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PHYSICAL ACTIVITY AND SLEEP PATTERNS DURING THE COVID-19 PANDEMIC: INSIGHTS FROM A CLUSTER ANALYSIS

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Aktywność fizyczna a wzorce snu podczas pandemii COVID-19: wnioski z analizy klastrowej

Streszczenie

Celem badania była analiza związku między poziomem aktywności fizycznej a jakością snu wśród studentów podczas pandemii COVID-19, z identyfikacją wzorców za pomocą analizy skupień. W badaniu uczestniczyło 1600 studentów Uniwersytetu Medycznego we Wrocławiu, a dane zbierano w dwóch etapach: Etap I (n = 845) po sześciu miesiącach oraz Etap II (n = 755) po roku pandemii. Poziomy aktywności fizycznej, mierzone skróconą wersją Międzynarodowego Kwestionariusza Aktywności Fizycznej (IPAQ-S), sklasyfikowano jako niskie, umiarkowane lub wysokie w minutach MET na tydzień, a jakość snu oceniono za pomocą Pittsburgh Sleep Quality Index (PSQI), klasyfikując uczestników jako „dobrych” lub „złych” śpiących. Wyniki MET dla chodzenia wzrosły z 2020 na 2021 rok, przy czym u kobiet odnotowano wzrost całkowitego MET, a u mężczyzn stabilizację wyników. Hierarchiczne grupowanie aglomeracyjne (HAC) na danych z 2021 roku wyłoniło cztery skupienia. Skupienie 1 i 2, o wysokiej aktywności chodzenia i intensywnej lub umiarkowanej aktywności dodatkowej, miały krótszy czas snu, co sugeruje, że wyższa aktywność

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wspiera lepszą jakość snu. Skupienie o niskiej aktywności, charakteryzowało się dłuższym snem, a z kolei ostatnie skupienie, z nieregularną aktywnością, miało najdłuższy czas snu, co może wskazywać na wyższe zapotrzebowanie na sen przy nieregularnym ruchu. Podsumowując, regularna i zróżnicowana aktywność fizyczna może wspierać optymalne wzorce snu wśród studentów.

Słowa kluczowe: zdrowie studentów; intensywność ćwiczeń; długość snu; analiza klastrow; wpływ edukacji zdalnej.

Abstract

This study examined the relationship between physical activity levels and sleep quality among students during the COVID-19 pandemic, identifying patterns through clustering analysis. A longitudinal cohort of 1,600 students from Wrocław Medical University, Poland participated from October 2020 to March 2021, with data collected in two stages: Stage I (n = 845) after six months and Stage II (n = 755) after one year. Physical activity levels, measured by the International Physical Activity Questionnaire-Short Form (IPAQ-S), were categorized as low, moderate, or high in metabolic equivalent of task (MET) minutes per week, while sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), classifying participants as “good” or “poor” sleepers. Clustering analysis applied hierarchical agglomerative clustering (HAC) on 2021 data. Walking MET scores increased for both genders from 2020 to 2021, with significant gender differences. Females showed increased total MET, while male scores remained stable. Four clusters emerged: Clusters 1 and 2, with high walking plus vigorous or moderate activity, had shorter sleep durations, suggesting higher activity supports better sleep. Cluster 3, with low vigorous and moderate activity, had longer sleep duration, while Cluster 4, with irregular activity, showed the longest sleep duration, indicating inconsistent activity may increase sleep needs. Overall, consistent and varied physical activity may support optimal sleep patterns among students.

Keywords: student health; exercise intensity; sleep duration; cluster analysis; remote education impact.

Introduction

Nowadays, physical activity is an important component of a healthy lifestyle (Park, 2014; Lathia et al., 2017; Kilpatrick et al., 2005; World Health Organization [WHO], 2020). It is carried out at every stage of human life and, what is important, it can be practised in the place of residence or outside it. In the literature on the subject, it is repeatedly emphasized in scientific studies that physical activity affects the quality of sleep (Kilpatrick et al., 2005; WHO, 2020). Nowadays, care for health is an element of lifestyle, especially for young people. Alejziak (2011) indicated that the development of awareness in this regard at all levels of school education is an important aspect. It is the state of health that depends on the individual themselves, because the knowledge that it is a person's own actions, their style, can determine the quality of functioning, and also indicates that health should be properly taken care of. Human awareness related to health plays a key role. Many researchers (Alejziak, 2015; Hanna et al.,

2019; Demeter & Brătucu, 2014; Cini & Passafaro, 2019; Cini et al., 2015; Kose-niak, et al., 2023; Castañeda-Babarro, et al., 2020; Pinto, et al., 2020) notice that currently a young person functioning in the 21st century strives to make physical activity present in their life. In addition to physical activity, the quality of sleep also plays an important role in promoting health. Numerous studies conducted over the last decade confirm that sleep disorders affect the risk of many civilization diseases, including cardiovascular diseases, cancer, mental disorders and depression.

The amount and quality of sleep affect a person's health. Sleep is a physiological phenomenon, and its disturbances lead to the deterioration of a given individual's health. Studies confirm that academic requirements, use of electronic media, poor diet, lack of physical activity can lead to sleep quality disorders. That is why it is so important to build awareness of a healthy lifestyle by highlighting the role and importance of physical activity in human life. It is physical activity among university students that can be an excellent factor improving concentration, metabolism and the quality of their sleep.

Appropriate physical activity is an excellent way to maintain health, energy for action, and well-being. It is an important and yet still underestimated element of a healthy lifestyle. In the literature, many researchers indicate that lifestyle, including physical activity, proper nutrition, avoiding stimulants and psycho-emotional overload, undoubtedly has an impact on human health (Centers for Disease Control and Prevention [CDC], 2023; Tremblay et al., 2007; Castiglione-Fontanellaz et al., 2022; Stutz et al., 2019; Hallal et al., 2006). Nowadays, more and more research centers are involved in research on physical activity, which expands the range of methods used in these studies, thus indicating new directions of research (Lang et al., 2016). At the same time, many scientists emphasize the importance of sleep and its quality (Schred & Hoffman, 2003). This means that sleep undoubtedly affects the state of the human body. Moreover, analyzing the philosophical perspective, dreaming is associated with having subjective experiences, and sleep is a specific pattern of subjective experience (Revonsuo et al., 2016; Sikka et al., 2018). There are theories that emphasize the autonomous role of deeper brain structures and see dreams as an epiphenomenon of REM sleep (Givrad, 2016). In the literature on the subject, the phenomenon of sleep and dreaming was first studied in the 19th century by Calkins (1893), who presented his results and argued that some aspects of dream content could be quantified. In subsequent years, the phenomenon of dreaming and sleep was further studied so that the research results could be used by psychologists, psychiatrists, and other scientists.

The aim of the research presented in this article was to examine the relationship between physical activity and sleep quality among Polish students. The study focused on two key research questions: first, how physical activity influ-

ences students' sleep quality, and second, whether engaging in physical activity positively impacts their overall health.

Materials and Methods

Study design and participants

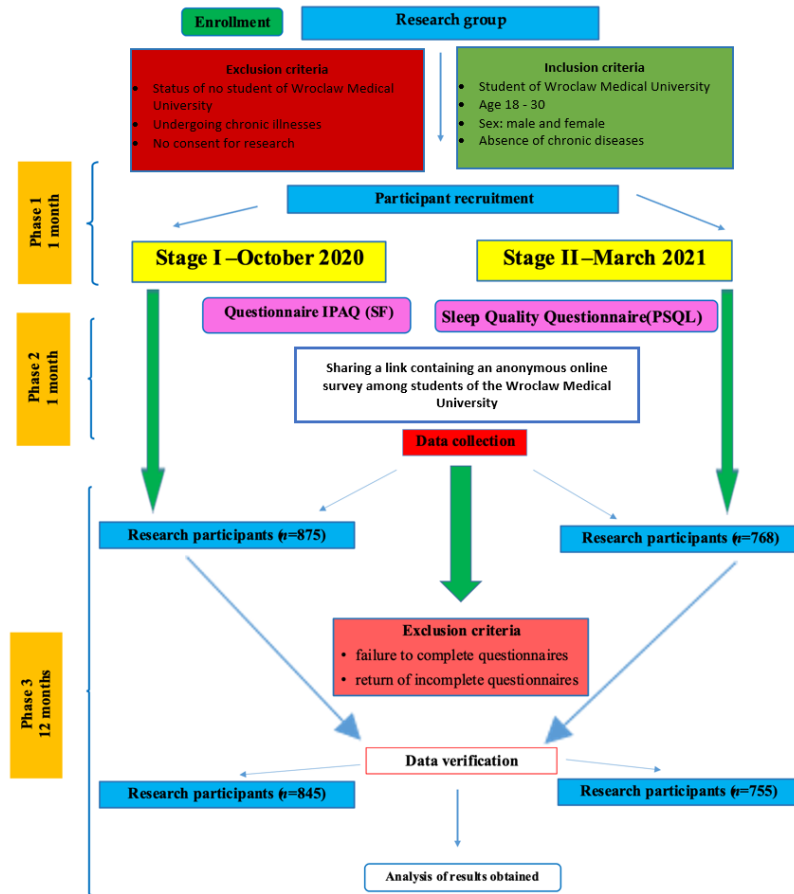


Figure 1

Overview of the research experiment design

Note: Adapted from Kosendiak et al. (2023). Physical activity and sleep quality among students of the Medical University of Wrocław. *Medycyna Ogólna i Nauki o Zdrowiu*, 29(4), 309–315; <https://doi.org/10.26444/monz/172587>.

This study was designed as a longitudinal cohort study and was conducted among a randomly selected group of students at Wrocław Medical University

between October 2020 and March 2021. A total of 1,600 adult students participated in the study, all of whom were enrolled in mandatory remote physical education classes during the 2020/2021 academic year. As presented in Figure 1, the study was divided into two stages:

- Stage I (n = 845): Conducted after six months of the COVID-19 pandemic (October 2020).
- Stage II (n = 755): Conducted after one year of the COVID-19 pandemic (March 2021).

The same cohort of students completed the survey questionnaire at both intervals (Stage I and Stage II). However, differences in sample size across the two stages resulted from some students not completing the questionnaire each time, with 89.3% of the initial group participating in Stage II. The student recruitment process remained consistent throughout the study period.

Outcome measures

An analysis of physical activity was conducted using the short version of the International Physical Activity Questionnaire (IPAQ-S), which monitors health risks and assesses physical activity levels. This version includes seven questions covering a one-week period, addressing moderate and vigorous intensity exercise, walking, and sitting. Data from the IPAQ-S allowed for the classification of the participants into three physical activity levels: inactive (low level), moderately active (medium level), and very active (high level), based on the classification system by López-Moreno et al. (2020). Physical activity levels were categorized into three groups—low (LPAL), moderate (MPAL), and high (HPAL)—following the IPAQ scoring guidelines and measured in metabolic equivalent of task (MET) minutes per week.

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a self-administered questionnaire developed by Daniel J. Buysse. The PSQI evaluates sleep quality and disturbances over the past month, comprising 19 items organized into seven subscales: (1) sleep quality (1 item), (2) sleep latency (2 items), (3) sleep duration (1 item), (4) sleep efficiency (3 items), (5) sleep disturbances (9 items), (6) use of sleep medications (1 item), and (7) daytime dysfunction (2 items). Each component is scored from 0 to 3, with the sum providing a global PSQI score ranging from 0 to 21. Respondents with a score greater than 5 are classified as “poor sleepers,” while those scoring 5 or less are classified as “good sleepers.” The original PSQI demonstrated an internal consistency of 0.83 (Wang & Boros, 2021).

Data analysis

The clustering analysis was conducted using R software (4.4.1). Hierarchical agglomerative clustering (HAC), a widely-used clustering algorithm in academic rese-

arch, was employed in this study. The objective of the clustering analysis was to group objects into clusters based on the similarity of selected variables. For this analysis, only records from the year 2021 were used, focusing on the following variables:

- X1: vigorous_days – Average number of days with vigorous activity
- X2: moderate_days – Average number of days with moderate activity
- X3: walking_days – Average number of days with walking activity

Prior to clustering, the variables were standardized to ensure comparability and prevent any one variable from disproportionately influencing the clustering outcome. Standardization was applied using the formula:

$$z_i = \frac{x_i - \bar{x}}{S_x}$$

where \bar{x} represents the mean of the variable within the sample, and S_x is the standard deviation of that variable within the sample. This transformation standardized each variable to a mean of zero and a standard deviation of one, enabling fair comparison across variables with different scales.

A key step in clustering analysis is determining the optimal number of clusters. To identify this, several indices (KL, CH, Hartigan, CCC, Scott, Marriot, TrCovW, TraceW, Friedman, Rubin, C, DB, Silhouette, Duda, PseudoT2, Beale, Ratkowsky, Ball, PtBiserial, Frey, McClain, Dunn, Hubert, SDindex, Dindex, and SDbw) were calculated for varying numbers of clusters. The optimal number of clusters was determined through a voting mechanism based on these indices (Mishra et al., 2022). The results of this clustering process are presented as a dendrogram (Figure 2) (Wang & Boros, 2021).

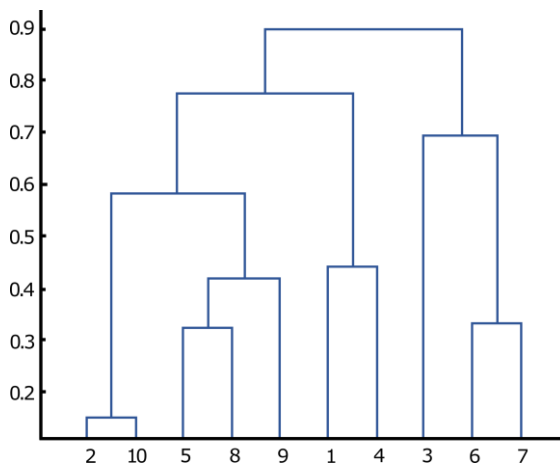


Figure 2

Example of a dendrogram for hierarchical agglomerative clustering

Note: Adapted from Gostkowski et al. (2021). Clustering Analysis of Energy Consumption in the Countries of the Visegrad Group. *Energies*, 14(18), 5612; <https://doi.org/10.3390/en14185612>.

Results

Participants Characteristics

Table 1 presents the relationship between gender and MET m/w scores for two time periods. MET m/w for walking increased for both females and males. The decrease for women was smaller compared to that for men. It is worth noting that the difference between genders was statistically significant in both 2020 and 2021. In summary, the total MET m/w for females increased between 2020 and 2021, while for males, it remained at the same level. Additionally, the subjective sleep quality index for females increased between 2020 and 2021, whereas for males, it slightly decreased.

Table 1
Comparison of mean physical activity levels between genders

Variables	2020 (n = 845)	2021 (n = 755)
<i>Walking MET, m/w</i>		
Female	868.36	1208.10
Male	971.25	1032.22
<i>p</i> -Value	<i>p</i> = 0.27	<i>p</i> = 0.12
<i>Moderate MET, m/w</i>		
Female	132.16	129.75
Male	147.69	162.71
<i>p</i> -Value	<i>p</i> = 0.25	<i>p</i> = 0.07
<i>Vigorous MET, m/w</i>		
Female	580.8	511.19
Male	799.39	797.74
<i>p</i> -Value	<i>p</i> = 0.004	<i>p</i> = 0.001
<i>Total MET, m/w</i>		
Female	1582.67	1849.05
Male	1918.35	1992.68
<i>p</i> -Value	<i>p</i> = 0.012	<i>p</i> = 0.351
<i>Sleep quality</i>		
Female	1.905	1.959
Male	1.962	1.957
<i>p</i> -Value	<i>p</i> = 0.29	<i>p</i> = 0.97

MET: metabolic equivalent of task; m/w: minutes per week.

The relationships between the study year and MET m/w scores are presented below. For MET m/w related to walking, an increase was observed in almost

every year. Similar to the details in the previous table, moderate physical activity levels in 2021 were comparable to those in 2020. Regarding MET m/w for vigorous physical activity, an increase was observed only in the third year; for the remaining years, either a constant level or a decrease was observed. Changes in the sleep quality index were variable: an increase was noted in the first, fourth, and fifth years, while a decrease was observed in the second and third years. Notably, the difference between years in 2021 was statistically significant.

Table 2

Comparison of mean physical activity levels across study years

Variables	2020 (n = 845)	2021 (n = 755)
<i>Walking MET, m/w1</i>		
First year	898.67	1024.93
Second year	904.64	1546.40
Third year	677.08	1081.23
Fourth year	1318.21	1153.09
Fifth year	814.50	1534.86
<i>p</i> -Value	<i>p</i> = 0.90	<i>p</i> = 0.002
<i>Moderate MET, m/w</i>		
First year	139.36	135.78
Second year	140.31	141.80
Third year	112.14	140.00
Fourth year	107.56	62.30
Fifth year	210.90	168.44
<i>p</i> -Value	<i>p</i> = 0.37	<i>p</i> = 0.88
<i>Vigorous MET, m/w</i>		
First year	583.88	538.67
Second year	706.60	588.35
Third year	645.23	1200.00
Fourth year	668.10	353.84
Fifth year	1112.72	752.00
<i>p</i> -Value	<i>p</i> = 0.08	<i>p</i> = 0.17
<i>Total MET, m/w</i>		
First year	1623.66	1699.39
Second year	1751.56	2276.55
Third year	1434.47	2421.23
Fourth year	2093.89	1569.25
Fifth year	2138.13	2455.31
<i>p</i> -Value	<i>p</i> = 0.32	<i>p</i> = 0.001

Table 2
 Comparison of mean physical activity levels across study years (cont.)

Variables	2020 (n = 845)	2021 (n = 755)
<i>Sleep quality</i>		
First year	1.902	2.004
Second year	1.976	1.885
Third year	1.933	1.785
Fourth year	1.888	2.080
Fifth year	1.600	1.700
<i>p</i> -Value	<i>p</i> = 0.59	<i>p</i> = 0.01

MET: metabolic equivalent of task; m/w: minutes per week.

Clustering Results

For the analyzed variables, the values of selected indices were calculated. Based on these index values, four clusters were identified as the optimal number of clusters. The results of the clustering analysis are presented below (Figure 3 and Figure 4). The largest cluster is Cluster Three.

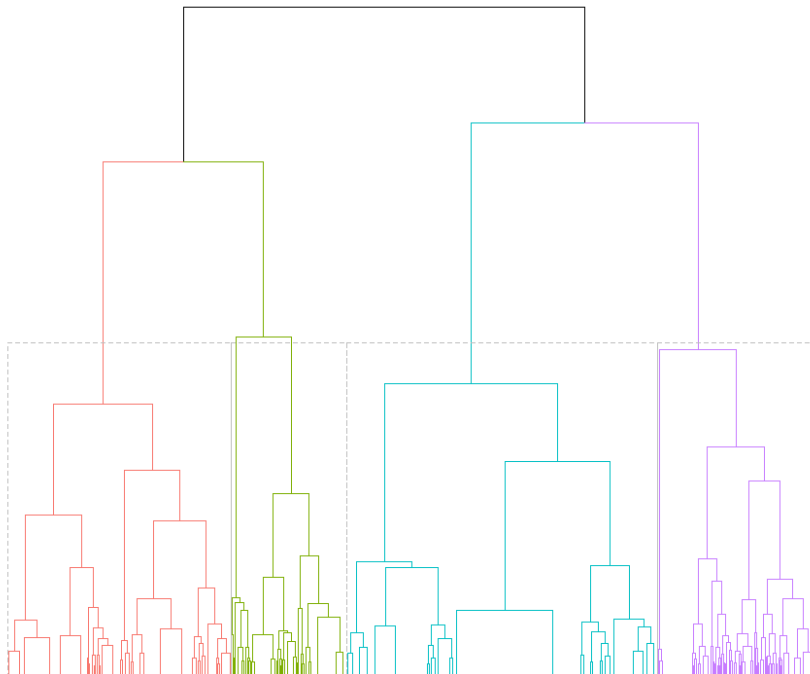


Figure 3
 The dendrogram of hierarchical clustering using Ward's method
 Source: own preparation.

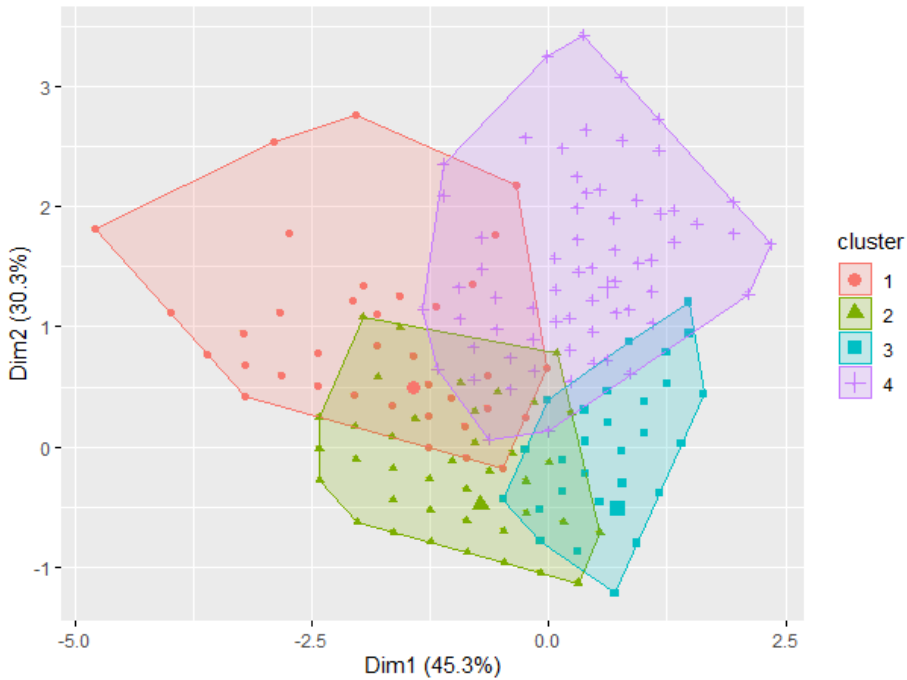


Figure 4

Results of hierarchical clustering after PCA, providing a visual representation of the clusters in relation to the principal components

Table 3

The mean values of analyzed variables for each cluster

Cluster	Sleep duration	Sleep quality	Vigorous days	Moderate days	Walking days	n
1	7.07	1.93	3.83	1.89	6.46	108
2	6.98	1.98	0.880	3.02	6.58	209
3	7.14	1.99	0.421	0.259	5.71	290
4	7.31	1.88	1.50	1.45	2.41	147
<i>p</i> -value	0.052	0.608	<0.001	<0.001	<0.001	

Based on the clustering analysis, the first and second clusters contain the students with the highest values for walking days compared to the other groups. The students in the second cluster show relatively high values for moderate days, while the students in the first cluster have relatively high values for vigorous days. At the same time, the students in the first and second clusters have the shortest sleep duration, which may indicate that engaging in physical activity (e.g., walking combined with gym or fitness exercises) enhances sleep quality, allowing these students to sleep for shorter durations compared to other groups.

The third cluster contains the students with the lowest values in vigorous and moderate days but moderate values in walking days. Compared to the first and second clusters, the students in the third cluster have longer sleep duration. This may suggest that physical activity limited to walking alone does not guarantee high sleep quality, leading these students to require more sleep than those in the first and second clusters.

The students in the last cluster have the lowest values for walking days and moderate values for vigorous and moderate days, suggesting that this cluster includes the students who engage in physical exercise but in a very irregular pattern. This irregularity results in the highest sleep duration in this group (CDC, 2023).

Discussion

The research conducted by the authors of this study confirms that physical activity affects sleep quality. The results suggest that regular and properly organized physical activity can optimize the quality and duration of sleep, potentially improving overall health and mental well-being. Encouraging consistent, regular physical activity can be a valuable strategy to improve sleep in various populations. Similar results were presented by Yint et al. (2022). According to them, for students of Chinese universities, too few hours of sleep and sleep quality have a significant impact on health. According to their research, students' lifestyle and factors related to mental health showed different patterns of relationships with sleep quality. In addition, it was indicated, among others, that aerobic exercise, mindfulness training, should be regularly carried out in groups. Also, the analyses presented by Rutkowska et al. (2022) confirmed that an adequate amount of sleep reduces nervous tension and reduces the occurrence of symptoms of depression. A similar position was presented in their studies (Castiglione-Fontanellaz et al., 2022; Stutz et al., 2019; Hallal et al., 2006; Lang et al., 2016; Ortega et al., 2011; Kalak et al., 2012), where it was noted that practicing any activity has a beneficial effect not only on the aspect related to health but also on sleep. Importantly, as the authors pointed out, practicing physical activity is an antidote to preventing lifestyle diseases such as cancer and diabetes.

Interesting research in the field of physical activity and sleep quality and the mental health of students was presented by Ghrouz et al. (2019). According to them, there is a strong connection between the level of physical activity and the quality of sleep and mental health. This means that a low level of physical activity, stress or anxiety negatively affects the quality of students' sleep and their mental health. In turn, Badicu (2018) indicated that physical activity among students is beneficial for the body if it is performed regularly and can affect the quality of sleep. In addition, as indicated in the study, there are significant sta-

tistical differences between the level of physical activity and the quality of sleep depending on the year of study, gender and academic specialization. Similar results were presented (Leger et al., 2012; Pelletier et al., 2014; Keating et al., 2005; Sepehr et al., 2016), where it was indicated that a poor diet and lack of physical activity among young people can lead to sleep disorders and poor quality of sleep. Another study looking at physical activity and sleep was conducted by Sepehr et al. (2016). According to them, sleep disorders mainly affect female students, because they are influenced by several factors, including stress, fear of exams, lack of acceptance.

Studies conducted by (Hirshkowitz et al., 2015; Kredlow, Capozzoli et al., 2015; Baum et al., 2014; Wunsch et al., 2017) show that people who regularly practice any sport sleep better and fall asleep faster. Presented results can be compared with the results of a study conducted among 1,326 students in Hubei Province, China during the COVID-19 pandemic (CDC, 2023). They confirm that physical activity plays a proactive role in sleep quality. The need to stay at home during the pandemic and the often associated lack of exercise contributed to a reduction in the quality of sleep.

This is confirmed in the study conducted by Badicu (2018), who showed that men and women in the first and second year of studies have a higher level of physical activity and then have better sleep quality compared to, for example, third or fourth year students. Another important study was presented by the team of Wunsch et al. (2017). According to them, an important factor is also stress, which affects both sleep and physical activity of students. This means that maintaining a high level of physical activity during periods of academic stress should be a goal for students as it also affects sleep quality.

At this point, it should be pointed out that with the increase in the intensity of human effort, the need for sleep increases. Therefore, e.g. so many athletes at the time of important competitions try to rest rationally and provide the body with the right amount of sleep. The main task of sleep is primarily rest related to the regeneration of vital forces, strengthening the immune system, as well as strengthening concentration and memory.

In the literature on the subject, the authors (Crowley et al., 2018; Ohayon et al., 2017) emphasize that the daily need for sleep is an individual feature and often changes with age, which means that the younger the person is, the greater the need for sleep.

The latest research shows that not all activities will affect the quality of sleep to the same extent (Hori et al., 2016; Hurdziel et al., 2017). Activities such as running, cycling, yoga or even gardening perform better than others (Hori et al., 2016). Studies also show that physical activity may not have an immediate impact on sleep quality. This means that only after the appropriate time has elapsed, there will be a change in terms of better quality and volume of sleep,

provided that the activity is practiced for a certain period of time. In turn, (Hurdiel et al., 2017; Kashefi et al., 2014) indicated that moderate exercise performed by humans showed a more promising effect on sleep quality than intense exercise.

Research by Mahfouz et al. (2020) indicated that the majority of Jazan University students had poor sleep quality and were physically inactive. This means that students struggled with many disorders, including concentration. Therefore, the authors of the study emphasized that an important aspect is the promotion of physical activity among students, as well as building awareness and prevention strategies in the field of good health.

Despite the growing demand for active leisure time, the COVID-19 pandemic that broke out in 2020 caused numerous and often negative changes in the physical activity of students. During the pandemic, many young people had more free time than before, but this did not translate into increased physical activity, as it was mainly due to the restrictions imposed by a given state on citizens (Halabchi et al., 2020; Jiménez-Pavón et al., 2020; Hull et al., 2020; Jakobsson et al., 2020; Jukic et al., 2020; Ferreira et al., 2020). The coronavirus pandemic has led to a change in current habits. Social isolation, closing swimming pools, fitness clubs, university gyms were intended to prevent the spread of the COVID-19 virus, but at the same time it affected physical activity and sleep.

However, the COVID-19 pandemic also produced other results (Chen et al., 2020; Roman et al., 2023; Roman et al., 2022; Alencastro et al., 2023; Narici et al., 2020). Students willingly chose physical activity in the open air while maintaining social distance. On the other hand, it has been noted that the Covid-19 pandemic has also had an impact on sleep quality. Many people locked up due to social isolation were unable to cope with such a situation and, unfortunately, this was reflected in the deterioration of the quality and quantity of sleep. This resulted mainly from the lack of motivation to engage in physical activity and thus led to a significant deterioration of physical condition (Hall et al., 2020; Hammami et al., 2020; Tremblay et al., 2007; Youngstedt, 2005; Stutz et al., 2018).

Conclusions

Physical activity is undoubtedly an important component of the life of a modern man (Füzéki et al., 2020; Lesser & Nienhuis 2020; Song et al., 2022; Yin et al., 2022; Rutkowska et al., 2022). Health-promoting behaviors undertaken by human beings are conscious actions. Regular practice of any activity develops not only physical condition but also intellectual self-awareness and affects the quality and duration of sleep. As presented in this article, people [especially young people] need movement, activity, because it is their natural ally

in the fight against lifestyle diseases and an excellent antidote to stress. Despite the growing demand for movement and active leisure time, the COVID-19 pandemic has caused many changes.

Physical activity, especially vigorous and moderate activities, appears to influence sleep duration and quality. The students from the first and second clusters with higher physical activity levels tend to have shorter sleep but of adequate quality. Moreover, the students from the third cluster, with minimal vigorous and moderate activity but higher walking days, require longer sleep, possibly to compensate for the lower intensity of physical activity. The students from the last cluster with irregular activity patterns might necessitate the longest sleep duration for sufficient rest. Described findings imply that regular and structured physical activity can optimize sleep quality and duration, potentially improving overall health and well-being. Encouraging consistent physical activity routines could be a valuable strategy for enhancing good sleep patterns among different populations.

STATEMENT OF ETHICS

This study was conducted in accordance with the World Medical Association Declaration of Helsinki. The study protocol was reviewed and approved by the Bioethics Committee at the Medical University of Wrocław, Poland (No. KB-251/2020; date: 10.05.2020). All participants provided written informed consent to participate in this study. The online questionnaire included information that the participation in the study is voluntary and that by completing it a given participant given informed consent to participate in the study.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interests with respect to the research, authorship, and/or publication of the article *Physical Activity and Sleep Patterns During the COVID-19 Pandemic: Insights from a Cluster Analysis*.

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