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Challenges in assessing cardiovascular risk in obstructive sleep apnea-hypopnea syndrome: applicability of existing tools

Izazovi u proceni kardiovaskularnog rizika kod sindroma opstruktivne apneje-hipopneje u snu: primenljivost postojećih skorova

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Abstract

Background/Aim. Obstructive sleep apnea-hypopnea syndrome (OSAHS) is associated with an increased cardiovascular risk (CVR). The aim of this study was to examine CVR in hypertensive patients with OSAHS using the Systematic Coronary Risk Evaluation 2 (SCORE2), SCORE2-Diabetes, and American College of Cardiology/American Heart Association for atherosclerotic cardiovascular disease (ACC/AHA ASCVD) risk scores. **Methods.** Due to strict exclusion criteria, out of 410 consecutive OSAHS patients, 92 hypertensive patients with moderate or severe OSAHS were included in the study. All patients underwent CVR assessment using SCORE2, SCORE2-Diabetes, and ACC/AHA ASCVD risk scores. Additionally, all patients, except for seven individuals with extreme obesity (weight over 130 kg) who were unable to perform the test, underwent an exercise stress test, and six of them required further diagnostic assessment using stress echocardiography (three), computed tomography coronary angiography (two), and/or invasive coronary angiography (three). **Results.** The results showed a substantial burden of moderate to high CVR across all scores. Severe OSAHS was associated with a higher percentage of moderate to high CVR, particularly with the ACC/AHA ASCVD calculator. However, no significant correlation was found between the apnea-hypopnea index and CVR. Furthermore, in three patients, invasive coronary angiography showed multivessel disease requiring myocardial revascularization. **Conclusion.** General CVR calculators may inadequately represent the specific CVR in OSAHS patients, highlighting the need for tailored risk assessment and increased screening for coronary artery disease in this population. Our results emphasize the clinical relevance of screening for coronary artery disease in individuals with OSAHS.

Key words:
sleep apnea, obstructive; sleep apnea syndromes; coronary artery disease; hypertension; risk factors.

Apstrakt

Uvod/Cilj. Sindrom opstruktivne apneje-hipopneje u snu (*obstructive sleep apnea-hypopnea syndrome* – OSAHS) povezan je sa povećanim kardiovaskularnim rizikom (KVR). Cilj rada bio je da se ispita KVR kod obolelih od hipertenzije i OSAHS korišćenjem skorova rizika *Systematic Coronary Risk Evaluation 2* (SCORE2), SCORE2-Dijabetes i *American College of Cardiology/American Heart Association for atherosclerotic cardiovascular disease* (ACC/AHA ASCVD). **Metode.** Zbog strogih krterijuma isključenja od 410 uzastopnih bolesnika obolelih od OSAHS, 92 hipertenzivna bolesnika sa umerenim ili teškim OSAHS uključena su u studiju. Svi ispitanici podvrgnuti su proceni KVR-a korišćenjem SCORE2, SCORE2-Dijabetes i ACC/AHA ASCVD skorova rizika. Takođe, svi bolesnici, osim sedmoro sa ekstremnom gojaznošću (težina preko 130 kg) koji nisu mogli da urade test, podvrgnuti su testu fizičkim opterećenjem, a šestoro njih zahtevalo je dalju dijagnostičku procenu korišćenjem stres ehokardiografije (troje), kompjuterizovane tomografije koronarnih arterija (dvoje) i/ili invazivne koronarne angiografije (troje). **Rezultati.** Rezultati su pokazali značajno opterećenje umerenim do visokim KVR-om prema svim skorovima. Teški oblik OSAHS bio je povezan sa višim procentom umerenog do visokog KVR-a, posebno prema ACC/AHA ASCVD kalkulatoru. Nije pokazana značajna korelacija između indeksa apneje-hipopneje i KVR-a. Takođe, kod troje bolesnika, invazivna koronarna angiografija pokazala je višesudovnu koronarnu bolest koja je zahtevala revaskularizaciju miokarda. **Zaključak.** Opšti sistemi bodovanja KVR-a mogu neadekvatno prikazati specifični KVR kod obolelih od OSAHS, što naglašava

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potrebu za prilagođenom procenom rizika i pojačanim ranim otkrivanjem koronarne arterijske bolesti u ovoj populaciji. Naši rezultati naglašavaju klinički značaj detekcije koronarne arterijske bolest kod osoba sa OSAHS.

Ključne reči:
apneja u snu, opstruktivna; apneja, spavanje poremećaji, sindromi; koronarna bolest; hipertenzija; faktori rizika.

Introduction

Obstructive sleep apnea-hypopnea syndrome (OSAHS) is the most common sleep-breathing disorder, affecting 34% of males and 17% of females aged 30 to 70 years [1]. However, the true prevalence of OSAHS is very difficult to estimate because it often remains undiagnosed and, consequently, untreated. It is characterized by intermittent episodes of partial or total airway collapse, which leads to snoring, night choking, arousals, and sleep fragmentation. Consequently, patients with OSAHS often experience daytime fatigue, reduced work productivity, increased sleepiness during the day, and a higher risk of motor vehicle accidents [2]. The diagnosis of OSAHS is established through a sleep study, and the severity of the disorder is typically quantified using the apnea-hypopnea index (AHI). The AHI is defined as the number of apneic or hypopneic episodes occurring during each hour of sleep [3].

There is a bidirectional connection between OSAHS and cardiovascular diseases (CVD), as OSAHS represents an independent risk factor for CVD, and patients with CVD frequently suffer from OSAHS [4]. Intermittent hypoxemia, autonomic dysfunction, and changes in intrathoracic pressure are the main reasons why patients with OSAHS have an increased risk for arterial hypertension (HTA), atrial fibrillation, pulmonary hypertension, heart failure, coronary artery disease (CAD), and sudden cardiac death. Furthermore, OSAHS and CVDs share many common risk factors such as age, male gender, obesity, and smoking [5].

Given the increased cardiovascular risk (CVR) in patients with OSAHS, accurate risk assessment is crucial in the prevention of CVDs. Assessing CVR is usually performed by CVR scores. Developed by European Society of Cardiology (ESC), the Systematic Coronary Risk Evaluation 2 (SCORE2) is an improved version of SCORE that is usually used in assessing the 10-year risk of fatal and non-fatal cardiovascular events in people aged 40 to 69 years without diabetes mellitus (DM), chronic kidney disease, extremely high cholesterol level, or preexisting CVD. While SCORE2 is designed for this specific age group, SCORE2-Older Persons (SCORE2-OP) is used in people who are 70 years old or older [6]. Furthermore, for patients with DM, the ESC recommends using SCORE2-Diabetes in assessing CVR [7]. On the other hand, the American College of Cardiology (ACC) and the American Heart Association (AHA) suggest using ACC/AHA atherosclerotic CVD (ASCVD) risk score in assessing individual's 10-year risk of having a first major atherosclerotic cardiovascular event (fatal and non-fatal stroke, non-fatal myocardial infarction, and fatal CAD death) [8]. However, the applicability and accuracy of these general CVR scores in the specific population of patients with OSAHS remain uncertain.

The aim of the study was to examine the applicability of general CVR assessment scores, such as SCORE2, SCORE2-Diabetes, and ACC/AHA ASCVD, in the specific population of hypertensive patients with OSAHS, and to highlight the potential need for tailored risk stratification strategies for this (potentially) high-risk group.

Methods

Out of 410 consecutive patients with OSAHS, 92 hypertensive patients were included in this prospective study due to strict exclusion criteria. Among them, 30 patients (32.6%) had moderate OSAHS [AHI 15–29 episodes *per* hour (15–29/hr)], while 62 patients (67.4%) had severe OSAHS (AHI ≥ 30/hr). The diagnosis of HTA was based on the latest guideline for the management of HTA published by the European Society of Hypertension [9]. OSAHS diagnosis was determined through full-night respiratory polygraphy (RPG) using the Alice NightOne device from Philips Respironics (Eindhoven, Netherlands). This assessment was conducted at the sleep laboratory of the Clinic for Lung Diseases, University Clinical Center Niš, Niš, Serbia, during the patients' typical sleep periods. The diagnostic criteria were based on the American Academy of Sleep Medicine Clinical Practice Guideline for Diagnostic Testing for Adult Obstructive Sleep Apnea [10]. The RPG parameters investigated during research were AHI, oxygen desaturation index, the time spent with oxygen saturation below 90%, and the minimum, average, and maximum oxygen saturation levels. Participants also completed the Epworth Sleepiness Scale.

Individuals not diagnosed with OSAHS (AHI < 5/hr) or those with mild OSAHS (AHI 5–14/hr) were not included in the study. Furthermore, exclusion criteria encompassed patients with a prior diagnosis of CAD, heart failure, severe valvular disease or artificial heart valve, chronic kidney disease (defined as an estimated glomerular filtration rate under 60 mL/min/1.73 m^2), individuals younger than 40 or older than 80 years, and those with considerable physical or mental health issues.

Following the completion of the sleep study, all participants were admitted to the Department of Cardiovascular Diseases at the Institute for Treatment and Rehabilitation "Niška Banja", Niš. During their hospitalization, anthropometric measurements were taken, and laboratory analyses were conducted. CVR was then evaluated using SCORE2 (for non-DM individuals), SCORE2-Diabetes (for those with DM), and the ACC/AHA ASCVD risk score. Subsequently, all patients, except for seven individuals with extreme obesity (weight over 130 kg), who were unable to perform the test, underwent an exercise stress test (EST). These ESTs were conducted on a treadmill (3017 Full Vision Drive, Newton, Kansas, USA) following

the Bruce protocol. The exercise tests were terminated due to reaching a submaximal heart rate, the onset of limiting symptoms such as dyspnea, fatigue, chest pain, or dizziness, the presence of ischaemic changes on the electrocardiogram (horizontal or downsloping ST segment depression of ≥ 1 mm), complex ventricular arrhythmias (couplets of premature ventricular contractions or ventricular tachycardia), a hypertensive response defined as a rapid increase in systolic blood pressure (BP) to ≥ 220 mmHg or a decrease in systolic BP of > 10 mmHg, or at the patient's request.

The subjects' written consent was obtained, according to the Declaration of Helsinki. The study was approved by the Ethics Committee of the Institute for Treatment and Rehabilitation "Niška Banja", Niš (No. 3560/1, from March 29, 2023).

Statistical analysis

Data were analyzed using SPSS software version 20. Categorical data were expressed as frequencies and percentages, while quantitative data were presented as mean ± standard deviations. Data distribution was tested using the Kolmogorov-Smirnov test. Means of normally distributed data were compared using Student's *t*-test, while the Mann-Whitney *U* test was used for data whose distribution deviates significantly from normal distribution. For the comparison of frequencies, the Chi-square test was used. In correlation analysis, Pearson's correlation was used for normally distributed variables, while Spearman's rank correlation was used for data whose distribution deviates significantly from normal distribution. Statistical significance was set at $p < 0.05$.

Results

This study involved 92 hypertensive patients (average age 54.45 ± 9.61 years) diagnosed with either moderate [30 (32.6%)] or severe [62 (67.4%)] OSAHS. Initial analysis of anthropometric data revealed no significant differences in age, weight, or height. Patients with severe OSAHS had higher values of waist circumference, neck circumference (NC), body mass index, and systolic and diastolic BP compared to patients with moderate OSAHS. However, only NC reached statistical significance ($p = 0.040$) (Table 1).

Subsequently, risk factors for CVD were assessed. There were no significant differences in smoking status, physical activity (defined as walking at least 3 km a day), heredity, stress, and dyslipidemia. In contrast, DM (40.32% vs. 31.52%, $p = 0.007$) and obesity (93.55% vs. 86.96%, $p = 0.011$) were more prevalent in the group of patients with severe OSAHS. In addition, the number of risk factors was significantly higher in patients with severe OSAHS compared to those with moderate OSAHS (4.84 ± 1.13 vs. 4.27 ± 1.46, $p = 0.049$) (Table 2).

Upon admission to the Institute for Treatment and Rehabilitation "Niška Banja", a laboratory assessment was performed. No significant differences were observed in the investigated parameters between the groups, except for high-density lipoprotein, which was significantly higher in patients with moderate OSAHS (1.21 ± 0.30 vs. 1.08 ± 0.32, $p = 0.034$) (Table 3).

We used SCORE2 to assess the CVR in hypertensive OSAHS patients aged 40 to 69 years and without CVD and DM (Figure 1). Among the 55 investigated patients, the majority had high [30 (54.55%)] or moderate [23 (41.82%)] CVR. There were no statistically significant differences between the groups. In patients with DM, SCORE2-Diabetes was used. Of the 27 patients, 6 (22.22%) had very high CV risk, 15 (55.56%) had high, and 6 (22.22%) had intermediate CVR (Figure 2). Although all six patients with very high CVR had severe OSAHS, the investigated groups did not differ significantly. In six patients who were 70 years or older and without DM, SCORE-OP was performed, and all of them had high CVR. In four patients, cholesterol levels were either excessively high (above 9 mmol/L) or unusually low (below 3 mmol/L), rendering risk calculation using standard tools unfeasible.

Table 1

Anthropometric parameters

Parameters	Total		AHI 15–29		AHI ≥ 30		*p*-value
	n	mean ± SD	n	mean ± SD	n	mean ± SD	
Gender							
female, n (%)		17 (18.48)		7 (23.33)		10 (16.13)	0.287†
Body weight, kg	90	111.41 ± 19.81	29	107.86 ± 24.61	61	113.1 ± 17.06	0.244
Body height, cm	90	176.12 ± 9.03	29	175.66 ± 11.44	61	176.34 ± 7.73	0.737
Age, years	92	54.45 ± 9.61	30	55.07 ± 9.4	62	54.15 ± 9.78	0.669
Waist circumference, cm	89	121.24 ± 14.36	29	117.55 ± 16.82	60	123.02 ± 12.79	0.093
Neck circumference, cm	88	45.53 ± 3.92	28	44.29 ± 4.28	60	46.12 ± 3.63	**0.040**
Body mass index, kg/m^2	91	35.92 ± 6.33	30	34.4 ± 6.5	61	36.67 ± 6.17	0.109
Epworth scale	86	12.16 ± 4.87	28	12.36 ± 4.92	58	12.07 ± 4.88	0.799
Systolic blood pressure, mmHg	85	123.12 ± 12.1	28	121.07 ± 12.2	57	124.12 ± 12.03	0.277
Diastolic blood pressure, mmHg	85	79.47 ± 11.02	28	77.86 ± 6.44	57	80.26 ± 12.66	0.347

AHI – apnea-hypopnea index; SD – standard deviation; n – number. The bold value indicates a significance level of $p < 0.05$. *Note*: †The significance was obtained using the Chi-square test. All other significances were obtained using Student's *t*-test for two independent samples.

Table 2

Risk factors for cardiovascular diseases

Parameters	Total	AHI 15–29	AHI ≥ 30	*p*
Smoking	48 (52.17)	14 (46.67)	34 (54.84)	0.304
Physical activity	37 (40.22)	9 (30.00)	28 (45.16)	0.122
Obesity	80 (86.96)	22 (73.33)	58 (93.55)	**0.011**
Stress	20 (21.74)	8 (26.67)	12 (19.35)	0.295
Diabetes mellitus	29 (31.52)	4 (13.33)	25 (40.32)	**0.007**
Hyperlipidemia	67 (72.83)	22 (73.33)	45 (72.58)	0.574
Heredity	53 (57.61)	19 (63.33)	34 (54.84)	0.293
Number of risk factors	4.65 ± 1.27	4.27 ± 1.46	4.84 ± 1.13	**0.049**†

AHI – apnea-hypopnea index.
All values are given as numbers (percentages) and mean ± standard deviation. Bold values indicate a significance level of $p < 0.05$.
***Note:* †The significance was obtained using the Mann-Whitney *U* test. All other significances were obtained using the Chi-square test.**

Table 3

Laboratory assessment

Parameters	Total		AHI 15–29		AHI ≥ 30		*p*-value
	n	mean ± SD	n	mean ± SD	n	mean ± SD	
Cholesterol, mmol/L	92	5.65 ± 3.59	30	5.42 ± 1.14	62	5.77 ± 4.31	0.68
LDL, mmol/L	91	3.26 ± 0.97	29	3.22 ± 0.93	62	3.28 ± 1.00	0.798
HDL, mmol/L	92	1.12 ± 0.32	30	1.21 ± 0.30	62	1.08 ± 0.32	**0.034**
Triglyceride, mmol/L	92	2.09 ± 1.03	30	2.22 ± 1.40	62	2.03 ± 0.79	0.665
Glucose, mmol/L	92	5.91 ± 0.99	30	5.87 ± 1.29	62	5.93 ± 0.81	0.364
AST, U/L	92	21.89 ± 8.21	30	21.57 ± 6.57	62	22.05 ± 8.95	0.874
ALT, U/L	92	30 ± 16.07	30	28.73 ± 15.62	62	30.61 ± 16.37	0.521
Creatinine, μmol/L	92	93.97 ± 16.22	30	91.44 ± 17.55	62	95.19 ± 15.54	0.546
Urea, mmol/L	92	5.31 ± 1.36	30	5.11 ± 1.33	62	5.41 ± 1.37	0.334
Uric acid	92	376.21 ± 85.31	30	355.93 ± 77.35	62	386.02 ± 87.83	0.112
Sedimentation	92	20.75 ± 17.02	30	22.27 ± 21.10	62	20.02 ± 14.78	0.686
Leukocyte	92	7.41 ± 1.67	30	7.22 ± 1.75	62	7.5 ± 1.64	0.543
Erythrocyte	92	4.88 ± 0.44	30	4.86 ± 0.48	62	4.89 ± 0.43	0.819
Hematocrit	92	0.43 ± 0.04	30	0.43 ± 0.04	62	0.44 ± 0.03	0.418
Hemoglobin	92	143.03 ± 18.84	30	137.7 ± 27.39	62	145.61 ± 12.35	0.301
Thrombocyte	92	257.14 ± 55.2	30	267.53 ± 54.21	62	252.11 ± 55.40	0.184
eGFR	92	122.41 ± 32.69	30	115.9 ± 36.57	62	125.56 ± 30.46	0.073
Modified eGFR*	90	96.33 ± 22.89	29	93.45 ± 25.49	61	97.7 ± 21.63	0.263

AHI – apnea-hypopnea index; SD – standard deviation; n – number; LDL – low-density lipoproteins; HDL – high-density lipoproteins; AST – aspartate aminotransaminase; ALT – alanine aminotransaminase; eGFR – estimated glomerular filtration rate.
The bold value indicates a significance level of $p < 0.05$. All significances were obtained using the Mann-Whitney *U* test.
***Note:* *used for an overweight patient.**

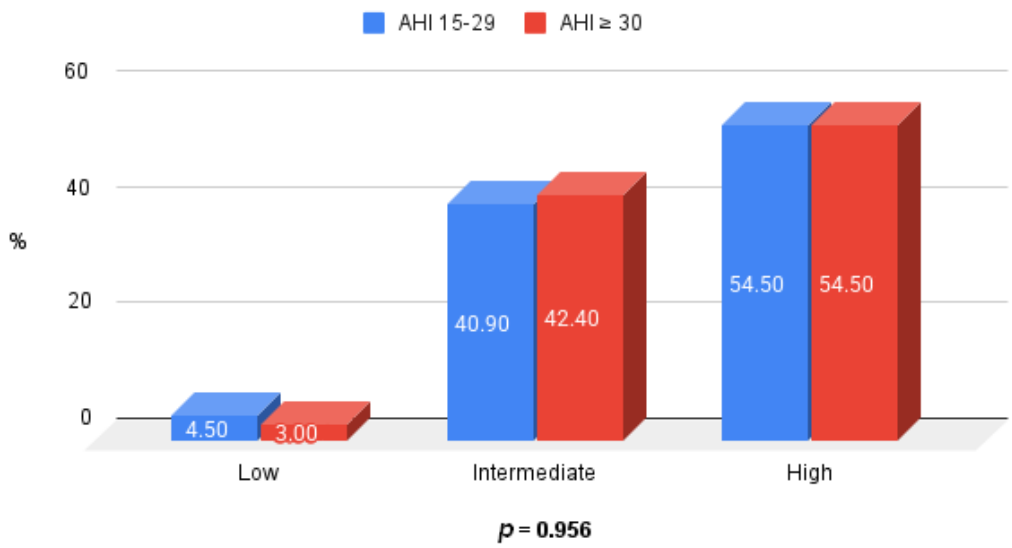

Fig. 1 – SCORE2 for assessing the CVR in hypertensive OSAHS patients.
CVR – cardiovascular risk; OSAHS – obstructive sleep apnea-hypopnea syndrome.
For other abbreviations, see Table 4.

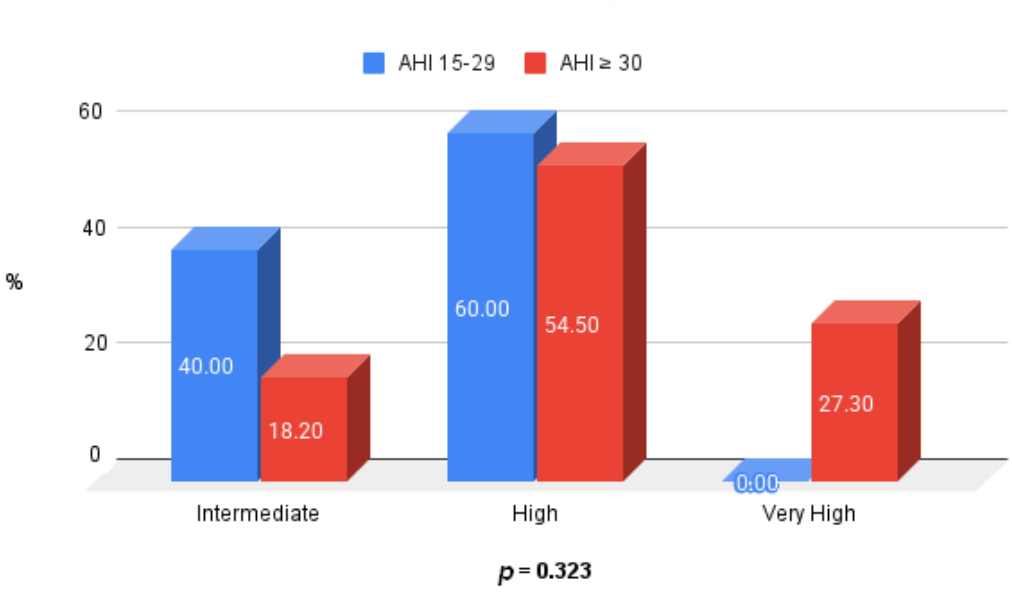

Fig. 2 – SCORE2-Diabetes in patients with diabetes mellitus for assessing the CVR in hypertensive OSAHS patients.
For abbreviations, see Table 4 and Figure 1.

The ACC/AHA ASCVD calculator was used in 91 patients. More than 70% of investigated patients had moderate or high CVR. This finding was even more pronounced in severe OSAHS, where 39.28% had moderate and 39.28% had high CVR. However, the investigated groups did not differ significantly (Figure 3). Finally, we performed a correlation between the AHI index and all three investigated scores and found no significant correlation (Table 4).

Patients with moderate OSAHS demonstrated better strain tolerance by achieving higher strain levels and longer duration of EST, but without statistical significance (Table 5). In contrast, patients with severe OSAHS reached submaximal heart rate more frequently than patients with moderate OSAHS (84.21% vs. 64.29%, $p = 0.038$).

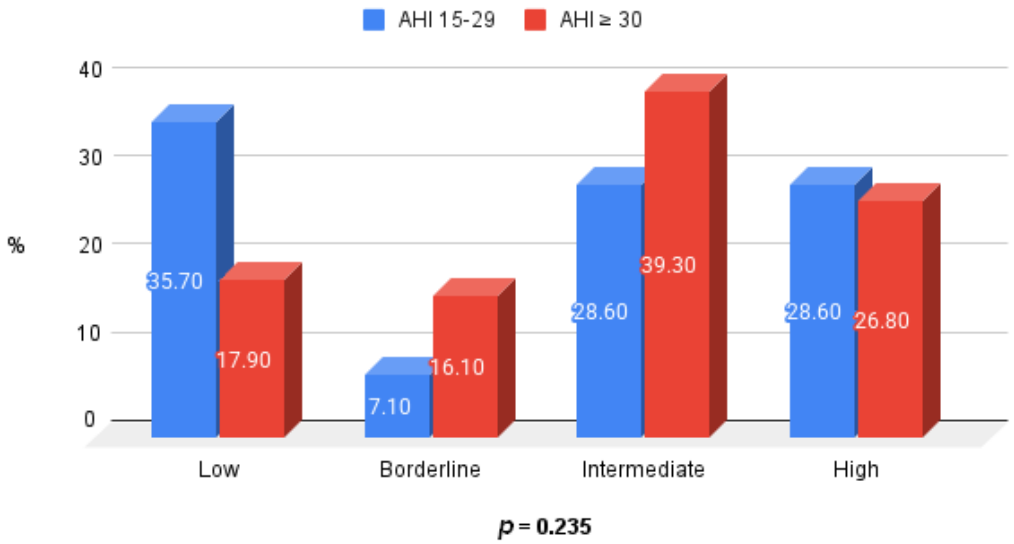

Fig. 3 – ACC/AHA ASCVD for assessing the CVR in hypertensive OSAHS patients. For abbreviations, see Table 4 and Figure 1.

Table 4

Correlation between AHI and risk SCORES

Risk scores	AHI		
	n	*r*	*p*
SCORE2	55	-0.013	0.926
SCORE2-Diabetes	27	0.062	0.760
ACC/AHA ASCVD	84	0.009	0.937

AHI – apnea-hypopnea index; SCORE2 – Systematic Coronary Risk Evaluation 2; ACC/AHA ASCVD – American College of Cardiology/American Heart Association for Atherosclerotic Cardiovascular Disease.
The Pearson correlation coefficient (*r*) was used.

Table 5

Exercise stress test

Parameters	Total	AHI 15–29	AHI ≥ 30	*p*-value
Level	2.68 ± 1.01	2.82 ± 1.22	2.61 ± 0.9	0.558
Duration	6.46 ± 2.99	6.9 ± 3.41	6.25 ± 2.77	0.403
Submaximal heart rate	66 (77.65)	18 (64.29)	48 (84.21)	**0.038**†
Ischemia	6 (7.06)	3 (10.71)	3 (5.26)	0.308†
Arrhythmias	8 (9.41)	1 (3.57)	7 (12.28)	0.188†
Double product before	9,556.82 ± 2,105.28	9,413.93 ± 1,695.78	9,627.02 ± 2,290.54	0.369
Double product after	23,293.41 ± 3,502.08	22,697.14 ± 3,269.47	23,586.32 ± 3,602.49	0.317

AHI – apnea-hypopnea index.
All values are given as numbers (percentages) or mean ± standard deviation.
The bold value indicates a significance level of $p < 0.05$.
***Note:* †Significance obtained using the Chi-square test. All other significances were obtained using the Mann-Whitney *U* test.**

Discussion

In the present study, OSAHS was more prevalent in males, which aligns with previous epidemiological studies [11]. Additionally, waist circumference and NC once again proved to be great indicators for diagnosing OSAHS [12]. Higher values of NC in severe compared to moderate OSAHS may indicate that NC positively correlates with the severity of OSAHS. Furthermore, this finding suggests that this simple anthropometric measurement may serve as a valuable clinical

tool for identifying patients at increased risk. In resource-limited settings like ours, where polysomnography may not be readily available, NC could serve as a cost-effective screening method. The study once again stressed the point that patients with OSAHS share many common risk factors with CVD [13]. Namely, the average number of risk factors was 4.65 ± 1.27, and patients with severe OSAHS had a higher number of risk factors compared to moderate OSAHS (4.27 ± 1.46 vs. 4.84 ± 1.13, $p = 0.049$). These findings are consistent with previous studies that have demonstrated a dose-dependent relationship between OSAHS severity and CVR [13]. Furthermore, obesity and DM were more prevalent in patients with severe compared to patients with moderate OSAHS, which also aligns with previous studies. Both obesity and DM contribute to increased CVR through mechanisms such as systemic inflammation, endothelial dysfunction, and autonomic dysregulation, which are further exacerbated by the intermittent hypoxemia and sleep fragmentation associated with OSAHS [14].

SCORE2, SCORE2-Diabetes, and ACC/AHA ASCVD are validated risk scores used for assessing the 10-year risk for CVD in individuals without established CVD [6–8]. SCORE2 is a relatively new score developed from ESC for assessing the 10-year risk for fatal and non-fatal CVD in individuals aged 40 to 69 years, without previous DM or CVD. It uses an algorithm that involves parameters such as gender, age, smoking status, total cholesterol, high-density lipoprotein cholesterol, and systolic BP. Importantly, the calibration of the risk calculator depends on the country. We used a calculator that was calibrated for Serbia and which uses the table for a very high overall risk for CVD. In the present study, a significant proportion of OSAHS patients aged 40–69 years, without CVD or DM (55 patients), exhibited high or intermediate CVR assessed by the SCORE2 calculator, which highlights the substantial cardiovascular burden in these patients.

For patients with DM and without CVD, we used SCORE2-Diabetes. Out of 27 patients, 6 (22.22%) had very high CV risk, 15 (55.56%) had high, and 6 (22.22%) had low CVR. All six patients with very high CVR were patients with severe OSAHS. In both groups, most patients had intermediate CVR. Notably, there was no single patient with low CVR, and the majority of patients with moderate or severe OSAHS had high or very high risk scores. However, in this group, as in the group of patients without DM, there was no significant correlation between CVR and OSAHS severity. Of note, SCORE2-OP was performed in six patients aged 70 years or older, and all six patients were found to have a high CVR. Three patients had cholesterol levels exceeding 9mmol/L, while one had a level below 3mmol/L. In these patients, the estimation of CVR could not be done.

The ACC/AHA ASCVD risk calculator uses parameters such as age, gender, race, systolic BP, total cholesterol, high-density lipoprotein cholesterol, smoking status, presence of DM, and treatment for HTA to estimate the 10-year risk of a first major atherosclerotic cardiovascular event (non-fatal myocardial infarction, coronary heart disease death, or stroke) in individuals aged 40–79 years without pre-existing ASCVD. More than 70% of investigated patients in our study had moderate or high CVR assessed by the ACC/AHA ASCVD calculator. This indicates that this score, as well as SCORE2 and SCORE2-Diabetes, highlights the high cardiovascular burden in hypertensive OSAHS patients. Once again, the group with severe OSAHS had a higher percentage of patients with moderate and high CVR compared to the group with moderate OSAHS. Nevertheless, this difference did not reach statistical significance ($p = 0.235$). Importantly, our investigation failed to show a significant correlation between the severity of OSAHS using AHI and all three scores: SCORE2, SCORE2-Diabetes, and ACC/AHA ASCVD. These findings are in contrast with previous studies employing other CVR scores. In these studies, CVR scores generally demonstrated a positive correlation with the severity of OSAHS. For instance, in the study by Archontogeorgis et al. [15], the severity of OSAHS was significantly associated with higher SCORE values ($p < 0.001$) and Framingham Risk Score values ($p < 0.001$). Furthermore, the authors reported significant positive correlations between the AHI and SCORE ($r = 0.251$, $p < 0.001$) and between AHI and Framingham Risk Score ($r = 0.291$, $p < 0.001$). The authors concluded that the 10-year risk of cardiovascular morbidity and mortality appeared to increase with OSAHS severity. Similarly, Borsini et al. [16] found a positive correlation between the ACC/AHA ASCVD risk score and OSAHS severity, as assessed by AHI.

Several factors may contribute to the aforementioned discrepancy. Firstly, these validated and generally accepted CVR scores do not consistently incorporate key CVR factors frequently present in patients with OSAHS, such as obesity [13, 17, 18] and metabolic syndrome [19]. Furthermore, important parameters derived from RPG, known to influence CVR, oxygen desaturation index [20], and hypoxic burden [21, 22], are not included in these scoring systems.

Patients with severe OSAHS showed better strain tolerance by achieving higher levels and longer duration of EST, which aligns with a previous study [23], but without statistical significance. On the other hand, a higher percentage of patients with severe OSAHS achieved submaximal heart rate compared to moderate OSAHS. This is partially due to higher values of heart rate and BP at the beginning of EST (the double product was higher in severe compared to moderate OSAHS). Notably, six patients had ischemia on EST. In three patients, a stress echocardiographic test was performed, two patients were sent for computer tomography coronary angiography, and one patient underwent invasive coronary angiography (ICA). The choice of diagnostic tool was made based on pre-test probability, risk factor-weighted clinical likelihood, and comorbidities. All three patients who were referred for a stress echocardiographic test showed no new wall-motion abnormalities. However, one of them survived a myocardial infarction during the trial and underwent ICA, which showed a significant multivessel disease. One of the two patients who underwent computed tomography coronary angiography was also found to have multivessel disease and, following ICA, was referred for cardiac surgery. Finally, the patient who was directly referred for ICA also had a significant multivessel disease that required percutaneous coronary intervention. Altogether, three (3.26%) patients had CAD, which required

revascularization. These results highlight the necessity of screening OSAHS patients for CAD [24, 25].

Study limitations

Several limitations should be considered when interpreting the present findings. First, the sample size was relatively small compared to some larger studies examining the assessment of CVR in patients with OSAHS [15, 16]. However, our study applied stricter inclusion and exclusion criteria, and to our knowledge, it is the first to investigate the usefulness of SCORE2, SCORE2-Diabetes, and ACC/AHA ASCVD risk scores in assessing CVR in patients with OSAHS. Second, RPG was utilized for OSAHS diagnosis instead of polysomnography, which is the established gold standard. This was necessitated by the limited availability of polysomnography facilities within our medical center. Despite its limitations, RPG remains a valuable and widely adopted tool for assessing respiratory events during sleep, particularly in settings with resource constraints.

Conclusion

Our study evaluated the cardiovascular risk profile of hypertensive patients with OSAHS using SCORE2, SCORE2-Diabetes, and ACC/AHA ASCVD risk scores. Our findings revealed a substantial burden of moderate to high cardiovascular risk across all three scores in our cohort. A higher percentage of patients with severe OSAHS exhibited moderate to high cardiovascular risk compared to those with moderate OSAHS across all risk scores, but without statistical significance. Importantly, our investigation failed to demonstrate a significant correlation between the apnea-hypopnea index and cardiovascular risk as assessed by any of the three scores. This finding suggests that these general risk calculators, primarily validated in the broader population, may not adequately capture the specific relationship between OSAHS severity and cardiovascular risk. Future research should investigate these findings in larger studies with diverse OSAHS populations and explore the potential for developing risk assessment tools that better account for the unique pathophysiological mechanisms linking OSAHS and cardiovascular diseases. Ultimately, these data emphasize the clinical relevance of screening for coronary artery disease in individuals with OSAHS.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

1. *Benjafield AV, Ayas NT, Eastwood PR, Heinzer R, Ip MSM, Morrell MJ,* et al. Estimation of the global prevalence and burden of obstructive sleep apnoea: a literature-based analysis. Lancet Respir Med 2019; 7(8): 687–98.
2. *Nguyen Hai C, Trinh Duc L.* Sleep Disorders and Traffic Accidents: Unveiling the Hidden Risks. Am J Case Rep 2024; 25: e943346.
3. *Osman AM, Carter SG, Carberry JC, Eckert DJ.* Obstructive sleep apnea: current perspectives. Nat Sci Sleep 2018; 10: 21–34.
4. *Kasai T, Floras JS, Bradley TD.* Sleep apnea and cardiovascular disease: a bidirectional relationship. Circulation 2012; 126(12): 1495–510.
5. *Blackwell JN, Walker M, Stafford P, Estrada S, Adabag S, Kwon Y.* Sleep Apnea and Sudden Cardiac Death. Circ Rep 2019; 1(12): 568–74.
6. *Graham IM, Di Angelantonio E, Huculeci R; European Society of Cardiology's Cardiovascular Risk Collaboration (CRC).* New Way to "SCORE" Risk: Updates on the ESC Scoring System and Incorporation into ESC Cardiovascular Prevention Guidelines. Curr Cardiol Rep 2022; 24(11): 1679–84.
7. *SCORE2-Diabetes Working Group and the ESC Cardiovascular Risk Collaboration.* SCORE2-Diabetes: 10-year cardiovascular risk estimation in type 2 diabetes in Europe. Eur Heart J 2023; 44(28): 2544–56.
8. *Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ,* et al. 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation 2019; 140(11): e596–95. Erratum in: Circulation 2019; 140(11): e647–8. Erratum in: Circulation 2020; 141(4): e59. Erratum in: Circulation 2020; 141(16): e773.
9. *Mancia G, Kreutz R, Brunström M, Burnier M, Grassi G, Januszewicz A,* et al. 2023 ESH Guidelines for the management of arterial hypertension The Task Force for the management of arterial hypertension of the European Society of Hypertension: Endorsed by the International Society of Hypertension (ISH) and the European Renal Association (ERA). J Hypertens 2023; 41(12): 1874–2071. Erratum in: J Hypertens 2024; 42(1): 194.
10. *Kapur VK, Auckley DH, Chowdhuri S, Kuhlmann DC, Mehra R, Ramar K,* et al. Clinical Practice Guideline for Diagnostic Testing for Adult Obstructive Sleep Apnea: An American Academy of Sleep Medicine Clinical Practice Guideline. J Clin Sleep Med 2017; 13(3): 479–504.
11. *Geer JH, Hilbert J.* Gender Issues in Obstructive Sleep Apnea. Yale J Biol Med 2021; 94(3): 487–96.
12. *Tom C, Roy B, Vig R, Kang DW, Aysola RS, Woo MA,* et al. Correlations between Waist and Neck Circumferences and Obstructive Sleep Apnea Characteristics. Sleep Vigil 2018; 2(2): 111–8.
13. *Mitra AK, Bhuiyan AR, Jones EA.* Association and Risk Factors for Obstructive Sleep Apnea and Cardiovascular Diseases: A Systematic Review. Diseases 2021; 9(4): 88.
14. *Kurnool S, McCowen KC, Bernstein NA, Malhotra A.* Sleep Apnea, Obesity, and Diabetes - an Intertwined Trio. Curr Diab Rep 2023; 23(7): 165–71.
15. *Archontogeorgis K, Voulgaris A, Nena E, Strempela M, Karailidou P, Tzouvelekis A,* et al. Cardiovascular Risk Assessment in a Cohort of Newly Diagnosed Patients with Obstructive Sleep Apnea Syndrome. Cardiol Res Pract 2018; 2018: 6572785.
16. *Borsini E, Blanco M, Bosio M, Schrappe M, Ernst G, Nosetto D,* et al. Prevalence of sleep apnea and cardiovascular risk factors in patients with hypertension in a day hospital model. Clin Exp Hypertens 2018; 40(3): 231–7.
17. *Wolk R, Shamsuzzaman AS, Somers VK.* Obesity, sleep apnea, and hypertension. Hypertension 2003; 42(6): 1067–74.

18. *Pennings N, Golden L, Yashi K, Tondt J, Bays HE*. Sleep-disordered breathing, sleep apnea, and other obesity-related sleep disorders: An Obesity Medicine Association (OMA) Clinical Practice Statement (CPS) 2022. Obes Pillars 2022; 4: 100043.
19. *Giampá SQC, Lorenzi-Filho G, Drager LF*. Obstructive sleep apnea and metabolic syndrome. Obesity (Silver Spring) 2023; 31(4): 900–11.
20. *Wang L, Ou Q, Shan G, Lao M, Pei G, Xu Y,* et al. Independent Association Between Oxygen Desaturation Index and Cardiovascular Disease in Non-Sleepy Sleep-Disordered Breathing Subtype: A Chinese Community-Based Study. Nat Sci Sleep 2022; 14: 1397–406.
21. *Trzepizur W, Blanchard M, Ganem T, Balusson F, Feuilloy M, Girault JM,* et al. Sleep Apnea-Specific Hypoxic Burden, Symptom Subtypes, and Risk of Cardiovascular Events and All-Cause Mortality. Am J Respir Crit Care Med 2022; 205(1): 108–17.
22. *Mehra R, Azarbarzin A*. Sleep Apnea-Specific Hypoxic Burden and Not the Sleepy Phenotype as a Novel Measure of Cardiovascular and Mortality Risk in a Clinical Cohort. Am J Respir Crit Care Med 2022; 205(1): 12–3.
23. *Butner KL, Hargens TA, Kaleth AS, Miller LE, Zedalis D, Herbert WG*. Association of Obstructive Sleep Apnea Severity with Exercise Capacity and Health-related Quality of Life. N Am J Med Sci 2013; 5(6): 362–6.
24. *Yeghiazarians Y, Jneid H, Tietjens JR, Redline S, Brown DL, El-Sherif N,* et al. Obstructive Sleep Apnea and Cardiovascular Disease: A Scientific Statement From the American Heart Association. Circulation 2021; 144(3): e56–67. Erratum in: Circulation 2022; 145(12): e775.
25. *Lüthje L, Andreas S*. Obstructive sleep apnea and coronary artery disease. Sleep Med Rev 2008; 12(1): 19–31.

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