SPORT TK-EuroAmerican Journal of Sport Sciences

https://revistas.um.es/sportk Online ISSN: 2340-8812

Received: **29/03/2025.** Accepted: **30/07/2025.** Published: **17/11/2025**

The impact of melatonin supplementation on auditory reaction time during sleep deprivation: A comparative study in college sportsmen

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ABSTRACT

Sleep deprivation is prevalent among athletes during competitions and is known to impair both motor and mental performance. This study aimed to assess how these performance decrements vary with melatonin supplementation. Sixty college sportsmen were divided into six groups (n=10 each): (a) disturbed sleep deprivation for 48 hours, (b) complete sleep deprivation for 48 hours, (c) disturbed sleep deprivation for 48 hours with melatonin supplementation, (d) complete sleep deprivation for 48 hours with melatonin supplementation, (e) normal sleep with melatonin supplementation, and (f) normal sleep. Melatonin, a hormone secreted by the pineal gland with known sleep-promoting effects, was administered orally at 6 mg for sleep-deprived groups and a placebo for non-supplemented groups. Auditory reaction time was measured using standard procedures. The results indicated that auditory reaction time decreased after 48 hours of disturbed and complete sleep deprivation, with a greater reduction observed in the melatonin supplementation group than in the placebo group. These findings underscore the complex interplay between sleep deprivation, melatonin supplementation, and auditory processing, suggesting that melatonin supplementation may mitigate the negative effects of sleep deprivation on auditory reaction time in athletes.

KEYWORDS

Sleep Deprivation; Melatonin Supplementation; Auditory Reaction Time; Sportsmen

1. INTRODUCTION

Sleep deprivation is a common challenge among athletes, particularly during competitive events, training camps, and travel across time zones. It is well-documented that inadequate sleep leads to declines in cognitive function, motor performance, reaction time, and overall athletic efficiency (Basner & Dinges, 2011; Fullagar et al., 2015). Sleep deprivation also disrupts psychomotor vigilance and executive function, impairing an athlete's ability to make split-second decisions, a crucial factor in competitive sports (Goel et al., 2009). Even a single night of sleep loss can significantly increase reaction times and reduce neuromuscular coordination, making sleep management a key aspect of sports performance enhancement (Watson, 2017).

One of the primary strategies to combat sleep deprivation's negative effects is the use of melatonin supplementation. Melatonin, a hormone secreted by the pineal gland, is a key regulator of the circadian rhythm, playing a fundamental role in sleep initiation and maintenance (Reiter et al., 2016). Exogenous melatonin supplementation has been widely studied for its effectiveness in improving sleep quality, reducing sleep onset latency, and enhancing recovery in athletes exposed to travel fatigue, late-night competition schedules, and high-intensity training (Arendt, 2005; Peuhkuri et al., 2012).

Beyond its role in sleep regulation, melatonin possesses neuroprotective, antioxidant, and anti-inflammatory properties, which may contribute to cognitive restoration and performance maintenance under conditions of sleep deprivation (Paryab et al., 2021). Research suggests that melatonin supplementation may enhance physical and psychomotor performance in sleep-deprived individuals, but its effects on specific cognitive functions, such as auditory reaction time, remain underexplored (Paryab et al., 2021). Auditory reaction time, which refers to the speed at which an individual responds to auditory stimuli, is crucial in many sports that rely on quick reflexes and sound-based cues, such as sprinting, swimming, and racket sports.

Despite the widespread use of melatonin among athletes, there is a gap in research regarding its direct influence on reaction time during sleep deprivation. While some studies have indicated that melatonin may help preserve reaction time, coordination, and cognitive function, its effects on auditory processing and reflexive responses in sleep-deprived athletes remain unclear (Vitale et al., 2019). Given the importance of reaction time in sports performance, further investigation is required to determine whether melatonin supplementation can mitigate sleep deprivation-induced impairments in auditory reaction time.

This study aims to examine the effects of melatonin supplementation on auditory reaction time in sleep-deprived college athletes. By investigating the potential cognitive and performance-enhancing benefits of melatonin under sleep-restricted conditions, this research seeks to provide valuable insights into sleep management strategies for athletes. The findings may contribute to evidence-based recommendations on the use of melatonin supplementation to optimize athletic performance, reaction time, and overall sleep health in competitive sports environments.

2. METHODS

2.1. Design and Participants

The study employed a randomized controlled trial (RCT) with a 6 × 3 factorial repeated-measures design. It involved 60 healthy college sportsmen in Pondicherry, aged between 19 to 21 years. The Pondicherry University Ethics Committee cleared the ethical approval. All subjects were hostellers, ensuring uniformity in nutrient status and daily activities. Informed consent was obtained from all participants prior to the experiment.

The first factor comprised six groups: 1. Disturbed sleep deprivation for 48 hours; 2. Complete sleep deprivation for 48 hours; 3. Disturbed sleep deprivation for 48 hours with melatonin supplementation; 4. Complete sleep deprivation for 48 hours with melatonin supplementation; 5. Normal sleep with melatonin supplementation; 6. Normal sleep.

The second factor included three testing periods: basal, 48 hours after sleep deprivation, and 24 hours after sleep recovery. Placebo was administered to the non-supplementation group following a double-blind placebo method.

2.2. Auditory Reaction Time Test

The auditory reaction time test measured the time taken to respond to auditory stimuli before and after sleep deprivation (Misra et al., 1985). The equipment included a 6V electric source, tap-keys, bulb, and a computerized polygraph unit (RM, 600, Nihon Kohden, Japan).

2.3. Procedure

Subjects were instructed to press the tap key with their dominant hand until they perceived a light stimulus. Upon perceiving the stimulus, they immediately released the tap key, opening the circuit and recording the response in a single channel of the polygraph. The polygraph output was fed to a computer system, where the time interval between stimulation and response was measured in milliseconds as auditory reaction time.

Auditory reaction time data were collected during basal conditions, after 48 hours of sleep deprivation, and 24 hours after sleep recovery for all six groups. Standardized conditions were maintained using identical apparatus, personnel, and procedures.

2.4. Statistical Analysis

Descriptive statistics (mean and standard deviation) were calculated for each group. One-way analysis of variance (ANOVA) was performed to examine the effect of melatonin supplementation during sleep deprivation on auditory reaction time. When the F ratio was significant, Scheffé's post hoc test was applied to identify pairwise differences between group means. All data analyses were conducted using a standard statistical software package.

3. RESULTS

3.1. Analysis of Auditory Reaction Time

Table 1 presents the mean and standard deviation (SD) of auditory reaction time data across six groups during basal conditions, after sleep deprivation, and after recovery.

Table 1. Analysis of variance on auditory reaction time for mean differences among six groups during basal, after sleep deprivation, and after recovery

Sl. No.	Groups	Basal		After Sleep Deprivation		After Recovery	
		Mean	SD	Mean	SD	Mean	SD
1	Disturbed Sleep Deprivation	171.70	24.46	177.80	21.88	173.40	18.37
2	Complete Sleep Deprivation	194.60	33.02	199.40	30.27	190.30	33.07
3	Disturbed Sleep Deprivation with Supplementation	191.00	21.37	197.40	41.16	174.20	16.61
4	Complete Sleep Deprivation with Supplementation	187.20	18.25	175.20	22.06	171.90	25.25
5	Normal Sleep with Supplementation	176.60	11.51	156.50	13.71	167.80	15.73
6	Normal Sleep	158.90	32.86	159.40	33.02	159.40	32.42

Note. *Sl. No: Serial Number*

Basal Condition: The group with normal sleep exhibited the shortest auditory reaction time (Mean = 158.90 ms, SD = 32.86), followed closely by the group with normal sleep and supplementation (Mean = 176.60 ms, SD = 11.51). The group experiencing disturbed sleep deprivation with supplementation had a mean auditory reaction time of 191.00 ms (SD = 21.37), while the group with complete sleep deprivation and supplementation had a mean of 187.20 ms (SD = 18.25). Subjects under disturbed sleep deprivation recorded a mean reaction time of 171.70 ms (SD = 24.46), whereas those under complete sleep deprivation exhibited a mean of 194.60 ms (SD = 33.02).

After Sleep Deprivation: The group subjected to disturbed sleep deprivation with supplementation showed the highest auditory reaction time (Mean = 197.40 ms, SD = 41.16), followed by the group experiencing complete sleep deprivation (Mean = 199.40 ms, SD = 30.27). Normal sleep with supplementation recorded a mean reaction time of 156.50 ms (SD = 13.71), while normal sleep without supplementation had a mean of 159.40 ms (SD = 33.02).

After Recovery: The auditory reaction time decreased for most groups after recovery compared to post-sleep deprivation. The group with normal sleep and supplementation had the shortest reaction time (Mean = 167.80 ms, SD = 15.73), followed by the group with normal sleep (Mean = 159.40 ms, SD = 32.42). Subjects experiencing complete sleep deprivation with supplementation exhibited a mean reaction time of 171.90 ms (SD = 25.25) after recovery, whereas those under disturbed sleep deprivation showed a mean of 173.40 ms (SD = 18.37).

The details of auditory reaction time during basal, after Sleep deprivation and after recovery among six groups are graphically present in Figure 1.

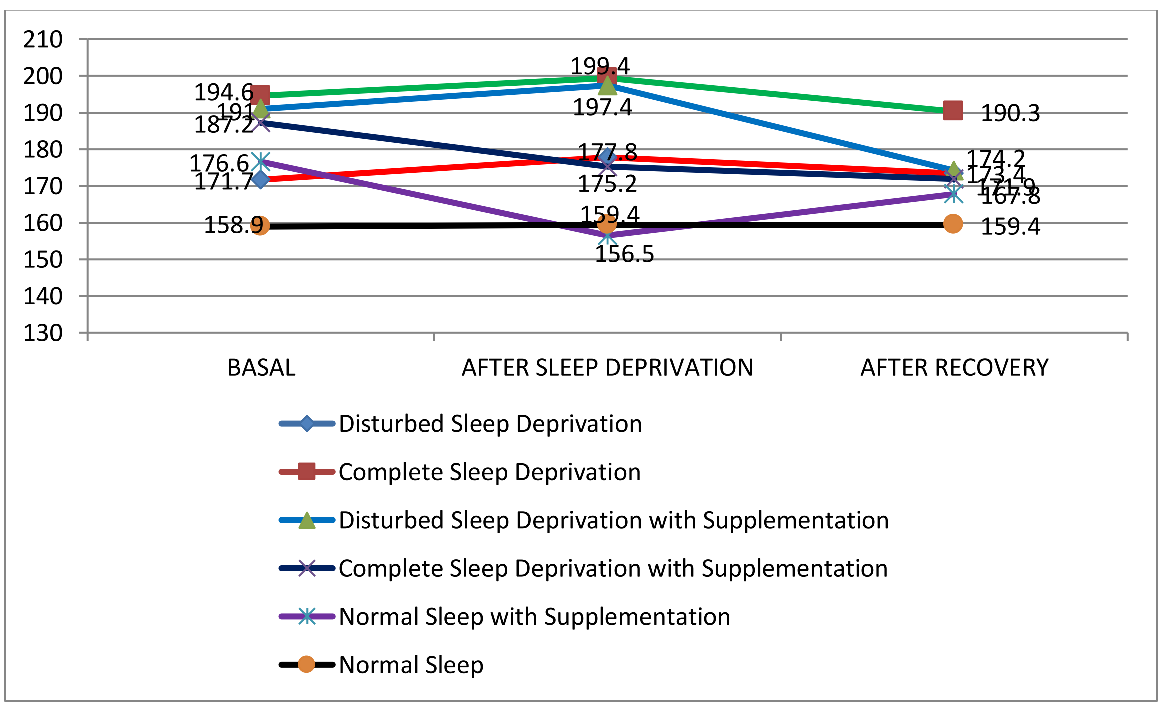

Figure 1. Graphical representation of auditory reaction time during basal, after sleep deprivation, and after recovery among six groups

The data pertaining to the changes on auditory reaction time among six groups during basal, after sleep deprivation and after recovery have been analyzed statistically and the details are presented in Table 2.

Table 2. Analysis of variance on auditory reaction time of basal value adjusted for 48 hours, 24 hours of sleep deprivation, and 24 hours after recovery

Testing Period	Source of variance	Sum of square	Df	Mean Square	F Ratio	p value
Basel value adjusted for 48 hours of sleep deprivation	Between Groups	6153.88	5	1230.77	1.46	>0.05
	Within Groups	45356.30	54	839.93		
Basel value adjusted for 24 hours of sleep deprivation	Between Groups	6417.08	5	1283.41	2.13	>0.05
	Within Groups	32533.10	54	602.46		
Basel value adjusted for 24 hours aAfter recovery	Between Groups	3072.33	5	614.46	1.36	>0.05
	Within Groups	24248.00	54	449.03		

Based on the results showed in Table 2, it was found that the obtained F ratio of 1.46 for the basal value adjusted for 48 hours of sleep deprivation was not statistically significant ($p>0.05$). This indicates that there was no significant variation in auditory reaction time among the six groups following 48 hours of sleep deprivation compared to the basal condition. Similarly, the obtained F ratio of 2.13 for the auditory reaction time after 48 hours of sleep deprivation adjusted for 24 hours of recovery was not significant ($p>0.05$). This suggests that there was no significant variation in auditory reaction time among the groups after 24 hours of recovery following 48 hours of sleep deprivation obtained F ration of 1.36. These findings imply that neither 48 hours of sleep deprivation nor the subsequent 24 hours of recovery significantly affected auditory reaction time among the six groups. Therefore, it can be inferred that the observed changes in auditory reaction time were not attributable to the effects of sleep deprivation or recovery on the groups studied.

Overall, these results contribute to our understanding of the relationship between sleep deprivation, recovery, and auditory reaction time, highlighting the need for further research to elucidate the underlying mechanisms and potential interventions to mitigate the impact of sleep disturbances on cognitive performance.

4. DISCUSSION

The findings of this study shed light on the relationship between sleep deprivation and auditory reaction time. Contrary to expectations, neither 48 hours nor 24 hours of sleep deprivation resulted in significant alterations in auditory reaction time across the six groups. These results diverge from previous research suggesting that sleep deprivation adversely affects various cognitive functions, including reaction time.

These findings align with recent studies suggesting that the impact of sleep deprivation on cognitive performance may not be as straightforward as previously assumed (Lim & Dinges, 2010; Pilcher & Huffcutt, 1996). For instance, Pilcher & Huffcutt (1996) conducted a meta-analysis examining the effects of sleep deprivation on cognitive performance and found considerable variability across studies, indicating the need for further investigation into individual differences and moderating factors.

A possible description for the lack of significant changes in auditory reaction time following sleep deprivation could be the presence of compensatory mechanisms. Studies have shown that the brain may employ adaptive strategies to maintain performance levels during sleep deprivation, such as increased neural activation in specific cognitive regions (Chee & Chuah, 2008; Van Dongen et al., 2003; Vanhelder, & Radomski, 1989).

These findings resonate with recent research suggesting that the impact of sleep deprivation on cognitive performance is multifaceted and context-dependent (Anderson & Platten, 2011; Philip et al., 2019). For instance, Anderson & Platten (2011) proposed the concept of "sleep resilience," wherein individuals exhibit differential susceptibility to the cognitive effects of sleep loss. This notion underscores the importance of considering individual variability in response to sleep deprivation when interpreting study findings.

One potential explanation for the lack of significant changes in auditory reaction time following sleep deprivation could be the presence of compensatory mechanisms. Studies have shown that the brain may employ adaptive strategies to mitigate the immediate impact of sleep loss on cognitive functions (Alhola & Polo-Kantola, 2007; Killgore et al., 2008). For example, Alhola & Polo-Kantola (2007) demonstrated that individuals subjected to acute sleep deprivation exhibited increased activation in cortical and subcortical regions associated with attentional processing, suggesting a compensatory response to maintain cognitive performance.

Regarding the study’ limitations, the sample size and composition of participant groups may have influenced the results' generalizability. Additionally, the duration and severity of sleep deprivation studied may not have been sufficient to elicit significant changes in auditory processing. Future research should consider employing larger and more diverse samples and exploring the effects of varying durations and types of sleep deprivation.

Furthermore, incorporating neuroimaging techniques such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) could provide insights into the underlying neural mechanisms associated with auditory processing during sleep deprivation (Benedict et al., 2007; Gujar et al., 2011).

5. CONCLUSIONS

Following 48 hours of both disturbed and complete sleep deprivation, there was a notable increase in auditory reaction time. However, this increase was observed to be statistically non-significant, suggesting that regardless of the type of sleep deprivation, the impact on auditory reaction time remained comparable. This indicates a consistent effect of sleep deprivation on auditory processing, irrespective of its intensity.

Interestingly, melatonin supplementation did not yield a significant difference in auditory reaction time for either the disturbed or complete sleep deprivation groups. Despite the potential role of melatonin in regulating sleep-wake cycles and improving sleep quality, its impact on auditory reaction time during sleep deprivation did not manifest as a significant mitigating factor in this study.

Upon the recovery phase following sleep deprivation, auditory reaction time did not exhibit significant differences among any of the experimental groups. This suggests that while sleep deprivation may temporarily disrupt auditory processing, the recovery process appears to be consistent across different conditions, indicating a robust resilience of auditory function to short-term sleep disturbances.

These findings underscore the complex interplay between sleep deprivation, melatonin supplementation, and auditory processing. Further research is warranted to elucidate the mechanisms underlying these relationships and explore potential interventions to mitigate the adverse effects of sleep deprivation on cognitive function, including auditory processing.

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AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

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