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Investigating the association between the lunar cycle and sleep, physiological, cognitive, and physical performance in children with Down syndrome

Zohra Lammouchi[1], Noomen Guelmami[2,3], Salma Abedelmalek[4], Mouna Saidane[2,5], Hatem Ghouili[2], Mahmoud Rebhi[2], Mohamed Saifedine Fessi[1], Mohamed Ben Aissa[2], Hafsi Bedhioufi[1], Helmi Ben Saad[4,6], Ismail Dergaa[2,7,8]

[1]Department of Human Sciences, High Institute of Sport and Physical Education of Sfax, University of Sfax, Sfax, Tunisia, [2]Department of Human and Social Sciences, High Institute of Sport and Physical Education of Kef, University of Jendouba, Jendouba, Tunisia, [3]Department of Health Sciences (DISSAL), University of Genoa, Genoa, Italy, [4]Department of Sport Science and Physical Activity, College of Education, Ha'il University, Saudi Arabia, [5]Higher Institute of Nursing Sciences of Kef, University of Jendouba, Jendouba, Tunisia, [6]Department of Physiology and Functional Explorations, Farhat HACHED Hospital, University of Sousse, Sousse, Tunisia, [7]Department of Preventive Health, Primary Health Care Corporation (PHCC), Doha, Qatar, [8]Research Laboratory Education, Motricité, Sport et Santé (EM2S) LR19JS01, High Institute of Sport and Physical Education of Sfax, University of Sfax, Sfax, Tunisia

Address for correspondence:
Dr. Ismail Dergaa,
Primary Health Care Corporation (PHCC),
Doha, P.O. Box 26555,
Qatar.
E-mail: Phd.dergaa@gmail.com

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Abstract:

BACKGROUND: Children with Down syndrome (DS) offer a compelling context within the fieldof human biology for examining potential lunar influences. While the exact mechanisms governing lunar effects are still under investigation, a growing body of scientific inquiry suggests possible connections between lunar phases and physiological, physical, and cognitive parameters. This investigation holds promise for uncovering the intricate interplay between lunar cycles (LCs) and the unique biology of children with DS. This study investigated the potential influence of the LC on physiological, physical, and cognitive parameters in children with DS, focusing on sleep patterns, physical performance, and cognitive abilities.

MATERIALS AND METHODS: Seventeen children with DS participated in this study. Sleep data, physical performance metrics, and cognitive test results were collected throughout the LC, including the new moon (NM), first quarter, full moon (FM), and third quarter. Statistical analyses were conducted to assess the differences in these parameters across lunar phases.

RESULTS: Significant differences were observed in sleep patterns, with reduced total sleep time ($P < 0.01$) and sleep efficiency ($P < 0.001$) during the FM phase. Heart rates (HRs) before ($P < 0.001$) and after ($P < 0.01$) exercise also displayed pronounced changes during LC. Additionally, the reaction time (RT) exhibited a significant difference ($P < 0.01$) across the lunar phases. However, physical performance metrics, including squat jump (SJ), sprint, and 6-minute walk distance (6MWD), did not show significant variations.

CONCLUSION: This study suggests that LC may have a moderating effect on sleep patterns, HR, and cognitive performance in children with DS. These findings have practical implications for caregivers and educators and highlight the importance of considering lunar-associated variations in planning schedules and interventions for children with DS.

Keywords:

Biological rhythms, circadian, cognitive abilities, lunar phase, rhythm

Introduction

Human physiology and behavior are regulated by various biological rhythms.[1] These rhythms, which are innate timekeepers, play a pivotal role in synchronizing internal processes with the external environment.[1] The most recognized of these rhythms is the circadian rhythm, which operates on a roughly

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24-hour cycle, governing processes such as sleep–wake cycles and hormone secretion.[2] Seasonal rhythms, however, align our physiology with annual changes, affecting mood, metabolism, and immune function.[3] Among these rhythms, the lunar cycle (LC), especially its impact on human health and behavior, has recently garnered significant attention.[4-7] Several studies have explored the relationship between LC and sleep patterns,[7,8] and Dergaa *et al*.[7] highlighted the alterations in sleep duration and quality during specific lunar phases. These findings were further supported by those of Benedict *et al*.[8] who observed similar sleep disturbances concerning LC. Beyond sleep, the LC has been linked to fluctuations in various biological markers.[9-11] For instance, melatonin, often referred to as the "sleep hormone," plays a crucial role in regulating sleep–wake cycles.[11] This hormone, which is primarily secreted by the pineal gland, is instrumental in determining sleep onset and duration.[11] In children, melatonin not only governs sleep but also plays a role in developmental processes.[9] Interestingly, children with Down syndrome (DS) often exhibit altered melatonin secretion patterns, which can influence sleep quality and duration.[10] Studies have further emphasized the potential influence of LC on melatonin secretion, suggesting a complex interplay between the phases of the moon, melatonin, and sleep. Sleep is fundamental to the growth, development, and overall well-being of children.[12] Adequate sleep is crucial for optimal physical performance, as it aids in muscle recovery, energy restoration, and coordination.[12] Cognitive functions, such as attention, memory, and decision-making, are also heavily influenced by sleep quality and duration.[12] Sleep disruptions can lead to diminished physical and cognitive performance, affecting a child's academic achievement and daily activities.[13] Children with DS present unique challenges related to sleep.[14] They often experience sleep disturbances, including sleep apnea, insomnia, and irregular sleep–wake patterns.[9,13,15] These disturbances can further exacerbate the cognitive and physical challenges that they already face.[15] Given these altered melatonin secretion patterns, understanding the factors that influence sleep in children with DS is of paramount importance.

Given the established impact of LC on sleep and biological parameters in healthy adults[5] and considering the known associations between reduced sleep and diminished physical performance, there is a need to explore these relationships further in specific populations. Given their unique melatonin secretion patterns and sleep challenges, children with DS present an ideal group for such exploration. Therefore, this study aimed to assess the effects of LC on sleep and physical and cognitive performance in children with DS.

Materials and Methods

Participants

Seventeen children with DS (mean ± standard deviation (SD): age: 9.73 ± 0.83 years; height: 1.41 ± 0.02 m) participated in this study. They were all from the Government of Kef, Tunisia. A week's worth of actigraphy data and parental sleep reports were gathered. Detailed interviews regarding participants' sleep and dietary habits were conducted. Parents maintained sleep diaries and responded to selected items from the Insomnia Severity Index (ISI), a tool for assessing sleep quality or identifying sleep disorders in pediatric age groups. Parents were comprehensively briefed on the study protocol. After understanding the study's protocol, risks, and benefits, written informed consent was obtained from the parents and oral consent was obtained from each child. All participants and their parents were keen to participate. Parents were provided with comprehensive information about the trials their children would undergo. The inclusion criteria for the study were consistent meal timing, similar economic status, age between 9 and 11 years, and no significant cognitive impairments. During the 2021–2022 academic year, participants were active and regularly attended physical education classes. The study protocol adhered to the Helsinki Declaration for Human Experimentation and was approved by the local University Ethics Committee under reference (35a-2021).

Experimental design

Before the commencement of the experiment, the participants and their parents were informed of the testing procedures to ensure clarity and compliance. They were familiarized with the equipment and experimental protocol to mitigate any learning effects that might arise from the repeated test sessions. It is noteworthy that these testing protocols have been integrated into the participants' regular physical education classes since September 2017.

Testing sessions were strategically scheduled between 17:00 and 18:00 on specific days, aligning with distinct lunar phases: new moon (NM), first quarter, full moon (FM), and third quarter.[7] The sequence of these sessions was randomized to prevent orderly effects. Body mass was measured using an electronic scale (Tanita, Tokyo, Japan). Physical assessments, including the 6-min walk test (6MWT), 10-m sprint, and squat jump (SJ), were conducted in conjunction with cognitive evaluations, namely the dart test, mental rotation (MR) test, and computer-based simple reaction time (RT) test. Data collection began manually at the onset of each test and was concluded automatically upon completion, after which it was prepared for analysis.

Sleep quality was monitored for each LC. Both participants and their parents were advised to maintain their usual physical activity levels and avoid strenuous activities for 24 hours before testing. The laboratory environment was controlled, and a consistent temperature of 22.2 ± 1.3°C was maintained throughout the study. All assessments were conducted between 17:00 and 18:00 on the day of each lunar phase to control for potential circadian influences on the measured parameters.

The assessments were categorized as sleep analysis, physical performance, cognitive performance, and accuracy. Detailed descriptions of each category are provided in the subsequent sections.

The study was synchronized with the lunar calendar as follows:

- NM was observed on April 01, 2022
- The first quarter took place on April 09, 2022
- FM occurred on April 16, 2022
- The third quarter was on April 23, 2022.

Our methodology was influenced by prior research exploring the relationship between LC, sleep, and physical and cognitive performance. In particular:

- Studies by Caochen[5] indicated that the deep quality tends to decrease during the FM phase. This phenomenon has been attributed to alterations in the melatonin hormone, often referred to as the "sleep hormone," which plays a crucial role in regulating sleep–wake cycles.
- On the day following FM, Ref.[6] reported a decline in physical performance. This decline was rationalized based on the reduced sleep quality and diminished melatonin levels observed at night preceding FM. Furthermore, the same studies highlighted that cognitive performance was also affected, suggesting that reduced sleep quality and melatonin levels affected not only physical abilities but also cognitive functions.

By integrating these findings into our methodology, we aimed to provide a comprehensive understanding of the potential impact of LC on participants, encompassing both their physical and cognitive performance. This approach underscores the intricate relationship between sleep, melatonin, and overall human performance in the LC context.

Sleep analysis

Analysis of sleep patterns is especially relevant when studying circadian rhythms in young children and those with intellectual disabilities. The participants were equipped with actimetric devices on their nondominant ankles, starting at 8:00 p.m. on each test day and continuing until the conclusion of the experiment. Data were collected using Actiwatch (Actiwatch Sleep and Activity software, version 5.32; Cambridge Neurotechnology, Cambridge, UK). These actigraphs were equipped with a piezoelectric transducer sensitive to 1-g acceleration movements. Upon completion of the experiment, actigraphs were retrieved and the data were transferred to a computer through an actigraph interface unit. The time frames were adjusted based on the daily programs to exclude periods when the monitor was not in use.

Physical performance

The 6MWT

The 6MWT was administered in alignment with the guidelines set by scholarly societies.[16] This test serves as a submaximal exercise measure to evaluate both aerobic capacity and endurance. It quantifies the distance a participant can walk on a hard, flat surface within 6 minutes. The primary objective is to achieve the maximum distance within this duration (i.e., the 6-min walk distance (6MWD)). Throughout the test, the participant's heart rate (HR) was monitored in real time, both before the start and immediately after the conclusion of the 6MWT, using HR monitors (Polar Team System, Polar Electro Oy, Finland).

SJ test

Before initiating the SJ test, participants underwent a warm-up routine that included 5 minutes of running, stretching exercises targeting the lower limbs, and 2 minutes of jumping exercises. The SJ test commenced with the participants positioning their knees at a 90°angle. They were then instructed to perform a vertical jump by exerting an upward force on their legs.[17] Each participant's performance was recorded over three jumps, with a 30-second recovery period allowed between each jump.

Sprint tests (10 m)

Before the sprint tests, a five-minute warm-up was conducted. Participants began from a standing start, positioned their front foot 0.2 meters behind the initial photocell beam, and then sprinted for a distance of 10 m. The completion times for the 10-m distance were recorded, and after three trials, the best time was selected for subsequent analysis.[18] Between each trial, the participants were given a recovery period ranging from 6 to 8 minutes.

Cognitive performance

RT

The RT test utilized the React software (version 4.05) to measure participants' response times to color-typed visual stimuli.[19] Upon the appearance of a stimulus on the screen, participants were instructed to press a designated button promptly. The test involved a sequence of various colored geometric shapes. The RTs were computed electronically, with intervals between the displays of colored shapes ranging from 200 to 250 ms. Scores recorded in seconds indicated performance, with longer times indicating slower reactions.

MR

The MR test involved the presentation of two-dimensional images that represent three-dimensional objects. The participants were tasked with determining whether the objects were identical and barring their orientation. The test utilized specialized MR software.[20] Within a specified time frame, participants had to identify an image from a pair that was oriented differently from the reference figure displayed on the screen's left side. The test comprises 10 items segmented into a single series of 10 tests. To succeed, participants had to mentally rotate the stimulus to match the reference orientation and make accurate and swift judgments.

Accuracy (Darts test)

In this task, participants aimed to throw darts as close to the bull's eye as possible.[21] Each throw's score was determined based on its proximity to the target, with scores ranging from 0 to 10. Throws that missed or bounced off the board were assigned a score of "0." The target board featured ten concentric rings. Three distinct scores assessed the accuracy and consistency of the participants' throws.[21] The first score represents the average of six throws, with scores ranging from 0 (all misses) to 10 (all bulls' eyes), serving as an accuracy measure. The second score recorded the number of zeros (missed targets), ranging from 0 to 6, with fewer zeros indicating better accuracy. The third metric, the coefficient of variation, was calculated as distance divided by mean score, with a lower coefficient signifying enhanced consistency.

Statistical analysis

A priori power analysis was performed using free G*Power software (version 3.1.9.6, University of Kiel, Kiel, Germany). Given the study design, the effect sizes (ESs) were considered to generate the sample. The results indicated that the required sample size to achieve 80% power and detect a medium effect ($f = 0.35$) was 13 participants ($\alpha = 0.05$, $1 - ß = 0.80$, and actual power = 82.80%).

Data are presented as the mean ± SD. Data normality was tested using the Kolmogorov–Smirnov test and was found to be normally distributed ($P > 0.05$).

One-way repeated-measures analysis of variance (ANOVA) was used to determine differences. Before performing the ANOVA, compound symmetry was tested using the Mauchly test. Thus, the Greenhouse–Geisser correction was performed if the sphericity test was not assumed. A Bonferroni *post hoc* test was performed when significant interactions were revealed. To determine the magnitude of differences, ESs were calculated as partial eta-squared ($\eta 2$) with threshold values of 0.0–0.1, trivial; 0.01–0.6, small; 0.06–0.14, moderate; and >0.14, large.[22]

Statistical analysis was performed using the Statistical Package for Social Sciences version 28.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $P < 0.05$.

Results

Sleep analysis

The analysis revealed a significant main effect on total sleep time ($F = 8.22$, $P < 0.001$, ES = 0.34) and sleep efficiency ($F = 6.93$, $P < 0.01$, ES = 0.29). Temperature measurements showed no significant variations ($F = 1.22$; $P = 0.29$; ES = 0.071) [Figure 1 and Table 1]. The *post hoc* Bonferroni tests further confirmed these findings. In particular, total sleep time showed significant differences between FM and NM ($P < 0.05$) and between the first quarter and NM ($P < 0.05$). Sleep efficiency differed significantly between the FM vs. first quarter ($P < 0.01$).

Physical performance

Regarding physical performance metrics, the SJ test ($F = 0.54$; $P = 0.66$; ES = 0.10), sprint test ($F = 0.43$; $P = 0.73$; ES = 0.08), and 6MWD test ($F = 1.25$; $P = 0.33$; ES = 0.21) demonstrated no significant differences over time [Figure 2 and Table 1]. However, resting HR measurements showed a pronounced change ($F = 52.88$, $P < 0.001$, ES = 0.77), as did those obtained at the end of the 6MWT ($F = 17.80$; $P < 0.01$; ES = 0.53) [Figure 3 and Table 1].

The *post hoc* Bonferroni tests further confirmed these findings. In particular, resting HR measurements revealed differences between FM and all other phases, as well as between the first quarter and the third quarter, and NM vs. the third quarter.

Cognitive performance

Cognitive tests revealed a significant difference in RT ($F = 4.63$, $P = 0.04$, ES = 0.22) and MR ($F = 5.62$, $P = 0.018$, ES = 0.26); however, precision ($F = 3.03$; $P = 0.055$; ES = 0.15) did not exhibit significant variations [Figure 4 and Table 1]. The *post hoc* Bonferroni tests further confirmed these findings. In particular, RT and MR displayed significant differences between FM and the third quarter and between FM and NM, respectively.

Discussions

This study was designed to investigate the potential influence of LC on various physiological and cognitive

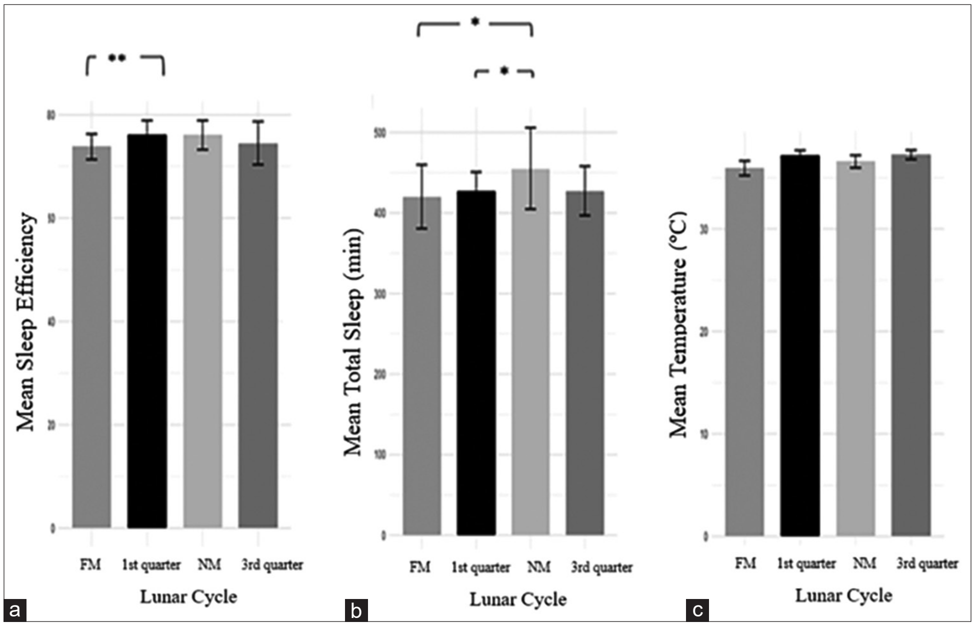

Figure 1: Sleep efficiency (a), total sleep time (b), and temperature (c) across the lunar cycle (*n* = 17). For sleep efficiency: $P < .01$ full moon (FM) vs. first quarter. For total sleep time: $P < .05$ for FM vs new moon (NM) and first quarter vs. NM

Table 1: Descriptive statistics of anthropometrics and physiological and psychological parameters across the lunar cycle (*n*=17)

	FM	First quarter	NM	Third quarter	$F^{£}$	η^2
Body mass (kg)	34.5±1.06	35.38±1.05	34.81±0.97	34.23±1.01	2.42	0.13
BMI (kg.m^{-2})	17.38±0.785	18.21±0.63	17.59±0.8	17.44±0.73	1.53	0.087
Total sleep (min)	420.35±39.62	427.11±23.75	455.29±50.47	427.41±30.62	8.22***	0.34
Sleep efficiency	73.82±2.46	76.35±2.89	75.24±3.07	74.53±4.17	6.93**	0.29
Temperature (c)	35.93±0.72	37.14±0.53	36.58±0.61	37.24±0.45	1.22	0.071
SJ (cm)	9.88±2.76	10.59±2.58	10.04±3.18	10.06±3.17	0.54	0.10
Sprint (s)	7.37±0.76	7.29±0.45	7.31±0.37	7.33±0.30	0.43	0.08
6MWT (m)	354.13±40.79	357.18±41.58	361.40±35.33	358.37±38.31	1.25	0.21
Heart rate (before)	92.82±2.10	90.53±2.07	90.47±2.19	89.20±2.29	52.88***	0.77
Herat rate (after)	118.8±0.80	115.8±0.88	116.1±1.05	115.5±0.76	17.80**	0.53
Reaction time (ms)	1269.04±126.48	1191.98±124.34	1161.19±105.13	1148.18±125.38	4.63*	0.22
Precision	2.64±0.60	3.58±1.06	2.94±1.02	3.17±1.01	3.03	0.15
Mental rotation	50.57±6.80	43.19±9.15	41.57±9.00	43.97±5.40	5.62*	0.26

bpm=Beats per minute, HR=Heart rate, SJ=Squat jump test, 6MWD=Six-minute walking distance. *$P<0.05$, **$P<0.01$, ***$P<0.001$. Degrees of freedom: 3–48

parameters in children. The overarching aim was to discern whether lunar phases, particularly the FM, have any tangible effects on sleep patterns, physical performance, and cognitive abilities.

Sleep analysis

The present findings indicate a significant main effect on total sleep time and sleep efficiency in children with DS but no significant variations in temperature measurements. Children with DS often exhibit sleep disturbances, which can be attributed to various factors, such as anatomical differences, medical conditions, and behavioral issues.[14] When comparing these findings with previous research, a study by Chaput *et al.*[23] was conducted across 12 countries, involving 5812 children aged 9–11 years. This study aimed to verify whether FM is associated with sleep and activity behavior in children. The results revealed that sleep duration was approximately 1% shorter during FM than NM. However, the difference in sleep duration was only approximately 5 min, which is consistent with the results of another study by Haba-Rubio *et al*.[24] Interestingly, this difference was statistically significant only because of the larger sample size in the present study. Another study by Sjödin, *et al.*[25] reported that children slept around 4.1 minutes longer during the FM compared with the NM. This discrepancy in findings suggests that while LC may have some influence on sleep duration, the clinical relevance of such differences remains questionable.

Several studies have explored the potential influence of LC on human sleep. For instance, Cajochen *et al.*[5] reported that

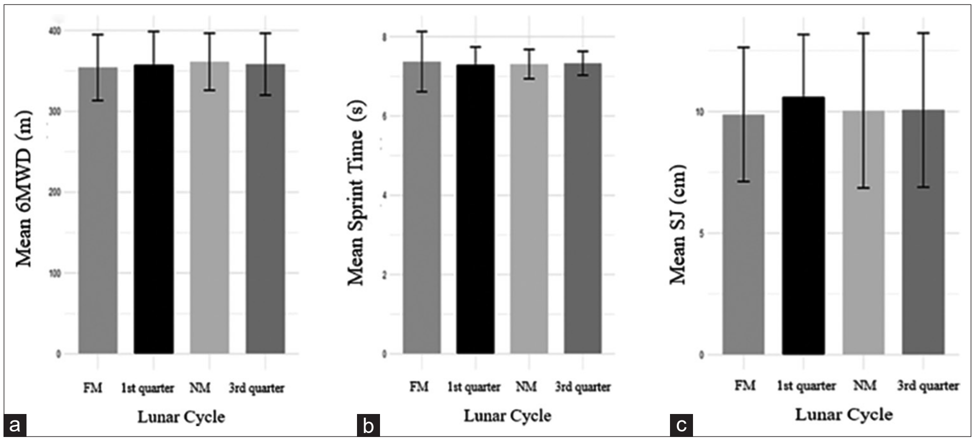

Figure 2: 6-min walk distance (6MWD) (a), sprint time (b), and SJ performance (c) across the lunar cycle (*n* = 17). FM: full moon. NM: new moon. Rest (before exercise): full moon (FM) vs. first quarter, FM vs. new moon (NM), FM vs. third quarter, first quarter vs. third quarter, and *P* < 0.05 NM vs. third quarter

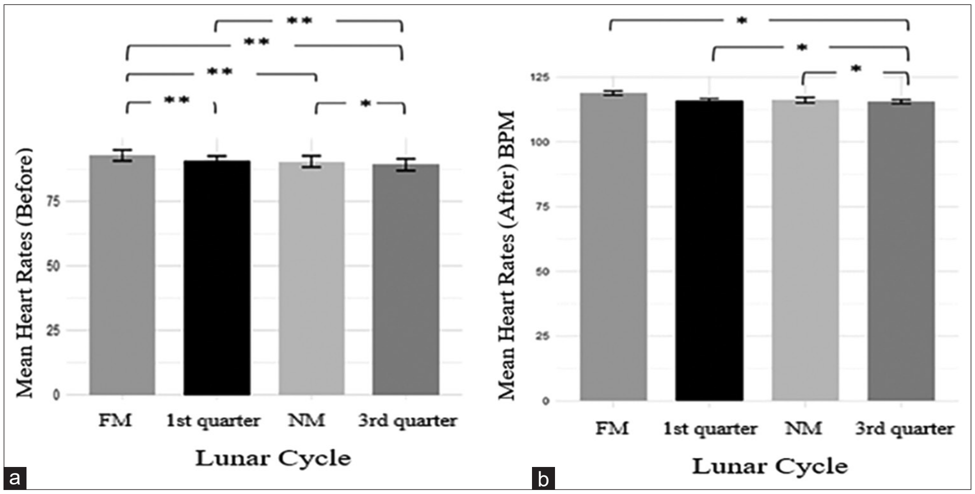

Figure 3: Differences in resting (a) and end-walking (b) heart rates (*n* = 17). Rest (before exercise): *P* < .01 full moon (FM) vs. first quarter, FM vs. new moon (NM), FM vs. third quarter, first quarter vs. third quarter, and *P* < .05 NM vs. third quarter. At the end of the walk (after exercise): *P* < .05 for FM vs. third quarter, first quarter vs. third quarter, and NM vs. third quarter

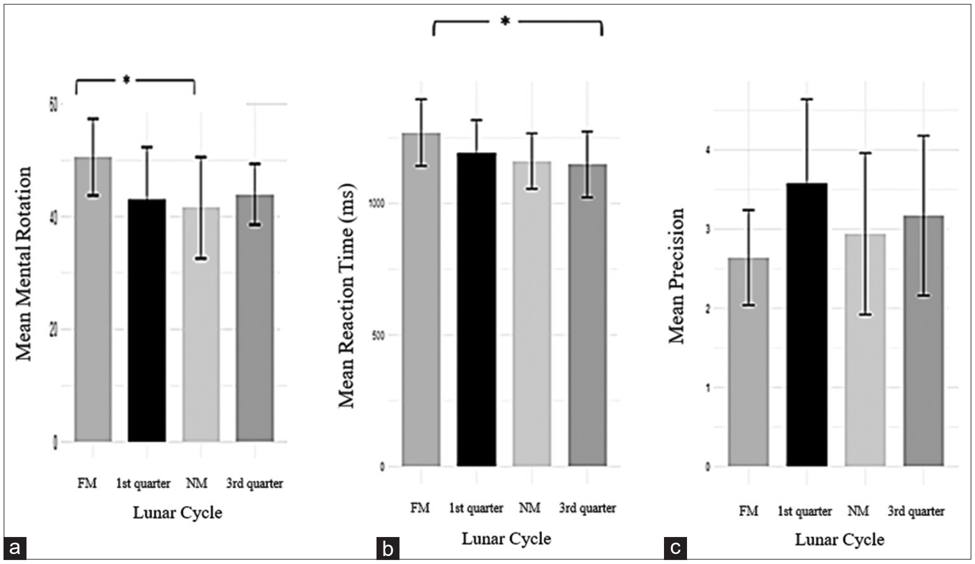

Figure 4: Mental rotation (a), reaction time (b), and precision (c) across the lunar cycle (*N* = 17). For mental rotation, *P* < 0.05 between full moon (FM) vs. first and third quarter. For reaction time, *P* < 0.05 between FM and new moon (NM)

sleep duration was reduced by 20 min, and sleep quality decreased in adults under controlled laboratory conditions. Similarly, Dergaa *et al*.[6] reported a decrease in perceived sleep during FM compared with NM. This reduction in sleep duration was more pronounced than that observed in this study. Another study by Smith *et al*.[26] found a reduction of 25 min/night in sleep duration around FM in healthy adults. However, a population-based study from Switzerland by Haba-Rubio *et al*.[24] found no significant influence of the lunar phase on human sleep. These varying results highlight the complexity of the relationship between LC and sleep patterns, and further research is required to draw definitive conclusions.

The significant differences in total sleep time and sleep efficiency observed in this study suggest that there may be underlying factors that influence sleep patterns in children with DS. While LC may play a role, the clinical significance of such differences is debatable. The lack of significant variations in the temperature measurements further complicates the interpretation. External factors, such as artificial lighting in modern societies, could mitigate the effects of moonlight on sleep. Additionally, the potential existence of a circadian clock in humans, similar to marine worms, could be a factor worth exploring in future studies. The variations in findings across different studies emphasize the need for more comprehensive research to understand the intricate relationship between LC and sleep patterns in humans, particularly in children with DS. Although this study provides valuable insights into the effects of LC on sleep in children with DS, the clinical relevance of the observed differences remains uncertain. Further research is needed to elucidate the potential mechanisms underlying these findings and determine whether they have any significant implications for public health.

Physical performance

The current study's findings on physical performance metrics in children with DS, such as the SJ test, sprint test, and 6MWT, showed no significant differences across the lunar phases. The influence of LC on physical performance remains relatively uncharted. Dergaa *et al*.[6] observed a decline in repeated sprint ability in the evenings following FM, attributing this to reduced sleep quality the previous night, akin to the effects of partial sleep deprivation. However, their study focused only on adults. The exercise physiology of the repeated sprint test used in the study by Dergaa *et al*.[6] was significantly different from the test used in our protocol. Additionally, the physiological process in children differs from adult to child, and in children with DS, this should be much more different.

Furthermore, children's physiological responses to exercise can vary significantly from those of adults owing to differences in metabolic rates, muscle mass, and hormonal levels. This distinction becomes even more pronounced when considering children with DS, who often exhibit unique physiological characteristics. For instance, children with DS often have reduced muscle tone, which can influence their performance on physical tests, and hormonal imbalances common in DS might further modulate their response to external factors, including LC.

Yousfi *et al*.[27] investigated the effects of lunar phases on short-term, explosive physical performance among young, trained athletes. The study identified that there was no significant effect of LC on all explosive test measures, suggesting that moon phase or illumination does not affect short-term physical performance in young, trained adolescents. This aligns with our findings, further emphasizing that LC may not have a pronounced effect on physical performance, even in children with DS.

The resting and end-of-walk HR measurements showed pronounced changes across the lunar phases. An elevated HR is indicative of increased cardiovascular stress or reduced cardiovascular efficiency. Hormonal interplay, particularly an increase in cortisol and testosterone levels, can have a profound effect on HR. Reference[11] reported an increase in cortisol levels during FM and a decrease in testosterone levels. Both cortisol and testosterone levels have been associated with cardiovascular responses, and their fluctuations can affect HR. For instance, cortisol, often referred to as the "stress hormone," can lead to HR, blood pressure, and blood glucose levels. However, testosterone, while primarily known for its role in male reproductive tissues, also has cardiovascular effects. Elevated testosterone levels can lead to increased HR and blood pressure.

In children with DS, the cardiovascular system might respond differently to hormonal fluctuations than in typically developing children. This population often has congenital heart defects, which might make the cardiovascular system more susceptible to external influences, including hormonal changes. Thus, the pronounced changes in HR observed in our study might be a combined result of the influence of LC on hormonal levels and the inherent cardiovascular characteristics of children with DS. However, it is essential to note that while our study provides valuable insights, further research is needed to understand the intricate relationship between LC, hormonal fluctuations, and cardiovascular responses, especially in populations with specific health conditions, such as DS.

Children with DS often exhibit cardiovascular abnormalities that can influence their HR response to physical activity. The pronounced changes in HR observed in this study, especially during the FM phase, might be indicative of an interaction between LC and the inherent cardiovascular challenges faced by children with DS. While the exact mechanisms underlying this interaction remain unclear, LC might exacerbate the cardiovascular stress experienced by these children during physical activity.

The lack of significant differences in physical performance metrics, despite the pronounced changes in HR, suggests that while LC might influence cardiovascular responses, it does not necessarily translate to noticeable changes in physical performance in children with DS. This is an important distinction because it highlights the resilience and adaptability of these children in the face of potential external stressors.

Cognitive performance

The cognitive performance of children with DS concerning LC remains a relatively unexplored area of research. In this study, a significant difference was observed in the RT across lunar phases, with the most pronounced difference being between the FM and the third quarter.

Children with DS often exhibit cognitive deficits that can manifest as delayed RTs, impaired precision, and challenges with tasks that require MR. The observed significant difference in RT in this study, especially during the FM phase, suggests that LC might have a modulating effect on the cognitive performance of these children. The exact mechanisms underlying this effect remain to be elucidated, but LC may interact with the inherent neurocognitive challenges faced by children with DS, leading to observable changes in specific cognitive domains.

While the lack of significant variations in precision and MR tests is noteworthy, it is possible that these specific cognitive domains are less susceptible to external influences, such as LC, or that the tests used in this study were not sensitive enough to detect subtle changes. The findings of the current study shed light on the potential influence of LC on cognitive performance in children with DS. The observed changes in RT, in particular, warrant further investigation to better understand their clinical implications and the potential underlying mechanisms.

Limitations and recommendation

Despite offering novel insights, this study has several limitations. The sample size of children with DS was relatively small, potentially limiting the generalizability of the findings. The absence of a control group of typically developing children restricts the comparative analysis. While the study controlled for certain environmental factors, other factors, such as ambient light exposure and daily routines, were not considered, which could influence the outcomes. Additionally, the study's focus on specific lunar phases may not capture the full effects over multiple cycles. Finally, given the reliance of children with DS on parental guidance, adherence to study protocols might have been influenced by parental precisions. These limitations should be considered when interpreting the results of this study.

Conclusion

This study offers valuable insights into the associations between LC and various physiological, physical, and cognitive parameters in children with DS. The significant variations observed in sleep patterns, HR, and RT during different lunar phases underscore the potential influence of LC on these children. Although the exact mechanisms remain to be fully understood, these findings have practical implications for caregivers, educators, and therapists working with children with DS. For instance, understanding these variations can aid in optimizing schedules, therapeutic interventions, and physical activities to align with the periods when these children might exhibit better sleep quality or cognitive responsiveness. Moreover, the observed HR variations can inform physical training programs, ensuring that exercises are tailored to the child's cardiovascular responses during specific lunar phases. By recognizing and adapting to these lunar-associated variations, we can potentially enhance the well-being and development of children with DS. Future research should explore these associations and their underlying mechanisms to provide more comprehensive guidelines for this population.

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Conflicts of interest

There are no conflicts of interest.

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