, differences in training load, or self-monitoring habits.

Despite these challenges, athletes also reported developing adaptations—such as adjusting wake times, utilizing naps, or moderating expectations—to continue their training. These physiological responses highlight the body’s remarkable resilience, but also its limitations

when faced with prolonged sleep loss. This implies that acute and chronic sleep disruptions require differentiated management strategies, and athletes, coaches, and health professionals should remain vigilant for signs of cumulative fatigue, which may not always be visible or self-reported. Unexpectedly, some athletes reported no major injuries despite chronic sleep loss, diverging from widely reported findings that link insufficient sleep to increased injury risk—particularly in endurance athletes—due to impaired recovery, neuromuscular coordination, and immune function (Fullagar et al., 2015; Medic et al., 2017; Riegler et al., 2023; Roberts et al., 2022). This may be attributed to the high health literacy and proactive self-monitoring among this sample.

Theme 9: Consequences and Contexts of Sleep Disruption (Physical Domain). Ultimately, the broad, integrative theme of sleep disruption highlighted the extensive range of negative outcomes associated with inadequate rest. Kelly's succinct observation—"Lack of sleep makes you exhausted"—was echoed by others who described persistent fatigue, diminished concentration, and, in some cases, increased susceptibility to illness. Emily shared, "I have experienced significant fatigue related to poor sleep, but no major injuries or illnesses," capturing the reality that, while not every athlete experiences overt injury, the cumulative burden of sleep disruption still erodes their physical and mental reserves. These findings are strongly supported by studies documenting the physiological risks and performance decrements associated with chronic sleep deprivation (Doherty et al., 2021; Fullagar et al., 2015). The implication is that regular monitoring and early intervention for sleep issues should be standard practice in ultra-endurance training environments. While some runners may develop coping strategies, others may be at increased risk for burnout or injury if chronic sleep loss is left unaddressed.

In summary, the implications of these themes for Research Question 1 underscore the importance of sleep optimization for physical health and performance in ultra-marathon runners. The findings underscore the need for individualized, context-aware interventions that integrate technology, behavioral routines, and a realistic understanding of life's competing demands. This work broadens the current literature by demonstrating how the physical, psychological, and social aspects of the athlete's experience are interconnected and must be addressed in any comprehensive strategy for athlete health.

Research Question 2. How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their psychological health during endurance events?

Theme 1: Strategic Sleep Optimization for Physical and Mental Recovery. Participants emphasized that their efforts to optimize sleep extended beyond physical health and had a direct impact on their psychological well-being. Many described sleep as a foundation for emotional regulation, resilience, and a positive mindset during both training and competition. For example, Andrea observed, "I am a lot less impulsive when I am well-rested. I negotiate with myself a lot better." This sentiment was echoed by Lisa, who stated, "Motivation and sleep are very connected… Good training, positive motivation, and a supportive community help your mental state." Such reflections align with the literature, which demonstrates that sufficient sleep supports cognitive functioning, mood stability, and the capacity to manage the psychological demands of ultra-endurance events (Fox et al., 2020; Fullagar et al., 2015).

Athletes also reported that sleep tracking and biofeedback tools contributed to their psychological security, enabling them to confirm their recovery status and alleviate anxiety regarding readiness for training or racing. For some, these tools lessened the cognitive load of self-monitoring, while for others, technological limitations sometimes became a source of

frustration. Overall, integrating intentional sleep strategies fostered a sense of control that supported athletes' ability to cope with setbacks and maintain motivation.

The implications of these findings reinforce the biopsychosocial model by demonstrating the interconnectedness of psychological and biological recovery processes (Engel, 1977). Interventions aimed at enhancing psychological resilience in ultra-marathon runners should prioritize both sleep optimization and emotional regulation, utilizing behavioral routines and supportive technologies when appropriate. It is also important to note that participants' psychological experiences were influenced by the broader context of their lives, including work and family responsibilities, which sometimes disrupted even the most carefully laid recovery plans.

Theme 3: Psychological Disruption and Adaptation Across the Ultra-Endurance Journey. A central theme in participants' narratives was the psychological disruption caused by inadequate sleep, particularly during crucial periods in the ultra-endurance timeline, such as pre-race anticipation and post-race recovery. Many described anticipatory anxiety and mental overactivity before races, with Sarah stating, "The night before, I just can't turn my brain off." These episodes of sleeplessness and rumination often led to a cascade of emotional and cognitive challenges, including increased anxiety, self-doubt, and irritability. Eric reflected on this pattern, explaining, "Before a big race, my mind is racing all night. I go through every worst-case scenario, even if I know I've trained hard."

Participants also described experiencing post-race emotional lows and psychological exhaustion, which were sometimes accompanied by disrupted sleep and extended mood disturbances. Lisa remarked, "After the race, it's like a mental crash. I just feel completely drained and can't sleep for days." These findings are strongly supported by research indicating

that sleep deprivation heightens emotional volatility, impairs coping mechanisms, and increases the risk of anxiety and depression symptoms in endurance athletes (Brace et al., 2024; Walsh et al., 2021).

Despite these challenges, athletes described various adaptation strategies to cope with psychological disruption, such as reframing negative thoughts, seeking social support, or adjusting expectations. Over time, many reported developing greater resilience and self-awareness, recognizing that disrupted sleep and fluctuating mood were inherent aspects of the ultra-endurance journey. Contrary to prior research suggesting pervasive psychological decline with sleep loss (Fox et al., 2020; Montero et al., 2022; Walsh et al., 2021), several participants described enhanced resilience. This divergence may reflect a selection bias toward mentally hardened athletes or may suggest adaptive capabilities unique to ultra-endurance contexts. The implication is that psychological interventions for ultra-athletes should not only target emotional regulation and stress management but also encourage acceptance and flexible coping in the face of unavoidable sleep challenges.

It is essential to acknowledge that data collection took place several years after the peak of the COVID-19 pandemic. However, ongoing societal changes and residual effects from the pandemic era—such as shifts in work structure, altered routines, and increased awareness of mental health—may have influenced participants' experiences. Psychological narratives may also have been shaped by cultural also shaped psychological narratives, potentially leading participants to underreport the depth of their distress. These long-term contextual factors could have affected levels of stress, adaptation, or sleep patterns, suggesting a need for further research into how external societal changes intersect with sleep and psychological health in this population.

Theme 5: Lifestyle Trade-Offs and Internal Conflicts in Endurance Commitment. The psychological cost of sustained ultra-endurance training was evident in participants' ongoing negotiation of boundaries, priorities, and personal identity. Many described internal conflict when trying to balance the demands of training, work, and family with their mental health needs. For example, Michelle expressed, "I constantly have to remind myself that skipping a run for more sleep isn't [a] failure. It's necessary for my health, even if it feels like I'm letting myself down." This statement highlights the deep-rooted association between self-worth, commitment, and training adherence—a relationship that can be both motivating and burdensome.

Several participants reported that insufficient sleep worsened existing psychological vulnerabilities, such as self-criticism, guilt, or performance anxiety. The necessity of prioritizing recovery sometimes conflicted with the cultural values of perseverance and grit, leading to challenging intrapersonal negotiations. Brian described this tension, stating, "There's always that voice that says, 'If you were tougher, you wouldn't need so much rest,' but I know that's not true. I'm learning to respect my limits." Unlike earlier studies that describe burnout or sport abandonment following chronic sleep issues, the participants in this study remained engaged. This may reflect a selection effect, as only currently committed athletes chose to participate.

The literature supports these accounts, indicating that athletes often experience identity conflict and psychological strain as they strive to reconcile their personal values with the reality of physical limitations (Brace et al., 2020; Colangelo et al., 2023). Participants' accounts of psychological disruption may have been shaped by their self-perception as resilient athletes, which could have led to underreporting of mental health struggles or overemphasis on adaptive coping. Given the retrospective nature of the interviews, memory bias may have affected how participants framed psychological responses to sleep deprivation, particularly during periods of

intense training or emotional strain. The implication is that psychological support for ultra-marathon runners must address not only sleep and mood but also the deeper questions of identity, motivation, and self-compassion. Interventions that promote cognitive reframing and internal boundary negotiation can help athletes sustain both high achievement and psychological well-being. While some studies emphasize sleep as a passive outcome of training load, participants in this study framed it as a moral and identity-driven choice, suggesting a deeper psychological entrenchment of recovery behavior than previously assumed.

Theme 9: Consequences and Contexts of Sleep Disruption (Psychological Domain). Sleep disruption was consistently linked to impaired concentration, diminished emotional stability, and increased susceptibility to stress. Sarah explained, "When I don't sleep enough, I tend to be more trigger-happy with my decisions. I don't think it through as much because I don't have the brain space it deserves." This observation is echoed throughout sleep science literature, demonstrating that inadequate sleep impairs executive function, increases impulsivity, and undermines resilience under pressure (Fox et al., 2020; Montero et al., 2022). Andrea added, "When I do not get enough sleep, I definitely have trouble focusing. I tend to multitask more, jump around from thing to thing, and struggle to sit and complete something when I am sleep-deprived." These cognitive and emotional symptoms were not isolated incidents but recurring experiences that shaped participants' daily functioning, relationships, and overall psychological health.

Some participants recognized that over time, they developed compensatory strategies, such as using nutrition, mindfulness, or structured routines to buffer the worst psychological effects of sleep loss. However, most agreed that chronic sleep deprivation had a cumulative, negative effect on their mood, concentration, and sense of well-being. The implication for

practice is that coaches, clinicians, and athletes themselves should prioritize regular screening for sleep disruption and psychological symptoms, integrating sleep health education into mental skills training and self-care routines. These findings also suggest that the social environment—including cultural norms, family expectations, and organizational demands—can exacerbate or mitigate the psychological impact of sleep loss. In summary, the implications for Research Question 2 demonstrate that the psychological health of ultra-marathon runners is closely intertwined with their sleep patterns, emotional regulation skills, and social context. Effective support for this population will require a biopsychosocial approach that addresses not only the symptoms but also the underlying dynamics of stress, identity, and adaptation.

Research Question 3. How do ultra-marathon runners in the United States perceive the role of inadequate sleep on their social factors during endurance events?

Theme 2: Bidirectional Sleep Negotiation Across Training and Life Demands. Ultra-marathon runners described the ongoing process of negotiating sleep, training, and life responsibilities as a core part of their social experience. This negotiation was particularly evident when athletes balanced family expectations, work demands, and the requirements of endurance training. For example, Justin explained, “Sometimes I get seven or eight hours. Sometimes it is three or four hours of somewhat good sleep. Even before one race, I only got two hours of sleep because of my daughter. Somehow, I still got top five. I was just going to have fun and survive, but I did better than I thought. Sleep is really random right now, especially with two kids. I have a third coming in June, so it will be even more inconsistent.” The need to accommodate childcare or partner needs often led athletes to adjust or sacrifice training plans, emphasizing that social context directly influenced both sleep and training routines.

Participants also highlighted that work schedules, unpredictable obligations, and shared living spaces contributed to irregular sleep patterns and forced compromises. Michelle shared, "On days I work, I'm lucky to get six hours of sleep, and if my husband snores or the kids get up, it's even less." These experiences align with findings in the literature, which show that endurance athletes are particularly vulnerable to social disruptions due to the unpredictability of daily life (Bender & Lambing, 2024; Walsh et al., 2020). As a result, runners learned to be adaptable and pragmatic, often prioritizing family or work over perfect sleep hygiene, even if it meant feeling less than optimal for training or racing.

The implication for both theory and practice is that sleep interventions for ultra-endurance athletes must acknowledge the interdependence of social and biological factors. These findings support the biopsychosocial model, as athletes' social roles and family responsibilities cannot be separated from their sleep management strategies (Engel, 1977). Coaches and sports health professionals—including, but not limited to, athletic trainers, physical therapists, and mental performance coaches—should develop flexible support systems that help athletes navigate these everyday social pressures, rather than expecting strict adherence to ideal routines.

Theme 4: Identity, Values, and Belonging in the Ultra-Endurance Community. The ultra-running community served as a vital source of identity and social belonging for its participants. Many runners described their social network within the sport as a shield against the isolation or misunderstanding they occasionally faced in other aspects of life. For instance, Mark stated, "Nobody cares about your time. They're impressed that you ran 50 miles. It's more about finishing than speed." This community emphasis on participation, resilience, and mutual respect enabled participants to view their efforts positively, even when sleep disruptions or physical fatigue threatened their motivation.

Athletes also described the cultural norms of ultra-running as focused on perseverance, positivity, and collective support. Lisa remarked, “The ultra community is so supportive. If you’re tired or struggling, someone is always there to encourage you or share their own crazy sleep story.” This social support often compensated for sleep-related setbacks, making athletes feel understood and valued, regardless of individual outcomes. The literature supports these findings, indicating that a strong sense of community and belonging can help athletes cope with the stresses of sleep loss, performance pressure, and balancing multiple roles (Byrne et al., 2024; Fox et al., 2020).

While the literature often portrays the ultra community as isolating, participants largely emphasized support and inclusion, which may reflect evolving cultural norms or selective memory recall during interviews. Participants’ ability to maintain relationships despite disrupted sleep may reflect pre-existing resilience or strong communication skills, not generalizable across all ultra-athletes. The implication is that the social environment of the ultra-running community is a powerful protective factor. When developing mental health and recovery interventions, it is essential to consider and leverage these cultural strengths, helping athletes connect with peers and access support networks that reinforce positive identity and resilience.

Theme 7: Navigating Social Expectations and Sleep Boundaries. A recurring challenge for ultra-marathon runners participating in this study was managing social expectations and setting boundaries to protect their sleep and recovery time. Participants described negotiating with partners, children, and friends about bedtime routines, training schedules, and social engagements. Sarah noted, “Scheduling training around family is a challenge. Sometimes you have to miss out on things, or your family thinks you’re obsessed.” The need to prioritize an early bedtime or miss social events to recover adequately often led to feelings of guilt or the

perception of being misunderstood by non-runners. Several athletes discussed the tension between relational obligations and their own need for rest. Jason explained, “If the running or lack of sleep affects my mood, like getting angry at my kids, I need to remember that running is not the main thing. As the kids get older, they will have their own sports, which will take away time from training, and that is a good trade-off.” This process of boundary negotiation and compromise demonstrates the constant adaptation required to maintain healthy relationships while pursuing demanding athletic goals.

Research supports these findings, highlighting that relational stress and conflicting expectations can lead to increased sleep disruption and negatively impact recovery (Fox et al., 2020; Smith et al., 2023). Because social dynamics are deeply embedded in cultural norms, interpretations of social strain or support may differ by region or community culture, which this study did not systematically control for. Participants’ reflections on social boundaries may have been influenced by their unique family structures or support systems, which were not standardized across the sample and may limit cross-case comparisons. While disrupted sleep is often linked to relational strain, some participants reported strengthened bonds due to shared commitment and mutual support—an unexpected finding that suggests endurance events may sometimes unify rather than divide households. The implication for practice is that sleep and recovery plans should address family communication, role expectations, and the need for athletes to advocate for their own health needs within their social circles. Education and counseling may be necessary to help both athletes and their support systems understand the importance of sleep and the need for mutual respect for boundaries.

Theme 9: Consequences and Contexts of Sleep Disruption (Social Domain). Participants often described the broader social consequences of inadequate sleep, noting

increased irritability, strained relationships, and reduced enjoyment of both training and family life. Lisa shared, “When I haven’t slept, I’m more impatient with my family, and sometimes I just want to be left alone instead of going out with friends.” These emotional and behavioral shifts were not always fully understood by family or colleagues, sometimes leading to misunderstandings or conflict. Brian added, “We have two young kids, and after they go to bed, we do too. It’s the only way to get enough sleep, but it means less time with each other in the evenings.” These trade-offs illustrate the social ripple effects of sleep deprivation and how athletes adjust their routines to cope.

These findings are supported by the literature, which indicates that chronic sleep deprivation increases interpersonal stress, decreases social engagement, and can undermine social support systems if not properly managed (Smith et al., 2023; Walsh et al., 2020). This suggests that sleep health should be viewed not only as an individual concern but also as essential for the functioning of relationships and communities. Social interventions that promote open communication, collaborative problem-solving, and empathy can alleviate the negative social effects of disrupted sleep. Contrary to literature suggesting withdrawal from social settings due to sleep debt, some participants reported increased family bonding through mutual sacrifice and schedule coordination, highlighting a potential adaptive trade-off unique to ultra-endurance households. In summary, the implications of Research Question 3 suggest that social factors are intricately linked to the sleep experiences of ultra-marathon runners.

The consequences of this research extend beyond individual athletes, informing broader discussions in public health, sports culture, and wellness about how society values sleep, performance, and resilience. The complexity of managing relationships, community expectations, and social commitments means that effective support for these athletes must

transcend physical recovery and psychological resilience, encompassing the full range of biopsychosocial influences on health and performance. At a societal level, this study suggests a growing cultural shift in endurance sports toward valuing recovery and holistic health, challenging the traditional glorification of 'pushing through' fatigue.

These findings highlight the urgent need to reframe existing societal narratives that equate sleep deprivation with mental toughness, especially in elite endurance contexts. The study presents a counternarrative by normalizing adaptive rest behaviors in high-performance communities, which may lead to lower injury rates and improved long-term athlete retention. Furthermore, the sleep strategies identified among ultra-endurance athletes could serve as a transferable model for broader health promotion efforts, fostering self-regulated, holistic recovery practices in similarly high-demand fields, such as medicine, education, and emergency services. If widely shared, these insights may influence public health campaigns that stress the interdependence of sleep, identity, and resilience, shifting away from one-size-fits-all interventions toward more culturally sensitive and contextually grounded recovery frameworks. By demonstrating the biopsychosocial ripple effects of sleep disruption, this research has implications not just for sport-specific interventions but also for developing sustainable wellness paradigms across occupational and societal domains.

Recommendations for Practice

The findings of this study provide several actionable recommendations for ultra-endurance athletes, coaches, mental performance coaches, and other healthcare professionals who support this population. Each recommendation is based on participant data and set within the broader context of current research and the biopsychosocial model (Engel, 1977; Fullagar et al., 2015). Collectively, these recommendations encourage the development of individualized,

evidence-based strategies for promoting sleep health, which in turn supports athletic performance and overall well-being (Fox et al., 2020; Miller et al., 2022).

First, it is recommended that ultra-endurance athletes and their support teams promote the integration of both personalized sleep tracking and behavioral interventions. Many participants benefited from wearable devices to monitor sleep stages and recovery status, reporting that these tools facilitated more informed decisions about rest and training adjustments. These findings align with research highlighting the value of combining technological tools with athlete self-awareness and data-driven decision-making (Fullagar et al., 2015; Roberts et al., 2022). However, technology alone was not enough, as behavioral interventions such as maintaining consistent bedtime routines, limiting caffeine intake, and creating a sleep-friendly environment were also described as vital components of effective recovery. The literature supports this integrated approach, noting that both objective feedback and behavioral modification can improve sleep quality and reduce the risk of injury and burnout (Bender & Lambing, 2024; Doherty et al., 2021). Practitioners should, therefore, assist athletes in identifying which tools and routines are most accessible and effective given their resources and circumstances rather than recommending a standardized set of practices.

Another important recommendation is for coaches and professionals to address the influence of work, family, and social demands in sleep management planning. Athlete participants in this study often reported modifying their training and sleep routines due to childcare, professional obligations, and household disruptions, a finding echoed in the literature as a major barrier to optimal recovery (Byrne et al., 2024; Walsh et al., 2020). Environmental and social demands have been shown to interact with training stress, influencing both sleep quality and overall well-being (Miller et al., 2022; Smith et al., 2023). Practitioners are

encouraged to collaborate with athletes to develop flexible sleep management plans that anticipate and accommodate these competing demands. Approaches such as family education sessions, workplace advocacy, and open communication between athletes and their support networks can help reduce conflict and enhance adherence to recovery routines (Fullagar et al., 2015; Roberts et al., 2022).

The psychological findings of this study also suggest the need to foster psychological resilience and identity flexibility in relation to sleep and recovery. Many participants reported struggling with internalized expectations of toughness or guilt when they required more sleep or missed a workout due to fatigue. Prior literature on athletic identity, mental toughness, and stress management highlights the importance of supporting athletes in developing flexible and resilient mindsets (Brace et al., 2024; Colangelo et al., 2023; Fox et al., 2020). Coaches, counselors, and professionals in mental performance roles—including licensed sport psychologists—should actively encourage athletes to reframe recovery as an essential aspect of performance, rather than a sign of weakness. Interventions such as mental skills training, group discussions about shared challenges, and integrating sleep education into performance reviews can facilitate this shift in perspective (Bender & Lambing, 2024; Walsh et al., 2021).

Additionally, utilizing community and social support networks is recommended as a protective factor for athletes experiencing sleep challenges or setbacks. The significance of belonging to a supportive community has been documented as a key factor in reducing psychological distress and enhancing adaptation to adversity in endurance sports (Byrne et al., 2024; Fox et al., 2020; Smith et al., 2023). Many runners in this study relied on peer encouragement, shared stories, and the normalization of sleep difficulties to maintain motivation and perspective. Practitioners should promote access to these networks by supporting group

training, online forums, or educational workshops where experiences and strategies can be exchanged (Fullagar et al., 2015; Roberts et al., 2022).

Finally, it is advisable that ongoing screening for sleep health be integrated into standard athlete care. Chronic sleep disruption has frequently been associated with negative effects on mood, concentration, and relationships in both this study and the broader literature (Montero et al., 2022; Smith et al., 2023). Undetected or untreated sleep problems can hinder both psychological well-being and physical performance, underscoring the importance of early detection and targeted support (Fox et al., 2020; Miller et al., 2022). Healthcare providers and coaches should be trained to recognize sleep-related issues, offer brief interventions, and refer athletes to specialists as necessary, adhering to best-practice guidelines for multidisciplinary athlete care (Bender & Lambing, 2024; Walsh et al., 2020).

In summary, these recommendations for practice emphasize individualized, holistic strategies that address the full range of biopsychosocial influences on sleep and recovery (Engel, 1977; Fox et al., 2020; Fullagar et al., 2015). By integrating technology, behavioral science, social support, and psychological flexibility, practitioners can assist ultra-endurance athletes in achieving healthier, more sustainable performance outcomes. These approaches not only tackle immediate sleep challenges but also foster improved resilience, better adaptation to life demands, and enhanced overall well-being for athletes pursuing extreme endurance goals (Miller et al., 2022; Smith et al., 2023).

Recommendations for Future Research

The results of this qualitative descriptive single case study provide important insights into how ultra-marathon runners perceive the role of sleep in their physical health, psychological health, and social well-being. However, like all research, this study also raises new questions and

highlights areas that require further exploration. The following recommendations are grounded in the biopsychosocial framework (Engel, 1977), the study's findings, and the limitations identified in Chapters 3 and 4.

Future researchers should aim to include larger and more demographically diverse samples to enhance the generalizability and depth of these findings (Fullagar et al., 2015; Roberts et al., 2022). Expanding research beyond a single region or event will facilitate meaningful comparisons across different age groups, cultural backgrounds, and competitive levels (Smith et al., 2023). For instance, previous studies have noted demographic differences in sleep patterns and stress responses among athletes (Fox et al., 2020), as well as the impact of community support on recovery and adaptation (Bender & Lambing, 2024). Thus, representative sampling is crucial for future investigations to clarify whether the strategies and challenges identified in this study apply broadly to the ultra-endurance community or exclusively to specific subgroups.

There is also a strong need for future research to employ mixed-methods or longitudinal approaches. While qualitative interviews provide rich detail, they are limited in their ability to quantify changes over time or test relationships between variables (Doherty et al., 2021). Combining interviews with objective measures such as actigraphy, sleep diaries, or physiological markers can deepen the understanding of both subjective and objective sleep health (Cunha et al., 2023). Longitudinal studies that track athletes across training cycles, races, and recovery periods can further illuminate how sleep strategies and biopsychosocial impacts evolve over time, providing insights into causal pathways and the timing of effective interventions (Fullagar et al., 2015; Miller et al., 2022).

Another key recommendation is to systematically investigate the effectiveness of specific sleep interventions tailored for ultra-endurance athletes. While participants in this study described various self-directed strategies, there is a need for randomized controlled trials or pilot intervention studies that evaluate cognitive-behavioral therapy for insomnia (CBT-I), mindfulness training, structured sleep extension, or targeted educational programs (Fox et al., 2020; Walsh et al., 2020). The literature indicates that structured interventions can enhance both psychological resilience and physical recovery in athletes (Bender & Lambing, 2024; Brace et al., 2024), but further work is required to adapt and validate these strategies for ultra-marathoners facing unique environmental, logistical, and social challenges (Doherty et al., 2021).

Future research should also investigate the role of social environment and family dynamics in shaping athletes' sleep and recovery, as highlighted by the significant influence of relationships, community belonging, and family responsibilities in this study (Byrne et al., 2024; Fox et al., 2020). Including insights from spouses, children, training partners, and community networks will aid in identifying new support strategies and clarifying how organizational policies, workplace flexibility, and cultural attitudes affect sleep behavior and adaptation (Smith et al., 2023). Social context can serve as both a barrier and a resource for athletes, making it a crucial area for systematic investigation (Roberts et al., 2022).

Methodological considerations are also crucial for advancing research in this area. Future studies should address potential response bias associated with virtual interviews (Merriam & Tisdell, 2016) and consider in-person or hybrid data collection, triangulating self-reports with objective sleep data, and employing follow-up assessments to enhance validity and reliability (Braun & Clarke, 2023). Researchers should remain aware of self-selection bias, as athletes with more extreme experiences may be more likely to participate, potentially skewing results (Guest

et al., 2006). Strengthening research design will ensure that future findings are robust and actionable for the ultra-endurance community.

Identifying critical moments during the training or competition calendar when sleep disruption is most pronounced—such as pre-race preparation, post-race recovery, and periods of significant life or training transitions—will also benefit both research and practice (Simim et al., 2020; Vitale et al., 2019). Personalized and adaptive approaches that leverage technology and behavioral science can then be developed and evaluated to help athletes proactively manage sleep challenges as they arise (Driller et al., 2023; Gratwicke et al., 2021). Understanding these vulnerable periods and the effectiveness of individualized management strategies will provide valuable guidance for both practitioners and competitors.

Finally, an essential direction for future research is to explore gender differences in sleep experiences and adaptation among ultra-marathon runners. Although this study included both male and female athletes, the sample size was inadequate for a focused analysis of gender-based trends. Prior research suggests that women and men may differ in sleep efficiency, stress responses, and adaptation strategies, with possible influences from hormonal cycles, social expectations, and support networks (Roberts et al., 2022; Walsh et al., 2021). Purposeful sampling of balanced and sufficiently sized groups will enable a more detailed understanding of these differences and support the development of interventions that address the unique needs of all athletes.

In summary, advancing the field will require collaborative, interdisciplinary research that integrates perspectives from sports science, psychology, medicine, and the social sciences (Engel, 1977; Miller et al., 2022). By building on the foundational insights of this study and addressing the limitations, future research can create more comprehensive and individualized

strategies to optimize sleep and performance in ultra-endurance athletes. Addressing these recommendations will ensure that support for athlete well-being continues to evolve in tandem with the changing demands of sport and society.

Conclusions

This study addressed the critical problem of how inadequate sleep negatively impacts the physical health, psychological well-being, and social lives of ultra-marathon runners in the United States. Using a qualitative descriptive single-case study design guided by the biopsychosocial model (Engel, 1977), this research explored the nuanced ways that sleep management, recovery strategies, and social and psychological factors intersect during endurance events. Through in-depth interviews with 15 ultra-endurance athletes, nine core themes and multiple subthemes were identified, demonstrating that athletes engage in complex, adaptive, and individualized approaches to optimizing sleep within the context of their demanding lifestyles (Fox et al., 2020; Fullagar et al., 2015). This approach provided a rich, participant-driven account that fills a significant gap in the literature regarding the perceptions of sleep disruption in ultra-endurance sports (Miller et al., 2022).

The results of this study highlight that sleep for ultra-marathon runners is not just a biological function but a dynamic process shaped by deliberate self-regulation, social negotiation, technological monitoring, and ongoing psychological adaptation (Brace et al., 2024; Doherty et al., 2021). The findings reinforce the importance of flexible, individualized strategies and the need for athletes to be supported by knowledgeable coaches, healthcare providers, and strong community networks (Bender & Lambing, 2024; Smith et al., 2023). Notably, these results contribute to and expand on previous research by illustrating how ultra-endurance athletes both struggle with and overcome the biopsychosocial challenges of sleep disruption. This

research highlights the interconnectedness of physical, mental, and social health in endurance sports, showing that effective sleep management is crucial for sustained performance, resilience, and overall well-being (Fox et al., 2020; Walsh et al., 2020).

The key takeaway from this study is that optimal sleep and recovery for ultra-endurance athletes require a holistic and context-sensitive approach. This approach must address not only the biological and behavioral aspects of sleep but also the psychological stressors, lifestyle trade-offs, and social expectations inherent to the ultra-marathon community (Engel, 1977; Fullagar et al., 2015). While individualized interventions and technological supports are important, the broader context of family, community, and athletic identity plays a critical role in shaping sleep experiences and outcomes (Byrne et al., 2024; Roberts et al., 2022). Ultimately, promoting athlete health and performance demands attention to the full spectrum of biopsychosocial influences, along with ongoing adaptive support and education for both athletes and those who work with them.

Considering previous research and theory, these results affirm the value of the biopsychosocial model in understanding athletes' sleep perceptions and expand the literature by providing new insights into how ultra-marathon runners navigate real-world barriers to sleep and recovery (Engel, 1977; Fox et al., 2020; Miller et al., 2022). The study’s recommendations emphasize more integrated, evidence-based practices, an increased focus on social context, and a sustained commitment to person-centered care in sports science. The findings also highlight opportunities for future research, including the exploration of gender differences, the efficacy of interventions, and broader societal factors that affect sleep health (Roberts et al., 2022; Walsh et al., 2021). By synthesizing empirical data with established theory, this study offers practical

guidance and a call to action for enhancing the well-being, resilience, and quality of life of athletes in endurance sports.

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Appendix A

Research Questions and Interview Questions

Research Questions

Research Question 1 (RQ1): How do ultra-endurance athletes perceive the role of sleep in their physical health?

Research Question 2 (RQ2): How do ultra-endurance athletes perceive the role of sleep in their psychological well-being?

Research Question 3 (RQ3): How do ultra-endurance athletes perceive the role of sleep in their social well-being?

Research Question Criteria/Interview Questions

- **RQ1:**
    1. Please describe your typical sleep routine during training and before competitions.
    2. How do you feel your sleep quality affects your physical performance during training or races?
    3. What effects, if any, have you noticed from sleep deprivation or poor sleep on your recovery after intense training sessions or competitions?
    4. What, if any, physical health issues have you experienced (such as injuries, fatigue, or illness) that you believe were related to inadequate sleep?
    5. What strategies, if any, have you used to improve your sleep quality?
        - How would you describe the impact of your identified sleep strategies on your physical health and performance?

- **RQ2:**
    1. How does your sleep pattern impact your mental state or mood during training and competitions?
    2. Please describe any psychological challenges you face when you do not get enough sleep, such as increased stress, heightened anxiety, or difficulties with focus or concentration.
    3. How do you think sleep quality affects your motivation during training and races?
        a. Can you also describe its impact on your confidence levels?
    4. Have you noticed any changes in your cognitive functioning (like decision-making or concentration) related to your sleep habits?
    5. What role do you believe sleep plays in managing the psychological demands of being an ultra-endurance athlete?
- **RQ3:**
    1. How does your sleep schedule impact your social interactions with friends, family, or fellow athletes?
    2. What social challenges, if any, have you encountered due to your sleep patterns or the need to prioritize sleep?
        a. Could you provide specific examples?
    3. How do you feel that your sleep habits affect your ability to participate in social activities or maintain relationships?
    4. How does the need for adequate sleep influence your involvement in community events or activities related to ultra-endurance sports?
    5. Please describe any support you receive from your social network regarding your sleep habits and needs as an ultra-endurance athlete.

Appendix B

Verbal Consent Notice

Introduction

Hello, my name is Bailey Trammell, and I am a doctoral student at National University. I am conducting a research study called "Managing Midnight Miles: A Qualitative Descriptive Single-Case Study on Sleep Strategies Among United States Ultra-Marathon Runners." This study will explore sleep's role in ultra-marathon runners' physical health, psychological well-being, and social interactions. I am seeking your consent to participate in this study. Participation in this study is entirely voluntary. You are welcome to ask questions or raise concerns at any point.

Eligibility

To participate in this study, you must meet the following criteria:

1. You are 18 years of age or older.
2. You are a resident of the United States.
3. In the past year, you have participated in at least one ultra-marathon event (races longer than the traditional marathon distance of 42.195 kilometers/26.219 miles).
4. You have access to a reliable internet connection and the ability to participate in a Zoom interview.

I hope to include 12–18 participants in this study.

What You Will Be Asked to Do (Activities)

If you agree to participate in this study, you will be asked to:

- Participate in a 60–90 minute online interview via Zoom.
- Review a summary of the interview via email, which will take approximately 10–15 minutes.

During the interview, I will ask you questions about:

- Your sleep routines
- Any challenges you face in achieving adequate sleep.
- The perceived impacts of sleep on your physical and mental performance.
- Strategies you use to improve sleep quality.

Participation in all activities and responses to each question are optional. You may skip any question you do not wish to answer or stop participation at any time. If you require accommodations, please let me know, and I will make alternate arrangements.

Recording

With your permission, I will audio-record the interview using Zoom to ensure accuracy during transcription. Zoom's video function will be disabled, and only audio will be recorded.

Risks

There are minimal foreseeable risks to participating in this study. Some questions about personal experiences with sleep and the challenges of ultra-endurance sports may cause discomfort. You may skip any question you do not wish to answer, take a break, or stop the interview anytime.

Benefits

There are no direct benefits to you for participating in this study. However, your participation may contribute valuable insights into the role of sleep in ultra-endurance athletics, which could benefit future athletes and researchers.

Privacy and Data Protection

I will keep the records of this study private and take reasonable measures to protect your personal information.

- Your responses will be anonymized, and a pseudonym will be assigned to replace your name in transcripts and reports.
- Data will be stored securely on a password-protected, encrypted device.
- All digital data will be securely destroyed three years after the study's completion.

Your data will be accessible only to me, my dissertation chair, Dr. Joel Goodin, and the National University Institutional Review Board (IRB). Your name or identifying information will not be included in any publications or presentations.

Mandated Reporting

As a Licensed Professional Counselor (LPC) and mandated reporter, I am legally required to report any disclosure of harm to yourself or others, child or elder abuse, or criminal activity to the appropriate authorities.

How the Results Will Be Used

The findings from this study will be used in my dissertation. Additionally, the results may be presented at academic conferences or published in academic journals. Any results shared publicly will not include your name or identifying information.

Voluntary Participation

Participation in this study is entirely voluntary. You may stop participating at any time without any penalty or loss of benefits to which you are entitled. You are not required to answer any question that you do not wish to answer.

Contact Information

If you have questions about this study, you may contact me at [b.trammell4781@o365.ncu.edu] or Dr. Joel Goodin, my dissertation chair, at [jgoodin@nu.edu].

If you have questions regarding your rights as a research participant, or to report any concerns, you may contact the National University Institutional Review Board (IRB) at irb@nu.edu.

Verbal Consent Questions

Before we proceed, I would like to confirm your consent to participate.

1. Did you receive the consent form I emailed?
2. Did you have time to review the consent form?
3. Do you have any questions about the research or the consent form?
4. Do you consent to participate in this research?

You need to answer "yes" to questions 1, 2, and 4 to participate.

Appendix C

Interview Protocol

Introduction

Thank you for taking the time to meet with me today. How is your day going so far? (Pause to listen and connect with the participant.)

Let me introduce myself. I am Bailey Trammell, a doctoral student at National University. I am conducting research to explore the sleep strategies and challenges experienced by ultra-marathon runners. This study focuses on how sleep impacts your physical health, psychological well-being, and social interactions.

I appreciate your willingness to participate and share your insights. Your responses will help us better understand sleep's role in ultra-endurance athletics and contribute to future research in this area.

Your participation in this study is entirely voluntary. You may skip any question or stop the interview at any time without penalty.

Confidentiality

Before we begin, I want to assure you that your responses will remain confidential. Pseudonyms will be used to protect your identity, and all data will be stored securely on an encrypted, password-protected device. The findings from this study will not include any identifying information.

Collect Verbal Consent

Before we begin with the interview questions, I would like to review the informed consent process with you. (Provide a copy if applicable, review each section, answer any questions, and obtain verbal consent for audio recording and voluntary participation.)

1. Did you receive the consent form I emailed?
2. Did you have time to review the consent form?
3. Do you have any questions about the research or the consent form?
4. Do you consent to participate in this research?

I will now begin recording via Zoom. Only audio will be recorded, and you are free to disable video if you wish.

Conduct the Interview

Let's begin the interview. I will ask a series of questions related to your experiences as an ultra-marathon runner, mainly focusing on how you manage and perceive sleep. This is your story, so please only discuss what you feel comfortable sharing. You are welcome to skip any questions you do not wish to answer.

The questions follow a semi-structured format, meaning I may ask follow-up questions to understand your experiences better. When answering, feel free to share your thoughts and experiences in as much detail as possible. You may ask me questions at any time during the interview. (Proceed with asking questions according to the semi-structured interview guide provided in Appendix A.)

Closing Statement

Thank you for sharing your insights and experiences. Before we conclude, do you have any questions or additional thoughts you'd like to share?

I will email you a summary of this interview for your review. Please feel free to reach out if you have further questions or concerns. I sincerely appreciate your participation in this study.

Appendix D

Recruitment Email

Subject: Invitation to Participate in a Research Study on Sleep and Ultra-Marathon Running

Dear [Potential Participant],

My name is Bailey Trammell, and I am a doctoral student at National University. I am conducting a research study called "Managing Midnight Miles: A Qualitative Descriptive Single-Case Study on Sleep Strategies Among United States Ultra-Marathon Runners." This study explores the role of sleep in ultra-marathon runners' physical health, psychological well-being, and social interactions.

I am recruiting individuals who meet the following criteria:

- Age 18 to 62 years.
- A resident of the United States.
- Have participated in at least one ultra-marathon (races longer than the traditional marathon distance of 42.195 kilometers/26.219 miles) within the past year.
- Have access to reliable internet and the ability to participate in a Zoom interview.

If you decide to participate in this study, you will be asked to:

1. Participate in a 60–90 minute online interview via Zoom.
2. Review a summary of the interview via email, which will take approximately 10–15 minutes.

During these activities, I will ask questions about:

- Your typical sleep routines.
- Challenges in achieving adequate sleep.
- How you perceive sleep's impact on physical and mental performance.

- Strategies you use to improve sleep quality.

Participation in this study is entirely voluntary. You may skip any question, pause the interview, or withdraw from the study anytime.

If you are interested in participating or have questions, please contact me at b.trammell4781@o365.ncu.edu.

Thank you for considering this opportunity to share your experiences and insights!

Best regards,

Bailey Trammell

Doctoral Candidate

National University

Appendix E

Demographic and Eligibility Questions

The following demographic and eligibility questions will be used to ensure participants meet the study criteria and collect general background information. Responses will be stored confidentially, and identifying information will be removed during analysis to maintain confidentiality and reduce the risk of re-identification.

1. What is your age?
    - Example: "I am 35 years old."
    - Eligibility note: Participants must be 18 to 62 years of age.
2. Are you currently based in the United States?
    - Example: "Yes, I live in California."
    - Eligibility note: Participants must reside in the United States.
3. In the last year, have you participated in at least one ultra-marathon (races longer than the traditional marathon distance of 42.195 kilometers/26.219 miles)?
    a. Example: “Yes, I have participated in 3 ultra-marathons in the last year.”
    b. Eligibility note: Participatns must have participated in at least one marathon in the last year.
4. How long have you been participating in ultra-endurance events?
    - Example: "I have been competing in ultra-endurance events for about 8 years."
    - Eligibility note: Participants must have completed at least one ultra-marathon event within the past year.
5. What level of experience do you have in ultra-endurance sports?
    - Example: "I am a seasoned competitor with several ultra-marathons under my belt."

- Example: "I'm relatively new and have completed only a few events so far."

6. What is your typical training frequency and duration?
    - Example: "I train 6 days a week, with sessions ranging from 1 to 3 hours on weekdays and longer sessions of 4 to 6 hours on weekends."
7. Do you have access to a reliable internet connection and the ability to participate in a Zoom interview?
    - Example: "Yes, I have reliable internet access and use Zoom regularly."
    - Eligibility note: Participants must be able to participate in interviews conducted via Zoom
8. What is your gender identity?
    - Example: "I identify as male," "I identify as non-binary," or "I identify as female."
    - Optional for participants to answer.

Appendix F

Recruitment Social Media Post

Header: Are You a U.S.-Based Ultra-Marathon Runner?

Body:

Hi, my name is Bailey Trammell, and I am a doctoral student at National University. I am conducting a research study to explore how sleep impacts ultra-marathon runners' physical health, psychological well-being, and social interactions.

I am looking for individuals who meet the following criteria:

- Age 18–62 years.
- A resident of the United States.
- Have participated in at least one ultra-marathon (races longer than the traditional marathon distance of 42.195 kilometers/26.219 miles) within the past year.
- Have access to reliable internet and the ability to participate in a Zoom interview.

If you decide to participate in this voluntary research, you will:

- Participate in a 60–90 minute online interview via Zoom.
- Review a summary of the interview via email, which will take approximately 10–15 minutes.

During these activities, I will ask you about:

- Your typical sleep routines.
- Challenges in achieving adequate sleep.
- The perceived impact of sleep on physical and mental performance.
- Strategies you use to improve sleep quality.

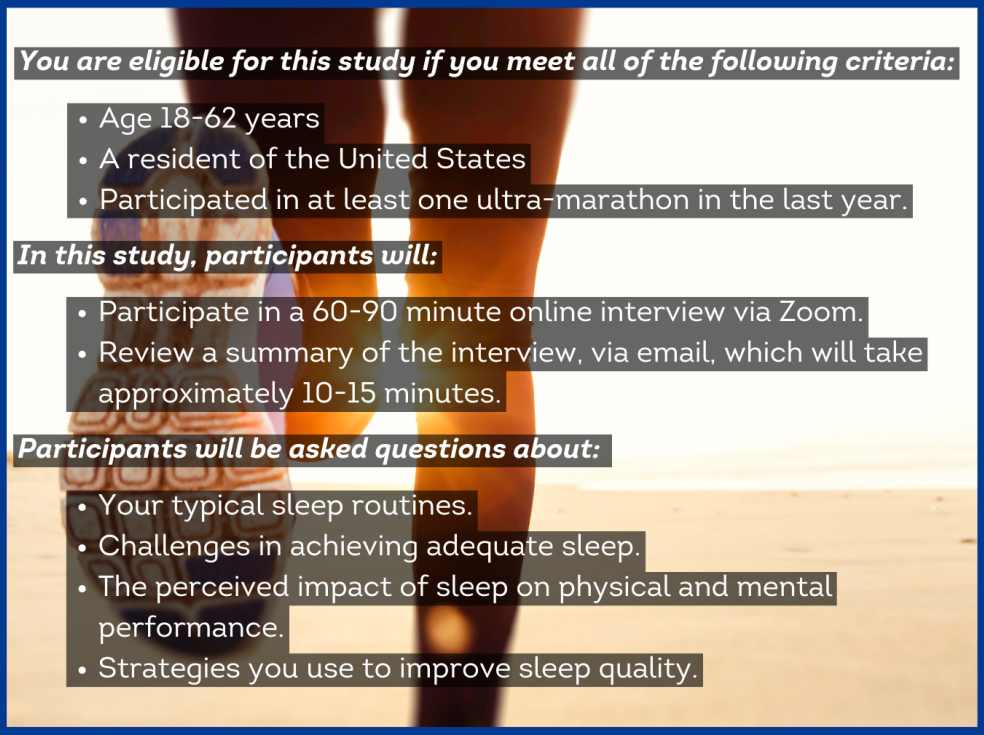
If you are interested in participating or have questions, please contact me at b.trammell4781@o365.ncu.edu.

Thank you for considering this opportunity to share your experiences and contribute to important research!

Image Description: Ultra-marathon runners on a scenic trail during a race.

RESEARCH VOLUNTEERS NEEDED

Study Purpose:
Explore how sleep impacts ultra-marathon runners' physical health, psychological well-being, and social interactions.



You are eligible for this study if you meet all of the following criteria:

- Age 18-62 years
- A resident of the United States
- Participated in at least one ultra-marathon in the last year.

In this study, participants will:

- Participate in a 60-90 minute online interview via Zoom.
- Review a summary of the interview, via email, which will take approximately 10-15 minutes.

Participants will be asked questions about:

- Your typical sleep routines.
- Challenges in achieving adequate sleep.
- The perceived impact of sleep on physical and mental performance.
- Strategies you use to improve sleep quality.

THANK YOU FOR CONSIDERING PARTICIPATING IN THIS VOLUNTARY RESEARCH!

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