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Sleep and stress in athletes with disabilities around the 2021 Tokyo Paralympic games during the pandemic

Piotr Kazimierz Urbański[1]✉, Britton W. Brewer[2], Michał Starczewski[3], Kwok Ng[4,6,7], Tomasz Tasiemski[1] & Maciej Tomczak[5]

This research evaluated the relation and fluctuations in stress and sleep quality in athletes with disabilities (AwD) during the period before and after the 2020 Tokyo Paralympics, amidst the COVID-19 pandemic. Assessments were conducted every 3 months over a period of 10 months, encompassing three distinct pandemic phases. Results showed significant variations in perceived stress ($F = 9.41$, $\eta p^2 = 0.09$, $p < 0.01$) and sleep quality ($F = 10.55$, $\eta p^2 = 0.10$, $p < 0.001$), with initial increased stress and poorer sleep, improving at the midpoint. Sleep quality components varied over time ($p < 0.05$), except for sleep medication use and daytime dysfunction. Results indicated a direct relationship where poor sleep potentially causes increased stress ($\beta = 0.24$, $p < 0.01$; $\beta = 0.13$, $p < 0.05$). The study underscores the need for regular stress assessments and development of sleep routines independent of external circumstances.

Optimal sleep is indispensable for achieving peak athletic performance, playing a crucial role in reducing injury risks, alleviating fatigue, facilitating sport-specific recuperation, and enhancing skill development[1–3]. Research indicates that various elements related to the sport itself, including the nature and intensity of training, the frequency and volume of exercises, travel demands, competitive pressures, and the rigorousness of athletes' schedules, significantly influence key sleep metrics such as duration, onset, efficiency, overall quality, and the prevalence of sleep disturbances[4,5]. Beyond the confines of sport, demographic and psychological factors, notably stress and anxiety, significantly influence sleep dynamics[6,7].

Expanding on the foundational role of sleep in sports performance, existing literature elucidates the bidirectional relationship between sleep and stress. Physiologically, sleep disruptions can intensify stress via neuroendocrine imbalances, highlighting the complex interplay between sleep cycles and stress hormones[8,9]. This dynamic is especially evident in competitive sports environments, where high-pressure situations can severely compromise sleep quality, leading to a cycle where stress begets poor sleep, which in turn further escalates stress levels[10,11]. The psychological dimension of this interplay is equally significant. The stress inherent in athletes' lifestyles, marked by intense training schedules and competitive demands, can severely affect sleep quality, underscoring the importance of managing stress to promote better sleep.

Recognizing the paramount importance of sleep, the International Olympic Committee advocates for optimal sleep practices, emphasizing the need for sufficient sleep duration, circadian rhythm alignment, and high-quality sleep, free from disorders like insomnia and sleep apnea[12]. Despite these guidelines, research consistently indicates that both emerging and established athletes grapple with maintaining optimal sleep quality and duration, frequently not meeting sleep standards[5,13,14]. This issue is particularly pronounced among young athletes, who not only have to contend with their developmental sleep needs but also face the dual pressures of sports and other life commitments[10].

Evidence indicates notable changes in sleep quality, particularly as athletes prepare for important competitions such as qualifiers[15]. The Tokyo Olympic and Paralympic Games, which took place during the

[1]Department of Adapted Physical Activity, Poznan University of Physical Education, Poznań, Poland. [2]Department of Psychology, Springfield College, Springfield, USA. [3]Faculty of Rehabilitation, Józef Pilsudski University of Physical Education, Warsaw, Poland. [4]Department of Physical Education and Sport Sciences, Physical Activity and Health Research Centre, Health Research Institute, Department of Physical Education and Sport Sciences, University of Limerick, Limerick, Ireland. [5]Department of Psychology, Poznań University of Physical Education, Poznań, Poland. [6]Institute of Innovation and Sports Science, Lithuanian Sports University, Kaunas, Lithuania. [7]Faculty of Education, University of Turku, Turku, Finland. ✉email: urbanski@awf.poznan.pl

challenging COVID-19 pandemic, added significant stress and complexity for athletes. This period was defined by widespread uncertainty, fluctuations in psychological variables such as anxiety, depression symptoms, loneliness, stringent restrictions, and substantial changes to training schedules along with the risk and fear of COVID-19 infection[16–20]. The additional pressure and stress brought by the Olympics and Paralympics, known to exacerbate psychological challenges[21], likely further impacted athletes' sleep quality and overall mental health. This aspect should be highlighted, as it emphasizes the compounded effects of both the pandemic and the inherent pressures of such a high-stakes event.

Within the athletic community, athletes with disabilities (AwD) face distinctive challenges, which became even more pronounced during the COVID-19 pandemic due to additional difficulties associated i.e. with their disabilities and limited access to specialized medical care[13]. Depending on the type of disability, key factors hindering the functioning of individuals with disabilities include cardiovascular dysfunctions, such as body temperature dysregulation, negative consequences of pharmacological treatments, and secondary health conditions such as pain, spasticity, motor control issues (including difficulty in changing sleep positions), urinary and bowel dysfunction, and psychosocial problems such as increased anxiety and depressive symptoms[22–24]. These factors can significantly impact various aspects of life for individuals with disabilities, including sleep[24–27].

Recent research indicates that AwD often experience inadequate sleep quality, adhere to less-than-ideal sleep routines, and typically fall short of achieving the recommended sleep duration[28]. This challenge was amplified during the pandemic, when sleep became even more crucial as the primary method of post-exercise recovery, particularly as access to alternative recovery methods, such as physical therapy was limited[13]. While many studies on sleep and stress in athletes without disabilities exist, research on AWD remains limited[10,11,28–32]. Previous studies have shown that AwD often experience lower sleep quality, irregular patterns, and increased sleep disturbances, all of which can impair recovery and performance[13,33–35]. For instance, Paralympic athletes report high rates of insomnia and poor sleep quality, factors associated with greater injury and illness risk. Additionally, differences in sleep quality have been observed based on impairment type, such as spinal cord injuries, underscoring a need for targeted investigations into sleep and stress within this group.

In this context, stress in Paralympic AwD refers to the psychological strain resulting from specific stressors related to both their athletic involvement and the pandemic. These stressors include uncertainties about future competitions, financial challenges due to reduced funding and sponsorship, changes in training routines and facility access, limited interactions with coaches and support staff, and a loss of daily structure and routine[21]. Additionally, athletes may experience heightened pressure from the expectations of representing their country, identity foreclosure due to a sole focus on sport, and concerns about health and safety during the pandemic[21].

Based on existing research that documents changes in pandemic-related restrictions[36], including limited interactions with coaches and changes in training opportunities[16], varied effectiveness of coping strategies during pandemic[37] and the diverse occurrence of loneliness, symptoms of depression and anxiety[18,19], we hypothesized that the levels of sleep and stress would vary according to the severity of the pandemic. This hypothesis is supported by similar findings in an earlier study conducted on different populations, where variations in stress and sleep levels were observed in relation to the intensity of pandemic restrictions[30,38]. Therefore, the primary aim of this study was to assess level and fluctuations in sleep and stress among AwD during the COVID-19 pandemic.

An additional aim of the study was to assess the relationship and directionality between stress and sleep. Previous findings have been inconclusive, with some studies indicating that elevated stress levels can deteriorate sleep quality, while others suggest that sleep disturbances may increase stress levels[8–11]. Due to the absence of longitudinal research in this context during the pandemic, this relationship was assessed descriptively, without establishing a prior hypothesis.

Method

Procedure

This study was approved by the Ethical Committee of Poznan University of Medical Sciences (KB-742/21). The study spanned three distinct time points (Times A, B, and C) over a 10-month period during the pandemic. These evaluations, conducted before (Times A and B) and after (Time C) the Tokyo Paralympic Games Tokyo Paralympic Games (August 24, 2021 – September 5, 2021), aligned with specific phases of the pandemic. Specifically, the study's intervals were associated with varying average daily infection rates: the third wave in April 2021 (Time A) recorded an average of 15,681 infections, accompanied by strict lockdown measures, limited access to training facilities, and mandatory quarantine for travel; a significant decrease in July 2021 (Time B) marked the second wave with approximately 102 infections, during which restrictions were eased, allowing limited group training and gradual reopening of facilities; and the fourth wave in November 2021 (Time C) saw an average surge to 22,591 infections, leading to the reintroduction of stricter measures, including reduced travel and restricted facility access[39].

The Polish Paralympic Committee was involved in the recruitment of participants and helped distribute the survey to all Paralympic athletes included in the Polish Paralympic preparation program. Individuals who did not participate in all scheduled research dates or did not correctly complete all research tools were excluded from the study. During the last week of each study month (April, July, November 2021), athletes were emailed a link to an online survey hosted by Google Forms, with completion reminders sent weekly during the subsequent two weeks. The study adopted a longitudinal research design, building upon the methodology used in previous investigations[19,37]. All participants gave informed consent to participate in the study. This was done through acceptance of a consent statement in the electronic online questionnaire, which was mandatory to access the survey with all study measures.

Measures

Sleep

The Pittsburgh Sleep Quality Index (PSQI) consists of 19 self-rated items that assess seven components of sleep: latency, subjective quality, duration, efficiency (defined as the ratio of sleep duration to total time spent in bed), disturbances, use of sleep medication, and daytime dysfunction. Each result (given in minutes, points, etc.) is ultimately converted to a score of 0 to 3. A higher PSQI score indicates poorer sleep quality, and individuals with a score exceeding 5.5 are considered to have poor sleep quality. The PSQI evaluates sleep patterns over the past month. This tool is recognized for its validity and reliability and is one of the most frequently used instruments for sleep assessment in AwD[28]. The Cronbach's α coefficient for the PSQI in the present study was satisfactory for particular study terms (Time A: $\alpha = 0.76$; B $\alpha = 0.73$; C $\alpha = 0.78$).

Stress

The Perceived Stress Scale (PSS)[40] is a premier tool for assessing general perceptions of stress and has been validated in studies involving athletes[41]. This instrument comprises 10 items and evaluates the extent to which individuals perceive their lives as unpredictable, uncontrollable, or overwhelming. Based on their experiences in the past month, participants rated their frequency of specific feelings and thoughts on a scale from 0 (never) to 4 (very often), resulting in a total score ranging from 0 to 40. A higher cumulative score denotes a greater level of perceived stress. The Cronbach's α coefficient for the PSS in the present study was satisfactory for particular study terms (Time A: $\alpha = 0.94$; B $\alpha = 0.93$; C $\alpha = 0.92$). The tool was used extensively across various research groups, including athletes and individuals with disabilities[41,42].

To assess socio-demographic variables, we developed a study-specific questionnaire. To measure changes in training schedules due to the pandemic, we asked participants during each evaluation to report their actual training time over the past month and to provide their originally planned training time for that same period. This methodology mirrored the approach used in a previous studies[16,19].

Data analysis

Repeated measures analysis of variance (ANOVA) was used to compare stress perception and general sleep quality across the three study periods. In the event of a significant main effect, detailed post hoc comparisons were conducted using the Bonferroni correction. The skewness values ranged between −0.26 and 0.91, and the kurtosis values ranged between −0.52 and 1.61. Given that none of the values exceeded the absolute value of 2, it is reasonable to assume that the variables are approximately normally distributed. Conversely, due to a breach of sphericity, the degrees of freedom were adjusted using the Greenhouse–Geisser correction[43].

For the comparison of individual components of sleep quality (on an ordinal scale) across the three time points, the Friedman test was used. Kendall's W coefficient served as the measure of effect size. In instances of a significant overall test result, post hoc analyses were conducted using the Dunn test. To evaluate the association between sleep quality and stress perception, Spearman's rho correlation coefficient was calculated.

Cross-lagged panel models were employed to assess the directional relationship between variables measured at multiple time points (Times A, B, and C), facilitating the exploration of potential causal relationships between variables[44]. The adequacy of the model fit to the data was evaluated using the chi-square test, the comparative fit index (CFI), and the root mean square error of approximation (RMSEA). A nonsignificant chi-square test, combined with CFI values exceeding 0.90 and RMSEA values less than 0.08, suggested a satisfactory fit of the model to the data[45]. All statistical analyses were performed with the IBM Statistical Package for Social Sciences software (IBM SPSS Statistics version 28, Chicago, IL, USA). Cross-lagged models were analyzed using IBM SPSS AMOS (Analysis of Moment Structures).

Results

In the study, 91 out of the 116 distributed surveys were successfully delivered across three measurement periods, yielding a deliverability rate of 78.4%.

Participants

A total of 91 AWD, enrolled in preparation programs for the Polish Paralympic Games, participated in this study. All the respondents were Polish and subordinated. The majority of participants were male (66%), with an mean age of 33 years (SD = 12.04). The most represented sports were paraswimming (17%), para-athletics (15%), goalball (13%), para-cycling (12%), and para-fencing (11%). On average, participants had 9.56 years (SD = 7.92) of training experience. The most prevalent types of impairment among these athletes were amputation (29%), "Les Autres" (24%), spinal cord injuries (22%), and visual impairments (18%). The average time since the occurrence of injury or diagnosis of disease was 17.9 years (SD = 14.48).

A statistically significant effect of time was observed for both stress perception (PSS) and overall sleep quality (PSQI). At Time A and Time C, stress perception levels were significantly greater than they were at Time B (Table 1; Fig. 1). Additionally, sleep quality values at Time A were significantly greater than those at Time B (Table 1).

Differences in individual components of sleep quality across Time A, Time B, and Time C were subsequently analyzed (Table 2).

Overall, significant differences across the three time points were noted for the first five components of sleep quality (Table 2). For subjective sleep quality, higher values were observed during Time A and Time B than during Time C. Sleep latency exhibited greater values at Time A and Time C than at Time B. Sleep duration had greater values at Time C than at Time B. For sleep disturbances, values during Time A were greater than those at Time B and Time C. Conversely, there were no significant differences between the time points for the other

Variables	Time A M (SD)	Time B M (SD)	Time C M (SD)	Post-hoc (Time)	F test	η_p^2
PSS	16.18 (7.77)[a]	13.97 (6.48)[a, b]	14.77 (6.67)[b]	A, C > B	9.41**	0.09
PSQI	6.64 (3.22)[a]	5.14 (2.90)[a]	5.84 (3.45)	A > B	10.55***	0.10

Table 1. Levels of perceived stress (PSS) and sleep quality (PSQI) at Time A, Time B, Time C ($n = 91$). ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$; PSS: ANOVA: df1 = 1.33, df2 = 119.40; post-hoc: a: $p < 0.001$, b: $p < 0.05$; PSQI: ANOVA: df1 = 1.73, df2 = 155.84; post-hoc: a: $p < 0.001$; post hoc – detailed comparison, F – value of test statistics, ηp[2]- effect size.

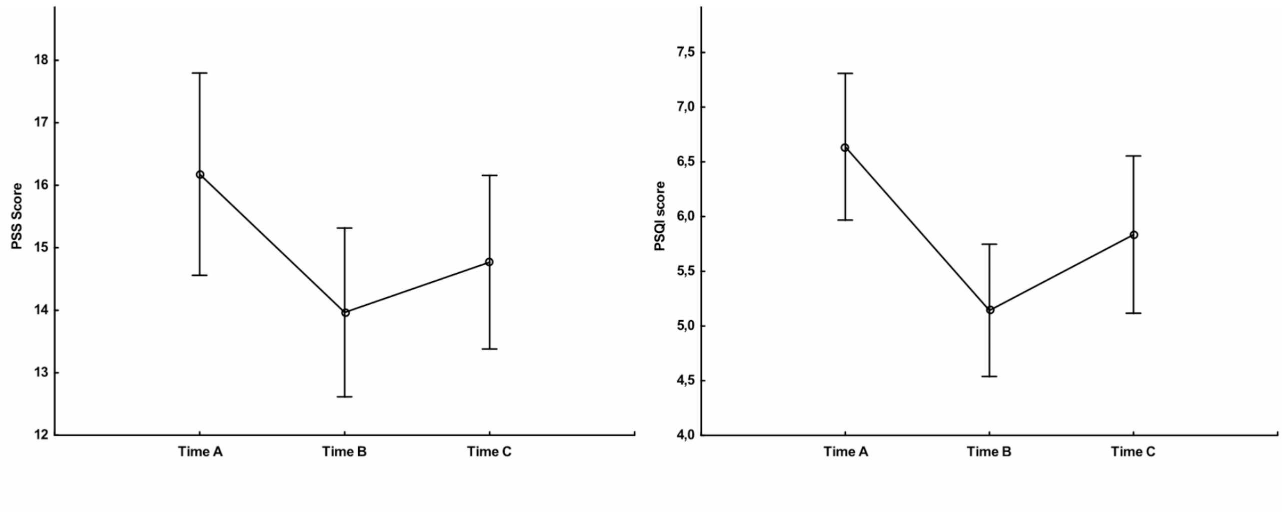

Fig. 1. Perceived stress level (PSS) and sleep quality (PSQI) level at Time A (April 2021), Time B (July 2021), and Time C (November 2021).

Components	Time A Me [Q1, Q3] Mean rank	Time B Me [Q1, Q3] Mean rank	Time C Me [Q1, Q3] Mean rank	Post-hoc	Friedman Test Chi-square (df = 2)	W
Subjective Sleep Quality	2.0 [1.0, 2.0] 2.20[a]	2.0 [1.0, 2.0] 2.18[b]	1.0 [1.0, 1.0] 1.63[a, b]	A, B > C	36.36***	0.20
Sleep Latency	1.0 [1.0, 2.0] 2.20[a]	1.0 [0.0, 1.0] 1.68[a, b]	1.0 [1.0, 2.0] 2.12[b]	A, C > B	25,34***	0.14
Sleep Duration	1.0 [0.0, 1.0] 2.02	0.0 [0.0, 1.0] 1.77[a]	1.0 [0.0, 1.0] 2.21[a]	C > B	14.93***	0.08
Habitual Sleep Efficiency	1.0 [0.0, 2.0] 2.12	1.0 [0.0, 1.0] 1.79	1.0 [0.0, 2.0] 2.10		10.58**	0.06
Sleep Disturbances	1.0 [1.0, 1.0] 2.39[a, b]	1.0 [0.0, 1.0] 1.87[b].	0.0 [0.0, 1.0] 1.74[a]	A > B,C	45.51***	0.25
Use of Sleep Medications	0.0 [0.0, 1.0] 2.03	0.0 [0.0, 0.0] 1.95	0.0 [0.0, 0.0] 2.02		1.04	–
Daytime disfunction	1.0 [0.0, 1.0] 2.09	1.0 [0.0, 1.0] 1.87	1.0 [0.0, 1.0] 2.03		5.18	–

Table 2. Variations in sleep quality components across Time A, Time B, and Time C ($n = 91$). Sleep quality components, post-hoc: 1-a:$p < 0.001$, b:$p < 0.001$; 2- a:$p < 0.01$, b < 0.01; 3-a:$p < 0.01$; 4: $p > 0.05$; 5: a:$p < 0.001$,b:$p < 0.01$; Chi-square: ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$; Me- median, Q- quartiles. A – Time A, B – Time B, C – Time C; W - Kendall's W coefficient, Me -median; Post-hoc detailed comparison, df – degrees of freedom.

components; use of sleep medications and daytime disfunction did not achieve statistical significance in the overall Friedman test, and habitual sleep efficiency did not show significant differences across the time points (Table 2). Subsequently, the relationships between sleep quality and stress perception were analyzed (Table 3).

Statistically significant associations were observed between sleep quality (both the total score and individual components) and the perception of stress. The most pronounced correlation values were identified for habitual

Components	PSS score Time A	PSS score Time B	PSS score Time C
PSQI Total	0.59***	0.64***	0.59***
	[0.443–0.713][1]	[0.500-0.747]	[0.437–0.710]
Subjective Sleep Quality	0.28**	0.38***	0.27**
	[0.080–0.461]	[0.191–0.545]	[0.069–0.452]
Sleep Latency	0.34***	0.26*	0.28**
	[0.147–0.512]	[0.060–0.445]	[0.077–0.458]
Sleep Duration	0.33**	0.34***	0.28**
	[0.129–0.499]	[0.146–0.512]	[0.079–0.460]
Habitual Sleep Efficiency	0.53***	0.48***	0.54***
	[0.369–0.667]	[0.300–622]	[0.380–0.674]
Sleep Disturbances	0.38***	0.41***	0.42***
	[0.183–0.539]	[0.224–0.568]	[0.230–0.573]
Use of Sleep Medications	0.38***	0.32**	0.29**
	[0.189–0.544]	[0.122-493]	[0.091–0.470]
Daytime disfunction	0.38***	0.49***	0.54***
	[0.185 – 0.1541]	[0.321–0.635]	[0.370–0.667]

Table 3. Correlations between stress perception and sleep quality ($n = 91$). ***$p < 0.001$, **$p < 0.01$, [1] 95% confidence intervals for rho.

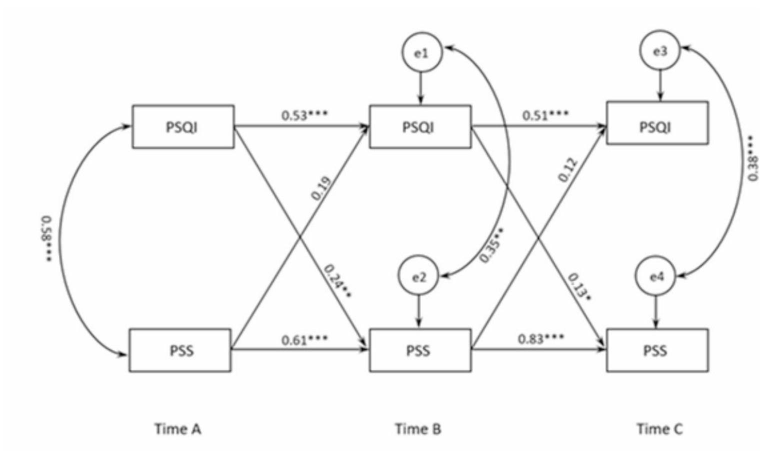

Fig. 2. Cross-lagged model of sleep quality and stress perception across at three time points ($n = 91$); e1-e4 – errors – residuals.

sleep efficiency and daytime dysfunction (Table 3). Subsequently, a cross-lagged model was employed to ascertain a potential causal relationship between the study variables (Fig. 2). The model demonstrated a strong fit to the empirical data (chi-square = 1.757, df = 4, $p = 0.780$; CFI = 1.00, RMSEA < 0.001). Stability coefficients for relationships between sleep quality measured at different times, as well as between stress perception measured at individual times, were statistically significant. Concerning the cross-lagged effects, the association between sleep quality and stress perception was found to be significant (from Time A to Time B and from Time B to Time C). However, there were no statistically significant effects in the opposite direction, i.e., stress perception on sleep quality (Fig. 2).

Discussion

The primary goals of this study were to explore and assess the fluctuations in perceived stress and sleep quality among AwD. The findings indicated that the underlying rationale for first hypothesis was valid. The study revealed significant fluctuations in both perceived stress and sleep quality throughout the various phases of the study. The initial assessment period, marked by a surge in infection rates and restrictions, was characterized by the highest levels of stress and significantly deteriorated sleep quality. In contrast, the midpoint – coinciding with a decrease in infection rates – exhibited the lowest levels of both, relative to all other assessment points in the study[39]. As indicated in the literature, AwD frequently encounter challenges such as diminished sleep quality, pain, and elevated risks of depression and anxiety[35].

The pandemic necessitated adaptations in training routines for AwD, introducing additional challenges related to transportation, facility access, and the unpredictability of sports competitions, further exacerbating mental health issues intensifying stress perception[16,46]. Moreover, the inadequacy of conventional coping strategies during the pandemic, particularly noted in its early stages[19,37], may have contributed to increased stress and mental health disturbances, additionally intensified by the approaching competitions.

During Time B, which occurred just before the Paralympic Games, athletes experienced a lower level of stress compared to other time points. This reduction may have been influenced by factors such as fewer restrictions, enhanced safety measures, and the athletes' awareness of their qualification for the Games, although further research would be needed to establish these as significant contributors[21]. Additionally, the attention focused on the athletes before the Games likely contributed to ensuring they received the necessary support[32].

Furthermore, throughout the study, the average sleep duration reported by participants was below the recommended 8 h. The average sleep durations were 7.3 h in the first measurement, 7.0 h in the second, and 7.1 h in the third. These results are consistent with findings from other studies[34,35]. Initially, it was hypothesized that the pandemic and its related disruptions might lead to shorter sleep durations; however, changes in athletes' routines, including the cessation of training and sports camps, seemed to allow for increased sleep duration[29,47]. Notably, athletes also spent significantly more time in bed without sleeping and took longer to fall asleep, resulting in lower average sleep efficiency. This suggests that while more time was available for rest due to reduced physical activity and the absence of regular competitive engagements[16], the quality of sleep did not necessarily improve.

Significant variations in sleep components such as subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, and sleep disturbances were observed, primarily between the first timepoint of the study and the subsequent two. In general, most sleep components exhibited higher scores during the first measurement, with the exception of subjective sleep quality. This might indicate that the participating athletes were adapting to the pandemic conditions[29], or that the lockdowns, restrictions, and their negative consequences were less felt in the realm of maintaining sleep hygiene[29,48]. Nevertheless, this requires further investigation.

No significant differences were observed in the use of medication and daytime dysfunction across the study intervals. This may be due to these factors not being directly tied to sleep quality, though they are related to it. Specifically, the use of sleep medication is often part of pharmacotherapy in people with disabilities aimed at inducing sleep[22,49], while daytime dysfunction may involve the impairments encountered during the day due to inadequate sleep. Moreover, expecting significant changes in medication usage within a short period is unjustified, especially among individuals for whom pharmacotherapy is integral to daily functioning[50].

In reference to the second objective, it turns out that the directionality analyzed here is from poor sleep quality to increased stress, rather than the reverse. This finding aligns with research results that point to this relationship[8,9] and suggests that poor-quality sleep, among the authors, by limiting full rest and recovery, may concurrently elevate stress levels. This cycle suggests that poor sleep can lead to heightened stress, with potential long-term consequences for athletes' ability to manage stress effectively. However, this relationship is likely a part of a broader issue involving feedback loops in the context of the stress-sleep-stress relationship, and it necessitates additional research within various research contexts. Recent studies indicate that disruptions in training routines due to pandemic restrictions not only alter sleep patterns but also exacerbate psychological stress, suggesting that these factors might collectively degrade sleep quality and overall athlete well-being even further[27,32,43].

Research implications

The conducted study supplemented existing longitudinal research on AwD and demonstrated that during the pandemic, levels of both stress and sleep, as well as many other variables significant for athletes, such as coping, symptoms of depression, anxiety, and loneliness[18,19], varied significantly depending on the study period and the severity of the pandemic. Given the linkage between sleep deficiencies and injury risk[5] and the health concerns among AwD[6,19], further research in this area is crucial. Despite International Paralympic Committee recommendations, there is a lack of progress in addressing these issues, highlighting the need for ongoing investigation and intervention. Future efforts should focus on continuous monitoring of sleep and stress, especially during critical pre-Paralympic phases, tailoring interventions to address specific sleep disturbances.

Study limitations

This study has several limitations to consider when interpreting the results. Firstly, the self-reported and retrospective tools used are subject to recall bias and may lack the precision of in-depth interviews or alternative measurement methods. Furthermore, the timeframes measured by these tools, which covered the month preceding the study, do not consistently align with the referenced pandemic waves. This misalignment was mitigated but not eliminated by using the average, rather than the sum, of infection rates. This could affect the accuracy of the findings. Additionally, while the study accounted for several key variables, the potential influence of unmeasured confounders on the observed relationship between sleep and stress cannot be entirely dismissed. For instance, factors such as individual coping mechanisms, daily stressors not captured in the study, baseline mental health conditions, or personality traits were not measured. These unmeasured confounders could bias the results by influencing both stress levels and sleep quality. Future research should incorporate more comprehensive models that include a broader range of potential confounders to enhance the clarity and validity of these relationships.

Conclusions

The results of our study confirmed significant variations in sleep and stress levels during the pandemic, with a notable worsening of these parameters in the initial study period. Additionally, our findings indicate that compromised sleep quality may significantly contribute to increased stress levels in AwD. Therefore, it is essential for AwD to undergo regular stress evaluations, especially during periods of heightened societal or environmental challenges, to enable prompt identification and management of stress indicators, thus promoting their psychological resilience and performance.

Data availability

The data presented in this study are available on request from the corresponding author.

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Author contributions

Contribution: PKU, BB, and TT - conceptualization, PKU - data collection, PKU, MT – methodology, data analysis and interpretation of study results. PKU – writing the original draft, BB, KN, MS, TT, MT – writing, review, and editing.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

This study was carried out in accordance with the Declaration of Helsinki of the World Medical Association and was approved by the Ethical Committee of Poznan University of Medical Sciences (KB-742/21).

Additional information

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Correspondence and requests for materials should be addressed to P.K.U.