

# Completion of 100 Miles: Sleep Quality, Neuromuscular Function, and Perceived Exertion in Ultramarathon Runners

Aaron Thompson<sup>1,\*</sup>, Ava Fortin<sup>2</sup>

<sup>1</sup>Human Performance and Movement Science, Clinical Assistant Professor, Keene State College, Keene, USA

<sup>2</sup>Exercise Science, Student Research Assistant, Keene State College, Keene, USA

\*Corresponding author: [DrAaron.Thompson@keene.edu](mailto:DrAaron.Thompson@keene.edu)

Received December 28, 2025; Revised January 30, 2026; Accepted February 06, 2026

**Abstract** This study examined sleep quality, neuromuscular performance, and perceived exertion in ultramarathon runners participating in events requiring completion of 100 miles during a multi-day ultramarathon. Eighteen participants completed pre-race data collection, which included a self-reported measure of sleep quality and baseline neuromuscular testing. Neuromuscular performance was assessed using hand grip strength, vertical jump height, and a functional sit-to-stand test. Following race completion, participants completed post-race neuromuscular testing and reported perceived exertion. Semi-structured interviews were conducted before and after the race to provide additional context related to fatigue, sleep, and recovery experiences. Descriptive analyses were used to examine changes in neuromuscular performance and participant-reported outcomes. Pre-race sleep quality varied across participants, with several individuals reporting poor sleep prior to competition. Among runners who completed post-race testing, declines in neuromuscular performance were commonly observed following completion of 100 miles, particularly in measures of lower-body power and functional performance, although the magnitude of change differed between individuals. Post-race perceived exertion scores ranged widely and did not consistently reflect the degree of observed neuromuscular impairment. Interview findings indicated that many participants viewed fatigue and physical discomfort as expected aspects of ultra-endurance running. These results suggest that runners completing 100 miles often begin competition with varied sleep quality and experience individual differences in neuromuscular fatigue that may not be fully captured by perceived exertion alone. Integrating objective performance measures with athlete-reported experiences may improve understanding of fatigue and recovery following ultra-endurance competition.

**Keywords:** ultramarathon running, sleep quality, neuromuscular performance, perceived exertion, functional fatigue

**Cite This Article:** Aaron Thompson, and Ava Fortin, "Completion of 100 Miles: Sleep Quality, Neuromuscular Function, and Perceived Exertion in Ultramarathon Runners." *American Journal of Sports Science and Medicine*, vol. 14, no. 1 (2026): 6-12. doi: 10.12691/ajssm-14-1-2.

## 1. Introduction

Participation in ultramarathon running has increased substantially over the past decade, with growing interest in race formats extending beyond the traditional marathon distance to include 100-mile and multi-day timed events. These ultra-endurance competitions impose prolonged physiological, neuromuscular, and psychological stress, often accompanied by extended periods of wakefulness and cumulative fatigue [1,2,3]. Despite the increasing popularity of such events, the combined effects of extreme endurance exercise, sleep disruption, and neuromuscular function remain incompletely understood.

Previous research has demonstrated that prolonged endurance exercise can result in significant neuromuscular fatigue, characterized by reductions in muscle strength,

power output, and functional performance [3,4,5,6]. Field-based investigations in ultramarathon runners have reported impairments in lower-extremity strength, altered running mechanics, and decreased postural control following competition [7,8,9]. These neuromuscular alterations have important implications for injury risk, post-race mobility, and recovery, particularly given the increasing participation of middle-aged and older adults in ultra-endurance events.

Sleep disruption is a defining feature of ultra-endurance competition, especially in races lasting 24 hours or longer. Athletes frequently enter competition with pre-existing sleep restriction related to training demands, occupational schedules, or travel, and may experience additional sleep deprivation during competition itself [10,11,12]. Independent of exercise, sleep loss has been associated with impaired neuromuscular performance, reduced reaction time, and diminished postural stability,

suggesting that sleep disruption may exacerbate exercise-induced fatigue during ultra-endurance participation [10,12,13]. However, sleep quality is infrequently assessed alongside neuromuscular outcomes in field-based ultramarathon research, limiting understanding of how baseline sleep status may influence post-race function.

Another challenge in ultra-endurance research is the reliance on subjective measures of fatigue and exertion. Ratings of perceived exertion (RPE) are commonly used to capture athletes' subjective experience during and after prolonged exercise; however, perceived exertion does not consistently align with objective indicators of neuromuscular impairment [6,14]. Experienced ultramarathon runners may normalize fatigue and discomfort as part of competition, potentially underestimating the degree of functional decline following race completion. This discrepancy underscores the importance of incorporating objective performance measures when evaluating post-race fatigue and recovery.

Integrating quantitative performance assessments with athlete-reported experiences offers a valuable approach for addressing these gaps by integrating quantitative performance assessments with athlete-reported experiences. The combination of objective neuromuscular testing, standardized sleep assessment, and qualitative interviews allows for a more comprehensive and ecologically valid examination of fatigue, recovery, and performance in ultra-endurance settings. Such approaches are particularly well suited to ultramarathon research, where inter-individual variability is high and laboratory-based protocols may fail to capture the complexity of real-world competition.

Therefore, the purpose of this study was to examine sleep quality, perceived exertion, and neuromuscular function in ultramarathon runners participating in a multi-day endurance event using a mixed methods design. This study integrated pre-race sleep assessment, pre- and post-race neuromuscular performance testing, and pre- and post-race interviews to contextualize objective performance changes within athletes' lived experiences. By examining these variables under real-world race conditions, this research aims to provide clinically and practically relevant insight into fatigue, functional status, and recovery considerations following ultra-endurance competition.

## 2. Materials & Methods

This study employed an observational design using on-site field-based testing and interviews conducted in conjunction with a multi-day ultramarathon event. Data collection occurred before and after race participation and included standardized assessments of sleep quality, neuromuscular performance, and perceived exertion. Qualitative interviews were also conducted to contextualize quantitative findings related to fatigue, sleep, and recovery.

### 2.1. Participants and Study Design

Participants were adult ultramarathon runners registered to compete in the Across the Years ultramarathon held in

Peoria, Arizona. Eligible participants were registered for one of the following race formats: 100-mile distance race, 24-hour timed race, 48-hour timed race, or 72-hour timed race. All participants who completed 100 miles during their respective event were included in the primary analysis. A total of 18 participants (11 females, 7 males; age range: 20–79 years) completed pre-race data collection and were included in the study.

Pre-race testing was conducted during race check-in or immediately prior to the start of each participant's event. Post-race testing was conducted as soon as feasible following completion of 100 miles. Due to the nature of ultra-endurance competition, not all participants were able to complete post-race testing as a result of race withdrawal, non-finish status, time constraints, or participant availability immediately following race completion. These instances were recorded, and available data were included in the analysis.

### 2.2. Ethics and Data Governance

This study was reviewed and approved by the Keene State College Institutional Review Board (Study #: IRB-FY2025-315). All data were collected and stored in accordance with institutional data governance requirements. Participant identifiers were replaced with numerical codes to maintain confidentiality. Electronic data were stored on password-protected devices accessible only to the research team, and any physical documents were stored in secured locations. Only de-identified data were used for analysis and reporting.

### 2.3. Data Analysis

Data analysis was conducted using a descriptive and integrative approach appropriate for an observational study with a small sample size and incomplete post-race data for some participants. Quantitative and qualitative data were analyzed separately and then considered together to provide a comprehensive interpretation of sleep quality, neuromuscular performance, and perceived exertion following completion of 100 miles.

#### 2.3.1. Quantitative Analysis

Descriptive statistics were used to summarize participant demographics, race characteristics, pre-race sleep quality scores, neuromuscular performance measures, and post-race perceived exertion. Measures of central tendency and dispersion were calculated where appropriate. Pre- and post-race neuromuscular performance values were compared descriptively to examine changes following race completion. Given the exploratory nature of the study, variability in race formats, and missing post-race data for some participants, inferential statistical testing was not emphasized. Available data were analyzed on a per-measure basis, and participants with incomplete post-race data were included in descriptive summaries when possible.

#### 2.3.2. Qualitative Analysis

Semi-structured interview transcripts were reviewed and analyzed using an inductive approach to identify recurring patterns related to sleep, fatigue, exertion, and

recovery. Transcripts were read multiple times to ensure familiarity with the data, and salient statements were noted and grouped into broader thematic categories. Qualitative findings were not intended to generate theory but to provide contextual understanding of participants' experiences and to support interpretation of quantitative outcomes.

### 2.3.3. Integration of Quantitative and Qualitative Data

Quantitative and qualitative findings were integrated during interpretation to enhance ecological validity and provide a more complete understanding of participant responses to ultra-endurance competition. Objective changes in neuromuscular performance and perceived exertion were examined alongside interview data to explore how athletes described fatigue, sleep, and recovery in relation to measured outcomes. This integrative approach allowed for identification of consistencies and discrepancies between objective performance measures and athlete-reported experiences.

## 3. Results

Across the study sample, meaningful variability was observed in baseline sleep quality, post-race neuromuscular performance, and perceived exertion following completion of 100 miles. Pre-race sleep quality scores ranged from minimal disturbance to clinically elevated levels, indicating that participants began competition with markedly different sleep profiles. Following race completion, objective measures of neuromuscular performance demonstrated declines in strength, power, and functional movement in many participants, although the magnitude and pattern of change varied considerably between individuals. Reductions in lower-extremity power and functional performance were more consistently observed than changes in upper-extremity strength. Post-race perceived exertion scores spanned a wide range and did not consistently correspond with the degree of measured neuromuscular impairment. Collectively, the results highlight substantial inter-individual variability in fatigue responses following completion of 100 miles and underscore the importance of integrating objective performance measures with athlete-reported outcomes when evaluating ultra-endurance fatigue and recovery.

### 3.1. Pre-Race Sleep Quality

Pre-race sleep quality scores demonstrated substantial variability across the sample. Global sleep quality scores ranged from 1 to 11, indicating that some participants reported very good sleep prior to competition, while others reported marked sleep difficulties in the weeks leading up to the event. Several participants exceeded the commonly used threshold associated with poor sleep quality, suggesting that a meaningful proportion of the sample entered competition with compromised baseline sleep.

Elevated sleep disturbance scores were observed across multiple age groups and were not confined to older participants. Both faster and slower finishers reported poor pre-race sleep, indicating that baseline sleep quality alone

did not distinguish performance outcomes but represented an important contextual factor for interpreting post-race fatigue and recovery.

## 3.2. Neuromuscular Performance Outcomes

### 3.2.1. Hand Grip Strength

Hand grip strength demonstrated variable changes following completion of 100 miles among participants who completed both pre- and post-race testing. Of the 18 participants who completed pre-race testing, 15 completed post-race grip strength assessment. Pre-race grip strength values ranged from 32.6 to 115.9 pounds, while post-race values ranged from 37.6 to 105.3 pounds.

Among participants with complete data, nine demonstrated a reduction in grip strength following race completion. The magnitude of decline ranged from 0.7 to 17.0 pounds. The largest decreases were observed in participants with higher pre-race grip strength values, including reductions from 112.4 to 95.4 pounds, from 99.6 to 83.7 pounds, and from 115.9 to 102.2 pounds. Several participants demonstrated modest declines of less than 5 pounds.

Six participants demonstrated either no change or an increase in post-race grip strength. These responses included identical pre- and post-race values (48.0 to 48.0 pounds) as well as increases ranging from 0.5 to 13.2 pounds. Notable increases were observed in participants whose pre-race values were below 80 pounds, including changes from 38.8 to 52.0 pounds and from 76.7 to 82.6 pounds. Three participants were unable to complete post-race testing and were recorded as missing data.

Overall, changes in hand grip strength following completion of 100 miles were less consistent than those observed for lower-extremity measures. Grip strength responses varied widely across participants and did not demonstrate a clear pattern based on age or finishing time, indicating heterogeneous upper-extremity fatigue responses following ultra-endurance competition.

### 3.2.2. Vertical Jump Performance

Vertical jump performance generally declined following completion of 100 miles among participants who completed both pre- and post-race testing. Of the 18 participants who completed pre-race testing, 15 completed post-race vertical jump assessment. Pre-race vertical jump heights ranged from 2.5 to 13.75 inches, while post-race values ranged from 2.5 to 11.5 inches.

Among participants with complete data, 11 demonstrated a reduction in vertical jump height following race completion. The magnitude of decline ranged from 0.5 to 5.5 inches, with several participants exhibiting reductions of 3 inches or greater. The largest decreases were observed in participants with higher pre-race jump values, including reductions from 13.75 to 8.25 inches and from 12.0 to 7.5 inches.

Four participants demonstrated either no change or a slight increase in post-race vertical jump height. These cases included identical pre- and post-race values (6.25 to 6.25 inches and 7.5 to 7.5 inches) as well as modest increases ranging from 0.5 to 1.5 inches. Three participants were unable to complete post-race testing and

were recorded as missing data.

Overall, reductions in vertical jump height were observed across a wide range of ages and finishing times, indicating that decreases in lower-extremity power were a common post-race outcome following completion of 100 miles. Compared with other neuromuscular measures, vertical jump performance demonstrated a consistent pattern of post-race change within the sample.

### 3.2.3. Five Times Sit-to-Stand Performance

Performance on the Five Times Sit-to-Stand test demonstrated variable changes following completion of 100 miles. Among the 15 participants who completed both pre- and post-race testing, pre-race completion times ranged from 4.80 to 13.41 seconds, while post-race times ranged from 5.41 to 12.76 seconds. Nine participants demonstrated slower post-race completion times, with increases ranging from 0.22 to 2.81 seconds. Six participants completed the test in similar or faster times post-race, with improvements ranging from 0.20 to 1.19 seconds.

Several of the largest post-race slowdowns were observed in participants aged 60 years and older, including individuals in the 60–69 and 70–79 age groups. However, variability was evident across all age categories, and some older participants demonstrated minimal change or improved performance. Changes in sit-to-stand performance did not consistently parallel changes observed in grip strength or vertical jump performance, suggesting task-specific functional fatigue responses following ultra-endurance completion.

### 3.3. Finishing Time Characteristics

Finishing times among participants who completed 100 miles ranged from 20–22 hours to 50–52 hours, reflecting wide variability in race duration and exposure to prolonged physical and sleep-related stress. Four participants completed 100 miles in under 24 hours, while the majority finished between 30 and 46 hours, and one participant required more than 50 hours. Two participants did not finish and were excluded from post-race performance analyses. Neuromuscular performance changes were observed across all finishing-time categories, with both faster and slower finishers demonstrating post-race declines in grip strength, vertical jump height, and functional performance. For example, participants finishing in 20–24 hours exhibited substantial reductions in vertical jump height (e.g., 13.75 to 8.25 inches and 12.0 to 7.5 inches), while participants finishing between 44–52 hours also demonstrated marked changes across multiple measures.

Pre-race sleep quality, as measured by the PSQI, varied across finishing-time groups and did not demonstrate a clear pattern in relation to completion time. Participants with elevated PSQI scores were present among both faster and slower finishers. For instance, participants finishing in 22–24 hours reported PSQI scores ranging from 3 to 9, while those finishing between 44–52 hours reported scores ranging from 3 to 4. Older participants (60–79 years) were represented across all finishing-time categories, including sub-24-hour, 30–32-hour, and 44–52-hour finishers. Several older participants demonstrated notable post-race

neuromuscular declines, particularly in vertical jump and five times sit-to-stand performance, although variability was evident within each age group.

Post-race ratings of perceived exertion ranged from 2 to 8 out of 10 and did not consistently align with finishing time or objective neuromuscular change. Some participants with longer finishing times reported low perceived exertion (e.g., RPE of 2 following 39–41 or 50–52 hours), while others completing 100 miles in shorter durations reported higher exertion (e.g., RPE of 7–8 following 20–24 or 30–32 hours). Across finishing-time categories, participants with similar completion times exhibited markedly different neuromuscular and perceptual responses, indicating that heterogeneous neuromuscular and perceptual responses were observed across finishing-time categories.

### 3.4. Perceived Exertion

Post-race perceived exertion scores were available for 15 participants and ranged from 2 to 8 on a 10-point scale. Five participants reported low perceived exertion scores of 2 or 3, while six participants reported moderate scores between 5 and 6. Four participants reported high perceived exertion scores of 7 or 8. Reported exertion did not demonstrate a consistent relationship with finishing time or age group.

Several participants who reported low perceived exertion scores exhibited notable declines in neuromuscular performance, including reductions in vertical jump height and slower sit-to-stand completion times. Conversely, some participants reporting higher perceived exertion demonstrated relatively modest changes in objective performance measures. Overall, perceived exertion did not reliably reflect the magnitude of post-race neuromuscular impairment observed across participants.

## 4. Discussion

The purpose of this study was to examine sleep quality, neuromuscular performance, and perceived exertion in runners completing 100 miles during a multi-day ultramarathon event. The primary findings indicate that participants entered competition with highly variable pre-race sleep quality and demonstrated heterogeneous neuromuscular fatigue responses following race completion. Declines in lower-extremity power and functional performance were commonly observed, while changes in upper-extremity strength were more variable. Importantly, post-race perceived exertion did not consistently correspond with objective measures of neuromuscular impairment, highlighting a potential disconnect between subjective fatigue and physiological function following ultra-endurance competition.

### 4.1. Sleep Quality Prior to Ultra-Endurance Competition

Pre-race sleep quality varied widely across participants, with several runners reporting elevated sleep disturbance prior to competition. These findings align with previous

research indicating that ultramarathon athletes frequently experience disrupted sleep in the weeks leading up to competition due to training volume, travel, pre-race anxiety, and logistical demands. Poor baseline sleep has been associated with altered recovery capacity, impaired neuromuscular function, and increased perception of fatigue, suggesting that pre-race sleep quality may influence how athletes respond to prolonged endurance stress.

Notably, poor pre-race sleep quality was observed across age groups and finishing times, indicating that sleep disturbance is not limited to a specific demographic or performance level. While this study was not designed to examine causal relationships, the variability in baseline sleep underscores the importance of considering sleep status when interpreting post-race fatigue and recovery outcomes in ultra-endurance athletes.

#### **4.2. Neuromuscular Fatigue Following Completion of 100 Miles**

Consistent with prior ultra-endurance research, neuromuscular performance declined following race completion in many participants. Reductions in vertical jump height were particularly common, suggesting substantial impairment in lower-extremity power following prolonged running. This finding supports previous laboratory and field studies demonstrating that ultra-endurance exercise results in both central and peripheral fatigue, with pronounced effects on explosive lower-body performance.

Functional performance, as assessed by the Five Times Sit-to-Stand test, also declined in a majority of participants, particularly among older runners. Slower post-race completion times likely reflect cumulative neuromuscular fatigue, reduced lower-extremity strength, and altered movement efficiency following prolonged exertion. However, variability was evident, with some participants demonstrating minimal change or improved performance, highlighting the individualized nature of fatigue responses in ultramarathon runners.

Changes in hand grip strength were less consistent than lower-extremity measures. While many participants demonstrated post-race reductions, others exhibited minimal change or slight increases. This variability may reflect differences in task specificity, compensatory effort during testing, or the lower relative demand placed on upper-extremity musculature during running compared with the lower extremities.

From a clinical perspective, these findings suggest that functional tasks may reveal post-race limitations not captured by isolated strength measures.

#### **4.3. Perceived Exertion and Objective Performance**

One of the most notable findings of this study was the lack of a consistent relationship between perceived exertion and objective neuromuscular performance outcomes. Some participants reported low to moderate perceived exertion despite clear declines in strength, power, and functional performance, while others

reported higher exertion with comparatively modest objective changes.

This dissociation aligns with prior research suggesting that experienced ultra-endurance athletes may recalibrate perceptions of effort and fatigue through repeated exposure to prolonged exertion. Athletes may normalize discomfort and physical limitation as expected components of competition, which may reduce the sensitivity of perceived exertion as a standalone indicator of neuromuscular fatigue following ultra-endurance events. These findings support the use of objective performance measures alongside subjective assessments when evaluating post-race fatigue and recovery.

#### **4.4. Individual Variability and Athlete Experience**

Substantial inter-individual variability was observed across all outcome measures, reinforcing the concept that fatigue and recovery responses to ultra-endurance exercise are highly individualized. Participants of similar age and finishing time demonstrated markedly different neuromuscular responses, suggesting that factors such as training history, pacing strategies, sleep behavior, and prior ultra-endurance experience may influence post-race outcomes.

Qualitative interview data provided valuable context for these findings. Many participants described fatigue and soreness as anticipated and manageable, often emphasizing mental strategies and prior experience as key factors in coping with physical decline. These narratives help explain why subjective exertion did not always align with objective performance measures and underscore the importance of integrating athlete perspectives into fatigue assessment frameworks.

#### **4.5. Qualitative Insights from Athlete Interviews**

To contextualize the quantitative findings, qualitative data from pre- and post-race interviews were examined. These interviews provided insight into athlete expectations, sleep behaviors, fatigue management strategies, and interpretations of physical discomfort.

##### **4.5.1. Pre-Race Perspectives on Sleep, Fatigue, and Preparation**

Across pre-race interviews, participants frequently described disrupted or insufficient sleep in the weeks leading up to the race, often attributed to training load, work stress, or travel. One participant stated, *“My sleep has been terrible the last week or two... I fall asleep early but wake up around one in the morning and I’m up for hours”* (Participant 1, pre-race interview). Another noted, *“I average about six hours a night, but I make up for it with naps when I can”* (Participant 6, pre-race interview).

Despite acknowledging poor sleep, many runners expressed confidence in their ability to manage fatigue during the race. Several emphasized experience and familiarity with discomfort, with one participant explaining, *“There’s always pain, but that’s just part of being an ultrarunner—you deal with it and keep moving”*

(Participant 6, pre-race interview). Others described deliberate strategies to manage fatigue through pacing, nutrition, and mental reframing rather than attempting to eliminate fatigue altogether.

These pre-race perspectives help explain why poor sleep quality did not uniformly predict post-race performance declines and highlight the role of expectation and experience in shaping athlete responses to extreme endurance demands.

#### 4.5.2. Post-Race Perspectives on Sleep, Fatigue, and Recovery

Post-race interviews provided detailed insight into how participants interpreted fatigue, sleep deprivation, and functional limitations following completion of 100 miles. Across interviews, runners consistently described a combination of physical exhaustion, localized soreness, and disrupted sleep, while also emphasizing that these experiences were expected outcomes of ultra-endurance participation rather than unexpected or alarming responses.

Several participants described immediate post-race fatigue as pervasive but manageable. One runner explained, *“Everything felt heavy, especially my legs, but it wasn’t surprising. That’s kind of the price you pay for going that far.”* Another noted difficulty with basic functional tasks, stating, *“I didn’t realize how wiped out I was until I tried to sit down and stand back up. That’s when it really hit me.”* These reflections align with the observed post-race declines in functional performance measures, particularly the Five Times Sit-to-Stand test.

Sleep disruption following race completion was also commonly reported. Participants described difficulty initiating sleep, frequent awakenings, and non-restorative rest in the hours and days immediately following the event. One participant stated, *“I was exhausted, but my body just wouldn’t shut down. I slept in short chunks and never really felt rested.”* Another reflected on cumulative sleep loss, saying, *“By the end, it wasn’t just muscle fatigue—it was the lack of sleep catching up all at once.”*

Despite these challenges, many participants framed post-race fatigue and sleep disturbance as temporary and anticipated. Several runners emphasized prior experience as a factor shaping their interpretation of post-race symptoms. As one participant explained, *“I’ve been through this before, so I knew it would take a few days to feel normal again. It’s uncomfortable, but it’s not something I worry about.”* This normalization of fatigue may help explain why some participants reported relatively low perceived exertion scores despite measurable neuromuscular impairment.

Overall, post-race interviews revealed that participants frequently distinguished between discomfort and dysfunction, viewing fatigue and sleep disruption as integral components of completing 100 miles rather than indicators of compromised performance or recovery failure. These qualitative findings provide important context for understanding the disconnect observed between subjective exertion ratings and objective neuromuscular performance outcomes following ultra-endurance competition.

## 5. Conclusions

This study provides a field-based examination of sleep quality, neuromuscular function, perceived exertion, and athlete experience surrounding completion of 100 miles during an ultra-endurance event. By integrating objective performance measures with athlete-reported outcomes and qualitative interviews, this research offers a comprehensive perspective on fatigue and recovery under real-world competitive conditions. The findings demonstrate that runners completing 100 miles enter competition with highly variable sleep quality and experience heterogeneous neuromuscular fatigue responses following race completion. Declines in strength, power, and functional performance were commonly observed, yet these impairments were not consistently reflected by perceived exertion alone.

A key contribution of this study is the identification of a disconnect between subjective perceptions of effort and objective neuromuscular performance following ultra-endurance participation. Many athletes normalized fatigue and physical limitations as expected components of completing 100 miles, which may reduce the sensitivity of perceived exertion as a standalone indicator of post-race functional status. These findings highlight the value of incorporating simple, field-based neuromuscular assessments when evaluating fatigue and recovery in ultramarathon populations.

This study also underscores the importance of considering sleep quality as a contextual factor in ultra-endurance performance and recovery. Pre-race sleep quality varied widely across participants, suggesting that athletes begin competition with different physiological and cognitive readiness states that may influence post-race outcomes. Addressing sleep behaviors before and after ultra-endurance events may represent an important target for athlete education and recovery planning.

Despite its strengths, this study was limited by a modest sample size, incomplete post-race data for some participants, and the inherent variability of real-world race environments. Future research should include larger samples, repeated post-race assessments, and longitudinal follow-up to better characterize recovery trajectories following ultra-endurance competition. Additional work examining the interaction between sleep, neuromuscular fatigue, and injury risk may further inform best practices for athlete monitoring and post-race care.

In conclusion, this study advances understanding of fatigue and recovery following completion of 100 miles by demonstrating that objective neuromuscular impairment and subjective fatigue do not always align. Integrating objective performance testing with athlete perspectives provides a more complete framework for assessing recovery and supporting athlete health in ultra-endurance sport.

## ACKNOWLEDGEMENTS

Research supported by New Hampshire-INBRE

through an Institutional Development Award (IDeA), P20GM103506, from the National Institute of General Medical Sciences of the NIH. This project was supported in part by funding from a Keene State College Faculty Development Grant.

This work reflects the support and generosity of many people and organizations. The authors are grateful to the ultramarathon participants who shared their time and experiences before and after the race; their openness made this study possible. The authors also thank Aravaipa Running and the Across the Years event staff for facilitating on-site access and for their professionalism throughout the data collection process.

## Statement of Competing Interests

The authors have no competing interests.

## Ethics Approval

This study was reviewed and approved by the Keene State College Institutional Review Board (IRB) (Study #: IRB-FY2025-315). All procedures were conducted in accordance with the ethical standards of the institutional research committee.

## List of Abbreviations

Pittsburgh Sleep Quality Index (PSQI) Rating of Perceived Exertion (RPE)

## References

- [1] Hoffman MD, Wegelin JA. The Western States 100-Mile Endurance Run: participation and performance trends. *Med Sci Sports Exerc.* 2014; 46(12): 2191–2198.
- [2] Knechtle B, Nikolaidis PT. Physiology and pathophysiology in ultra-marathon running. *Front Physiol.* 2018; 9: 634.
- [3] Scheer V, Valero D, Millet GP. Neuromuscular fatigue during ultra-endurance exercise. *Appl Physiol Nutr Metab.* 2016; 41(9): 971–978.
- [4] Millet GP, Lepers R. Alterations of neuromuscular function after prolonged running, cycling and skiing exercises. *Sports Med.* 2004; 34(2): 105–116.
- [5] Vernillo G, Savoldelli A, Zignoli A, et al. Influence of the world's most challenging mountain ultra-marathon on energy cost and running mechanics. *Eur J Appl Physiol.* 2014; 114(5): 929–939.
- [6] Temesi J, Arnal PJ, Rupp T, et al. Are females more resistant to extreme neuromuscular fatigue? *Med Sci Sports Exerc.* 2015; 47(7): 1372–1382.
- [7] Saugy J, Place N, Millet GY, et al. Alterations of neuromuscular function after the world's most challenging mountain ultra-marathon. *PLoS One.* 2013; 8(6): e65596.
- [8] Khassetarash A, Vernillo G, Millet GP. Fatigue and recovery in ultra-endurance running. *Sports Med.* 2023; 53(2): 291–306.
- [9] Degache F, Van Zaen J, Oehen L, et al. Alterations in postural control after ultra-endurance running. *Eur J Appl Physiol.* 2014; 114(10): 2115–2124.
- [10] Roberts SSH, Teo WP, Warmington SA. Effects of total sleep deprivation on neuromuscular function. *Eur J Appl Physiol.* 2019; 119(2): 319–332.
- [11] Lastella M, Lovell GP, Sargent C. Athletes' precompetitive sleep behaviour and its relationship with subsequent performance. *Eur J Sport Sci.* 2014; 14(sup1): S123–S130.
- [12] Vitale JA, Banfi G. Sleep quality in high-level athletes: assessment and intervention. *Sports Med.* 2019; 49(4): 505–517.
- [13] Walsh NP, Halson SL, Sargent C, et al. Sleep and the athlete: narrative review and 2021 expert consensus recommendations. *Br J Sports Med.* 2021; 55(7): 356–368.
- [14] Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index (PSQI): a new instrument for psychiatric research and practice. *Psychiatry Res.* 1989; 28(2): 193–213.

