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ABSTRACT

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CARDIORESPIRATORY MONITORING OF CHILDREN AND ADOLESCENTS WITH METABOLIC SYNDROME AGED 10-17 YEARS: A CROSS-SECTIONAL DESCRIPTIVE STUDY

Study objectives. This study aims to investigate potential differences in sleep parameters between children with metabolic syndrome (MetS) and their healthy counterparts using the portable cardiorespiratory monitoring device SOMNOcheck micro CARDIO.

Methods. The study included 71 children and adolescents aged 10 to 17 years, with 39 in the MetS group and 32 in the control group. The main anthropometric parameters were: neck circumference (NC), waist circumference (WC) and waist-to-height ratio (WHtR). All children were assessed using the Friedman tongue position (FTP) scale. Children completed the Epworth Sleepiness Scale for Children and Adolescents (ESS-CHAD) and the Montreal Cognitive Assessment (MoCA). Salivary cortisol was collected in the morning immediately after waking up. The sleep study was performed using a portable SOMNOcheck micro CARDIO device with a special cardiac sensor. Statistical analysis of the data was performed using EZR version 1.61.

Results. Significant differences in cardiorespiratory sleep monitoring were observed between between the MetS and non-MetS groups. Patients with MetS had higher daytime sleepiness scores and lower MoCA scores compared to the control group. Cortisol levels in morning saliva showed a marked increase among children with obstructive apnea/hypopnea index ≥ 1. A logistic regression model established a link between FTP stages III and IV and the autonomous arousal index.

Conclusions. These findings highlight the differences ($p < 0.05$) in sleep-related parameters between the MetS and non-MetS

groups, which may indicate an increased risk of sleep-disordered breathing and cognitive impairment in such children.

Keywords: metabolic syndrome, sleep apnea, obstructive, sleep deprivation, cognitive dysfunction, disorders of excessive somnolence.

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РЕЗЮМЕ

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КАРДІОРЕСПІРАТОРНЕ МОНІТОРУВАННЯ ДІТЕЙ ТА ПІДЛІТКІВ З МЕТАБОЛІЧНИМ СИНДРОМОМ ВІКОМ ВІД 10 ДО 17 РОКІВ: ПЕРЕХРЕСНЕ ОПИСОВЕ ДОСЛІДЖЕННЯ

Мета дослідження: вивчити потенційні відмінності в параметрах сну між дітьми з метаболічним синдромом (МС) та їхніми здоровими однолітками за допомогою портативного приладу кардіореспіраторного моніторингу SOMNOcheck micro CARDIO.

Матеріали і методи. У дослідження включено 71 дитину віком від 10 до 17 років, з них 39 дітей з МС та 32 дитини контрольної групи. Основними антропометричними параметрами були: окружність шиї (ОШ), окружність талії (ОТ) та співвідношення окружність талії-до-зросту (WHtR). Всіх дітей оцінювали за шкалою положення язика за Фрідманом (FTP). Діти заповнювали шкалу сонливості Епворта для дітей та підлітків (ESS-CHAD) та Монреальську когнітивну оцінку (MoCA). Кортизол слини збирали вранці відразу після пробудження. Дослідження сну проводили за допомогою портативного приладу SOMNOcheck micro CARDIO зі спеціальним кардіосенсором. Статистичний аналіз даних проводили за допомогою програми EZR версії 1.61.

Результати. Виявлено значні відмінності в кардіореспіраторному моніторуванні сну між групами пацієнтів з МС та без МС. Окрім того, пацієнти з МС мали вищі показники денної сонливості та нижчі показники MoCA порівняно з контрольною групою. Рівень кортизолу в ранковій слині був помітно підвищений у дітей з індексом обструктивного апное/гіпопное ≥ 1. Логістична модель регресії встановила зв'язок між FTP III та IV стадій та індексом автономного збудження (AAI).

Висновки. Отримані дані свідчать про відмінності ($p < 0,05$) в параметрах, пов'язаних зі сном, між групами з МС і без МС, що може вказувати на збільшений ризик порушення дихання уві сні та когнітивних проблем у цих дітей.

Ключові слова: метаболічний синдром, апное сну обструктивне, депривація сну, когнітивна дисфункція, розлади надмірної сонливості.

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ABBREVIATIONS

AAI	autonomous arousal index
AAI resp	arousal index with respiratory events
AAI non resp	arousal index without respiratory events
AI	apnea index
AHI	apnea-hypopnea index
BMI	body mass index
cRDI	central respiratory disturbance index
ESS-CHAD	Epworth Sleepiness Scale for Children and Adolescents
FTP	Friedman tongue position
HI	hypopnea index
IQR	interquartile range
MetS	metabolic syndrome
MoCA	Montreal Cognitive Assessment
NC	neck circumference
oRDI	obstructive respiratory disturbance index
OSA	obstructive sleep apnea
RCRD	Reduced chronotropic reaction to desaturation
RDI	respiratory disturbance index
RERA	respiratory effort-related arousal
SpO2	the proportion of hemoglobin that is saturated with oxygen (oxygenated hemoglobin) in peripheral arterial blood determined by pulse oximetry
TRT	total recording time
WC	waist circumference
WHtR	waist to height ratio

INTRODUCTION / ВСТУП

Metabolic syndrome (MetS) is a cluster of metabolic abnormalities that significantly increases the risk of cardiovascular disease and type 2 diabetes [1]. While sleep disturbances have been observed in adults with MetS, there is limited research on their occurrence in children and adolescents [2].Obesity contributes to sleep apnea by causing intermittent hypoxia and fragmented sleep [3]. The repeated micro-arousals refer to the disruption of normal sleep architecture, resulting in poor sleep quality, contributing to excessive daytime sleepiness and may lead to neurocognitive and behavioural problems [4]. The Autonomous Arousal Index (AAI) is a sleep-related index that reflects the frequency of awakenings or arousals during sleep. It provides valuable information about sleep fragmentation and sleep quality [5]. Further research and clinical guidelines specific to paediatric populations are needed to establish normative values for the AAI and its clinical significance in children with MetS.

Some studies suggest that sleep deprivation and chronic stress may lead to hyperactivation of the hypothalamic-pituitary-adrenal (HPA) axis with increased cortisol levels. Conversely, sleep disturbances and metabolic changes are observed in conditions of hypercortisolism [6].

Polysomnography is the gold standard for diagnosis [7], but home monitoring offers accessibility and a convenient screening option [8, 9]. Using overnight cardiorespiratory monitoring, we will analyse sleep-related indices and compare them between the experimental group (MetS group) and the control group (non-MetS group). This research will provide valuable insights into sleep abnormalities associated with MetS in children and contribute to existing knowledge in this area.

Materials and Methods

A total of 71 children aged 10 to 17 years were examined in Kyiv, Ukraine. The study group comprised 39 children with metabolic syndrome (MetS) who were admitted to the cardiology department of the Children's Clinical Hospital No. 6 in Kyiv. The control group (non-MetS) included 32 children without metabolic syndrome, obesity or related genetic disorders.

The sample size was calculated using G*Power 3.1.9.7 software [10]. Calculations were performed using an odds ratio = 4 with a 1σ change, a critical significance level of 0.05, and a power of 0.8 to measure the association between two categorical variables in case-control studies. The diagnosis of MetS was made according to the International Diabetes Federation (IDF) 2007 criteria, which include the following criteria: waist circumference (WC) ≥ 90th percentile and at least two of the following criteria: triglycerides (TG) ≥ 1.24 mmol/L, High-Density Lipoprotein Cholesterol (HDL-C) <

1.03 mmol/L, systolic blood pressure (BP) ≥ 130 mmHg or diastolic BP ≥ 85 mmHg, fasting plasma glucose (FG) ≥ 5.5 mmol/L [11].

The neck circumference (NC) of all children was measured by the physician in both the standing and supine positions, without the use of a pillow, on a flat surface. WC was measured in the standing position using a standardised method recommended by the World Health Organization (WHO) protocol and was determined using growth charts developed for British children [12]. Body mass index (BMI) was calculated using the formula: body weight (kg) divided by height (m^2). circumference (NC) was measured in both the supine and standing positions. In our study, we used the Friedman Tongue Position (FTP) classification for children as the primary assessment of obstructive sleep apnea in children [13]. According to this classification, the following stages were identified FTP I: At this stage the observer could see the entire uvula, tonsils and tonsillar pillars. FTP II: Only partial visualisation of the uvula, tonsils and pillars was possible. FTP III: The observer could visualise most of the soft palate. FTP IV: Only the hard palate was visible to the observer. The Epworth Sleepiness Scale for Children and Adolescents (ESS-CHAD) [14] is used to assess daytime sleepiness in children and consists of simple questions about the likelihood of falling asleep in eight different scenarios. Each scenario is rated on a scale of 0 to 3, where 0 is "would never doze off" and 3 is "high chance of dozing off" [14]. The Montreal Cognitive Assessment (MoCA) was used to assess the children's cognitive function, and a score of 26 or above is considered to be within the normal range [15]. Laboratory tests (glucose, insulin, lipid profile, cortisol) were performed using the Roche Diagnostics Cobas 6000 analyser and testing system. Saliva for cortisol testing was collected by swabbing the mouth immediately upon awakening. Ambulatory blood pressure monitoring was performed with an ABM-04 device (Meditech, Hungary).

The sleep study was performed using the SOMNOcheck micro CARDIO device (WM94570), which was attached to the patient's forearm with a wrist strap. A special pulse oximetry sensor was placed on the patient's finger. Airflow and snoring were recorded using a nasal cannula. The SOMNOcheck micro CARDIO device has a high level of agreement with polysomnography and shows consistent results when compared to the gold standard sleep study method [16]. The SOMNOcheck micro CARDIO device has a special cardiac sensor (WM94585) that allows it to perform additional functions related to cardiorespiratory monitoring. It can detect the Cardiac Risk Index (CRI) with sub-parameters, arrhythmia (atrial fibrillation) and Cheyne-Stokes respiration. The interpretation of the results was presented in the form of a report with all parameters and a CARDIO mesh diagram, using the SOMNOlab 2.19 software for Windows 10. The cardiorespiratory study included the following parameters: Cardiac Risk Index (CRI), Respiratory Disturbance Index (RDI), Obstructive Respiratory Disturbance Index (oRDI), Central Respiratory Disturbance Index (cRDI), Apnea Index (AI), Hypopnea Index (HI), Apnea/Hypopnea Index (AHI), Obstructive Apnea/Hypopnea Index (oAHI), Central Apnea/Hypopnea Index (cAHI), Snoring, Flattening, Longest apnea, Mean apnea duration, Oxygen Desaturation Index (ODI), Lowest saturation, Mean saturation, time SpO2 < 95%, time SpO2 < 90%, time SpO2 < 85%, Hypoxaemia duration (SpO2 <90% for more than 5 minutes), Lowest pulse rate, Mean pulse rate, Highest pulse rate, Autonomous Arousal Index (AAI), Respiratory Effort-Related Arousal (RERA), Arousal Index with Respiratory Events (AAI resp), Arousal Index without Respiratory Events (AAI non resp), Irregular pulse, Reduced chronotropic reaction to desaturation (RCRD), Low pulse rate variability, Low pulse wave variability, Short pulse wave propagation time, Periodic symmetrical desaturations, Frequent desaturations, Low baseline saturation.

Statistical analysis of the data was performed using EZR version 1.61 (11 November 2022). Data were tested for normality of distribution using the Shapiro-Wilk test with a significance level of 0.01. For samples with a normal distribution, the mean, standard error of the mean (SEM), minimum (Min) and maximum (Max) were calculated. For samples that did not follow a normal distribution, the median (Me), median error (m) and interquartile range (IQR) were calculated instead. The 95% confidence interval (95% CI) was calculated using a significance level of 0.05 (5%).

The study was conducted in accordance with the tenets of the Declaration of Helsinki. The research protocol was approved by the Commission on Bioethical Expertise and Ethics of Scientific Research at the Bogomolets National Medical University (Protocol No. 127 of 2 December 2019). Informed consent for the study was obtained from the parents of the children.

Results. 71 children aged 10–17 years were studied. The median age in the MetS group was 14 years [IQR 13–16] and was not significantly different (p=0.117) from the median age in the control group – 12.5 years [IQR 11–15]. There were more males in the study group than in the control group – 66.7% (n=26) and 33.3% (n=13) respectively. In both groups, the medians of anthropometric parameters (weight, height, BMI, WC, WHtR, NC) were significantly different (p≤0.001), Tab. 1. The median standing NC in the MetS group was 41 [IQR 39–44] and the median supine NC was 42 [IQR 39.5–45]. The difference in median neck circumference between standing and lying was not statistically significant (p=0.523), as confirmed by the Wilcoxon t-test. 46.2% (n=18) of the children in the study group had a Friedman III–IV degree tongue position. The median FTP in the MetS group was significantly higher than the median FTP in the control group with p=0.002 (Table 1). According to the ESS-CHAD scale, 41% of the children (n=16) with MetS had mild deviations from the norm (score 4–8) and 8% (n=3) had moderate daytime sleepiness (score 9–12). The median daytime sleepiness score was significantly higher in the MetS group (p=0.005). When assessing cognitive function in children with MetS, 66.7% of children (n=26) failed the MoCA test. The median MoCA score was significantly higher in the control group (p=0.012), Table 1.

Table 1 – Demographic characteristics and test results in children of two groups (MetS and non-MetS)

Values	MetS group (n=39)	Non-MetS group (n=32)	p-value
Age range (y)	14 ± 0.38[IQR 13 – 16]	12.5 ± 0.92 [IQR 11 – 15]	p=0.117
Weight (kg)	94 ± 4.66 [IQR 85 – 107]	46.5 ± 5.51 [IQR 39 – 55]	p<0.001
Height (cm)	177 ± 2.32 [IQR 163 – 181.5]	156.5 ± 4.42 [IQR 153 – 164]	p=0.001
BMI (kg/m^2)	30.27 ± 1.23 [IQR 27.69 – 32.38]	18.16 ± 1.25 [IQR 16.66 – 21.56]	p<0.001
WC (cm)	96.5 ± 2.38 [IQR 92 – 102]	63.5 ± 3.08 [IQR 60 – 65]	p<0.001
WHtR	0.54 ± 0.014 [IQR 0.52 –0.59]	0.41 ± 0.014 [IQR 0.38 –0.43]	p<0.001
NC in standing position (cm)	41 ± 0.84 [IQR 39 – 44]	30.5 ± 0.97 [IQR 30 – 33]	p<0.001
FTP I-IV	2.5 ± 0.27 [IQR 2 – 3.5]	1 ± 0.18 [IQR 1 – 1]	p=0.002
ESS-CHAD (score)	3.5 ± 0.75 [IQR 1 – 5.5]	1 ± 0.29 [IQR 0 – 1]	p=0.005
MoCA (score)	24 ± 0.93 [IQR 21.5 – 26]	26 ± 0.25 [IQR 26 – 26]	p=0.012

**Values are presented as Me ± m [Q1– Q3]. BMI = body mass index, WC = waist circumference, WHtR = waist to height ratio, NC = neck circumference, FTP = Friedman tongue position, ESS-CHAD = Epworth Sleepiness Scale for Children and Adolescents, MoCA = Montreal Cognitive Assessment*

The results of the overnight cardiorespiratory monitoring sleep study showed that the mean AI was significantly higher in the MetS group (0.95 ± 0.11) compared to the non-MetS group (0.33 ± 0.16), with a p-value of 0.006. Similarly, the mean HI was significantly increased in the research group (1.63 ± 0.18) compared to the control group (0.37 ± 0.18), with a p-value of <0.001. The mean AHI was significantly higher in MetS patients (2.44 ± 0.22) than in non-MetS individuals (0.65 ± 0.31), with a p-value of <0.001. A similar trend was observed for obstructive events (oAHI), which were significantly more frequent in the study group (0.80 ± 0.12) than in the control group (0.25 ± 0.12), with a p-value of 0.002. In addition, central events (cAHI) were also significantly more frequent in the MetS group (1.34 ± 0.15) than in the non-MetS group (0.31 ± 0.1), with a p-value of <0.001.

Although no statistically significant difference in AAI was found between the two groups (p=0.342), the

mean AAI respiratory was significantly higher in the MetS group (2.64 ± 0.50) compared to the non-MetS group (1.09 ± 0.09), with a p-value of 0.004. In addition, the RERA index, which is responsible for sleep arousals not meeting the criteria for apnea or hypopnea, was significantly higher in the MetS group (1.29 ± 0.41) compared to the non-MetS group (0.18 ± 0.05) (Table 2).

Table 2 – Results of cardiorespiratory sleep monitoring in the study group (MetS) and the control group (non-MetS)

	MetS group (n=39)		**non-MetS group (n=32)**		
Variables	**Mean ± SEM**	**Min÷Max**	**Mean ± SEM**	**Min÷Max**	**p-value**
TRT (hours)	9.91 ± 0.18	8 – 12	9.86 ± 0.49	6.5 – 12	p=0.930
AI (events/hour)	0.95 ± 0.11	0 – 2.4	0.33 ± 0.16	0 – 1.6	p=0.006
HI (events/hour)	1.63 ± 0.18	0.3 – 5.2	0.37 ± 0.18	0 – 1.8	p<0.001
AHI (events/hour)	2.44 ± 0.22	0 – 5.7	0.65 ± 0.31	0 – 2.5	p<0.001
oAHI (events/hour)	0.80 ± 0.12	0 – 2.6	0.25 ± 0.12	0 – 0.9	p=0.002
cAHI (events/hour)	1.34 ± 0.15	0.2 – 4.9	0.31 ± 0.14	0 – 1.3	p<0.001
RDI (events/hour)	3.17 ± 0.55	2.1 – 3.9	2.1 ± 0.32	0.5 – 3.1	p=0.115
oRDI (events/hour)	1.87 ± 0.56	1.3 – 3	0.83 ± 0.12	0.3 – 1.4	p=0.215
cRDI (events/hour)	0.63 ± 0.18	0.3 – 0.9	0.64 ± 0.09	0.1 – 0.8	p=0.961
AAI (events/hour)	32.25 ± 2.10	0.6 – 60.5	28.3 ± 2.45	15.1 – 40.7	p=0.342
AAI resp (events/hour)	2.64 ± 0.50	0 – 15.8	1.09 ± 0.09	0.6 – 1.6	p=0.004
AAI non resp (events/hour)	29.59 ± 1.94	0 – 54.7	27.17 ± 2.38	14.4 – 39.1	p=0.525
RERA (events/hour)	1.29 ± 0.41	0 – 11.5	0.18 ± 0.05	0 – 0.6	p=0.010
	Me ± m	**95% CI (Q1 – Q3)**	**Me ± m**	**95% CI (Q1 – Q3)**	**p-value**
Flattening (%)	0.5 ± 0.82	0 – 2	0 ± 0.13	0 – 0	p=0.021
Longest apnea (seconds)	14 ± 2.18	12 – 19	0 ± 3.62	0 – 12	p=0.006
Mean apnea duration (seconds)	12 ± 0.96	11 – 13	0 ± 2.25	0 – 12	p=0.009
ODI (events/hour)	0.6 ± 0.51	0.3 – 2.2	0.5 ± 0.23	0 – 1	p=0.086
Lowest saturation (%)	85 ± 1.03	81 – 91	88 ± 2.9	76 – 90	p=0.796
Mean saturation (%)	97 ± 0.29	96 – 97	98 ± 0.25	97 – 98	p=0.012
Mean pulse rate (beats/min)	67 ± 1.58	61 – 75	68 ± 4.13	61 – 72	p=0.760
Highest pulse rate (beats/min)	109 ± 1.97	102 – 114	103 ± 2.07	101 – 105	p=0.049
Lowest pulse rate (beats/min)	41 ± 1.04	37 – 44	42 ± 1.57	40 – 45	p=0.284

**The two-samples t-test was used to compare the means of two independent samples. The W-test Wilcoxon was used to compare the medians of two independent sample. TRT = total recording time, AI = apnea Index, HI = hypopnea Index, AHI = apnea/hypopnea index, oAHI = obstructive apnea/hypopnea index, cAHI = central apnea/hypopnea index, RDI = respiratory disturbance index, oRDI = obstructive respiratory disturbance index, cRDI = central respiratory disturbance index, AAI = autonomous arousal index, AAI resp = arousal index with respiratory events, AAI non resp = arousal index without respiratory, RERA = respiratory effort-related arousal*

In the MetS group, 23.1% of children (n=9) were found to have nocturnal snoring, whereas cardiorespiratory monitoring did not detect snoring in any of the children in the control group.

The median value of flattening was significantly higher in the MetS group than in the non-MetS group (p=0.021). The longest apnea duration for a patient in the study group was 52 seconds, compared to 24 seconds in the control group. Overall, the median

longest apnea was significantly higher in the research group (p=0.006). The mean apnea duration was also higher in the research group (p=0.009). The median minimum saturation was not different between the two groups (p=0.796), but the median mean saturation was lower in the research group (p=0.012).

The maximum time that SpO2 was less than 95% was 79 seconds in the study group compared to 1 second in the control group. The duration of time that SpO2 was below 90% was 66 seconds in the study group, while there were no such events in the control group. For SpO2 values below 85%, it was 1 second in the study group and none were observed in the control group. The duration of hypoxaemia (SpO2 < 90% for more than 5 minutes) was observed only in the MetS group, with a maximum duration of 42 minutes and 52 seconds over the entire sleep period. The median peak pulse rate in the MetS group was 109 ± 1.97, which was significantly higher than in the non-MetS group with a median of 103 ± 2.07 (p=0.049).

Morning salivary cortisol levels in the study groups with oAHI < 1 and oAHI ≥ 1 were compared using the Wilcoxon W test. The median salivary cortisol in oAHI ≥ 1 was 0.62 [IQR 0.52–0.73] and was significantly higher than the median salivary cortisol in oAHI < 1 of 0.32 [IQR 0.21–0.44], p=0.015.

Using the logistic regression model, a correlation was found between the Autonomous Arousal Index (AAI) and FTP stages III and IV in the study group (Figure 2). The area under the curve (AUC) was 0.762 (95% CI: 0.575–0.949) with a p-value of less than 0.05, indicating that the model construction was adequate (Table 3).

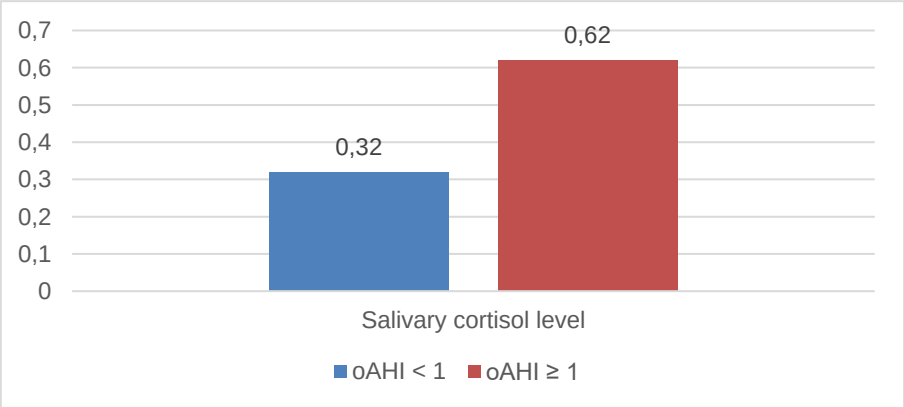

Figure 1 – Comparison of central tendencies of morning salivary cortisol levels for two independent groups oAHI < 1 and oAHI ≥ 1

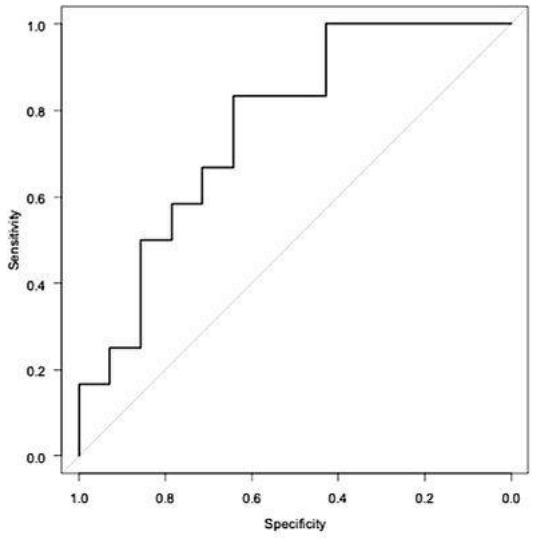

Figure 2 – ROC curve analysis for AAI in predicting sleep fragmentation based on Friedman tongue position

Table 3 – Logistic regression results for the correlation between Autonomous Arousal Index (AAI) and FTP stages III and IV

Predictor	**Odds Ratio**	**Lower 95% CI**	**Upper 95% CI**	**p-value**
(Intercept)	0.043	0.00235	0.784	0.0337
AAI	1.090	1.01000	1.180	0.0325
Coefficients:				
	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	-3.14765	1.48200	-2.124	0.0337 *
AAI	0.08788	0.04110	2.138	0.0325 *

Upon conducting the correlation analysis, it was found a positive correlation between the measurements NC in a standing position and the values AAI resp (r=0.508, p=0.00114), Figure 3.

The SOMNOcheck micro CARDIO report also includes information about the Cardiac Risk Index (CRI), which has values between 0 and 1. The risk model for the patient is presented in the form of a radar chart, with the outer area of the radar chart indicating high risk and the inner area indicating low risk. The radar includes the following indicators Irregular Pulse, Reduced Chronotropic Response to Desaturation (RCRD), Low Pulse Rate Variability, Low Pulse Wave Variability, Short Pulse Wave Propagation Time, Periodic Symmetric Desaturations, Frequent Desaturations and Low Baseline Saturation.

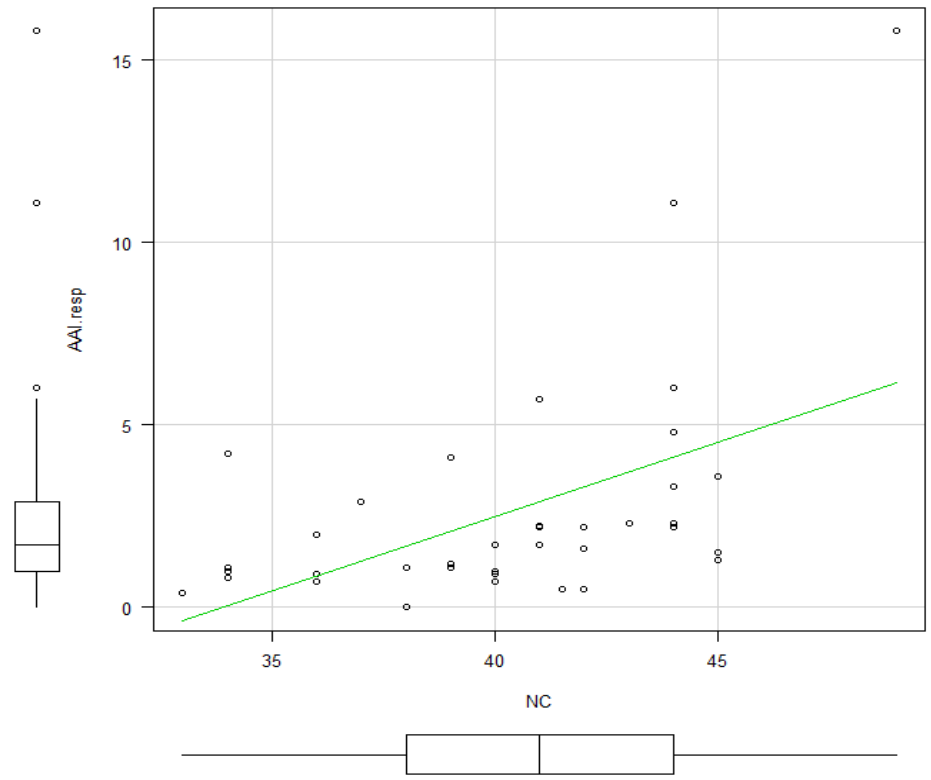

Figure 3 – Correlation field in coordinates: NC (X axis) and AAI resp (Y axis).

**Spearman's rank correlation coefficient 0.508 p.value = 0.00114*

Clinical case: A 12-year-old boy is admitted to the cardiology department with complaints of high blood pressure, headache, shortness of breath at rest and occasional nausea. The sleep questionnaire shows that sleep is calm and even, but the parents note sleepwalking. Elevated blood pressure has been observed for 2 years, but the patient has not sought medical attention or treatment. ESS-CHAD = 4 points. MoCA test = 23 points. Mother is obese and has hypertension. The father is obese. Objective: purple stretch marks on the skin of the abdomen and thighs, Subcutaneous fat thickness – 4 cm. WC – 94 cm. WHtR = 0.58. BMI = 31.24. NC in standing position= 39 cm. NC in supine position= 40 cm. The report of 24-hour ambulatory blood pressure monitoring showed average BP 161/78 mm Hg, daytime BP 164/82 mm Hg, nighttime BP 150/69. Since the pressure at night decreased by about 8.54% compared to the pressure during the day (the norm is at least 10%), the patient was assessed as a non-dipper in terms of systolic blood pressure.

Cardiorespiratory monitoring using the SOMNOcheck micro CARDIO device was recommended for the patient. Key findings from the monitoring: AHI – 1.2, oAHI – 0.1, cAHI – 1.1, AI – 0.2, HI – 1.0, AAI – 55.9, AAI resp – 1.2, AAI non resp – 54.7, lowest saturation – 80%, mean saturation – 97% , CRI – 0,45.

An individual cardiovascular risk pattern diagram was constructed for the patient (Figure 4).

The patient was found to have reduced saturation, a high sleep fragmentation index, low pulse rate variability and low pulse wave variability, which may indicate autonomic neuropathy and a nocturnal increase in blood pressure.

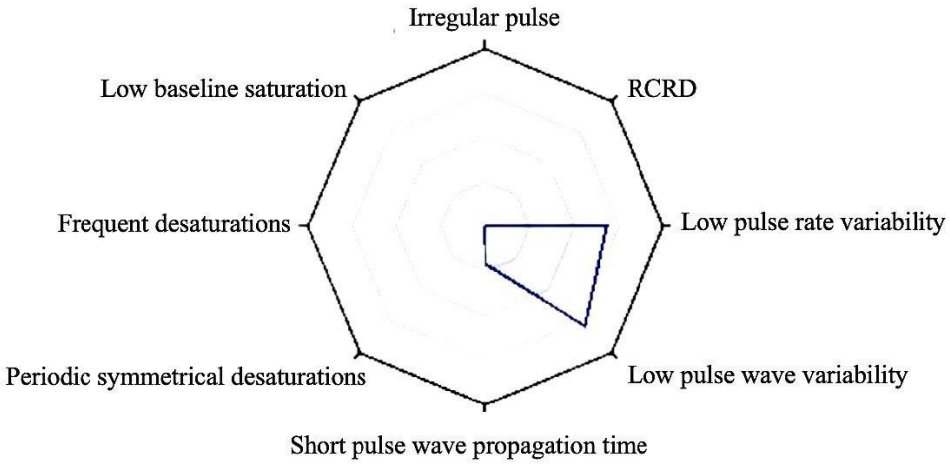

Figure 4 – Individual cardiovascular risk pattern diagram

Discussion

This study investigated sleep patterns and cardiorespiratory parameters in children aged 10–17 years, including children with metabolic syndrome (MetS), compared with a control group without MetS. The analysis revealed several noteworthy findings that shed light on possible associations between sleep disturbances, cardiorespiratory parameters, and factors associated with metabolic syndrome in this population.

The study group was predominantly male, suggesting a possible gender predisposition to MetS, consistent with previous studies [17].

A meta-analysis conducted in 2023 showed that children and adolescents with OSA had a higher neck circumference than controls, which was the only anthropometric measure with high strength of evidence. In our study, we found a positive correlation between neck circumference and AAI resp [18]. In terms of sleep characteristics, the AHI, the main measure of sleep apnea severity, was significantly higher in the MetS group compared to the control group. The occurrence of obstructive (oAHI) and central (cAHI) events was also significantly higher in the MetS group, strengthening the association between MetS and sleep apnea.

This suggests a higher incidence of apnea and hypopnea in people with MetS, which could potentially contribute to sleep fragmentation and daytime sleepiness. In addition, daytime sleepiness, as assessed by the ESS-CHAD scale, was more pronounced in the MetS group, suggesting a possible

link between MetS and increased sleepiness. The results of the MoCA test were significantly lower in patients with MetS than in patients without MetS. A study by Min-Hee Lee et al. showed that intermittent hypoxia and sleep fragmentation can also lead to mitochondrial dysfunction in microglial cells in cortical neurons. This can lead to an increase in the production of reactive oxygen species, which can damage brain tissue and cause neuronal cell death by apoptosis. These factors can also lead to inflammatory responses, cellular oedema, increased gliosis and changes in the structure of dendrites and neuronal branches. These physiological changes can affect neuronal development and may explain the increased risk of several neurocognitive and behavioural disorders associated with OSA, such as impaired concentration, memory, hyperactivity and learning difficulties [19].

Morning salivary cortisol levels were significantly higher in the group of patients with an oAHI greater than or equal to 1. This observation suggests a possible interaction between sleep disturbances and the hypothalamic-pituitary-adrenal (HPA) axis, which regulates cortisol secretion. These findings may highlight the role of sleep disturbance in affecting hormonal regulation in people with MetS. By building a logistic regression model, it was found that tongue position according to FTP III–IV may influence sleep fragmentation, which has been studied for the first time in a group of children. The clinical case shows that the patient did not complain of poor sleep, but mild daytime sleepiness and cognitive impairment were noted as possible consequences of poor sleep quality. The failure to reduce systolic blood pressure overnight may be explained by the high degree of sleep fragmentation [20]. Consequently, these frequent awakenings may maintain nocturnal hypertension, which may lead to resistance to drug treatment in the future.

CONCLUSIONS / ВИСНОВКИ

1. It was found that the parameters of cardiorespiratory sleep monitoring, including Apnea Index (AI), Hypopnea Index (HI), Apnea/Hypopnea Index (AHI), Obstructive Apnea/Hypopnea Index (oAHI), Central Apnea/Hypopnea Index (cAHI), Mean Apnea Duration, Mean Saturation, Respiratory Effort-Related Arousal (RERA), Arousal Index with Respiratory Events (AAI resp.) were significantly ($p < 0.05$) higher in the study group than in the control group, which may indicate a potential risk of respiratory disorders during sleep in the group of children with metabolic syndrome.

2. Patients with metabolic syndrome had significantly higher ($p = 0.005$) daytime sleepiness test scores and lower MoCA test scores than the control group.

3. It was found that in the group of children with an Obstructive Apnea/Hypopnea Sleep Index greater than or equal to 1, the level of morning salivary cortisol was statistically significantly ($p = 0.015$) higher, which may indicate activation of the hypothalamic-pituitary-adrenal system.

4. The logistic regression model (AUC = 0.762, 95%CI: 0.575 – 0.949) showed that tongue position grade III–IV on the Friedman scale was associated with sleep fragmentation in children and adolescents with metabolic syndrome due to respiratory obstruction.

5. The clinical case of a child with metabolic syndrome and a high Apnea/Hypopnea Index (AHI), who had high sleep fragmentation, non-dipping systolic blood pressure and cognitive impairment according to the MoCA test, highlights the need to introduce home cardiorespiratory monitoring into paediatric clinical practice. This is an important step to improve the prognosis and effective control of cardiovascular risk in children with metabolic syndrome and to identify possible causes of poor school performance.

PROSPECTS FOR FUTURE RESEARCH / ПЕРСПЕКТИВИ ПОДАЛЬШИХ ДОСЛІДЖЕНЬ

Several limitations of this study must be acknowledged. First, the cross-sectional design of the study limits the ability to establish causal relationships between MetS and sleep parameters. Longitudinal studies would provide a better understanding of the temporal dynamics between these variables. Second, the study focused on associations in a paediatric population; therefore, the findings may not be directly applicable to the adult population. Finally, this study could have been conducted using the gold standard – polysomnography (PSG); however, our primary goal was to investigate sleep parameters using a portable cardiorespiratory monitoring device.

CONFLICT OF INTEREST / КОНФЛІКТ ІНТЕРЕСІВ

The authors declare no conflict of interest.

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B – Data Collection and Analysis
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