Sleep duration and the risk of metabolic syndrome – a cross-sectional study

Czas snu a ryzyko zespołu metabolicznego – badanie przekrojowe

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Key words: sleep duration, metabolic syndrome, men, women.

Słowa kluczowe: czas snu, zespół metaboliczny, mężczyźni, kobiety.

Abstract

Introduction: It has been stated that besides the traditional elements of lifestyle such as diet and physical activity, an additional factor, namely sleep, is involved in metabolic processes, hormonal functions, and energy homeostasis.
Aim of the research: To examine relationships between self-reported sleep duration and the risk of metabolic syndrome (MetS) and its components, both for men and women.
Material and methods: The study involved 10,367 individuals, aged 37 to 66 years. The definition of MetS applied in this paper was developed by the International Diabetes Federation (IDF). Logistic regression was applied to assess the risk (odds ratio – OR) of MetS and its components.
Results: There was no relationship observed between short sleep duration (≤ 6 h) and the risk of MetS. Long sleep duration (≥ 9 h) was connected with a higher risk of MetS only in the unadjusted model (OR = 1.11). After adjusting for confounders, a significant association was found between long sleep duration and a higher risk of abdominal obesity in the test group as a whole (OR = 1.16), as well as in the men in the group (OR = 1.22). In women, both with short (OR = 1.08) and long (OR = 1.12) sleep duration, the risk of increased concentration of glucose was found.
Conclusions: Our study did not confirm the existence of an association between inadequate sleep duration and the risk of MetS, defined in accordance with IDF criteria. Sleep duration, however, is connected with some of the MetS components. It is therefore necessary to conduct further, long-term tests in this regard.

Streszczenie

Wprowadzenie: Stwierdzono, że obok tradycyjnych elementów stylu życia, takich jak dieta i aktywność fizyczna, dodatkowym czynnikiem zaangażowanym w procesy metaboliczne, funkcje hormonów i homeostazę energetyczną jest sen.
Cel pracy: Zbadanie zależności między deklarowanym czasem snu a ryzykiem wystąpienia zespołu metabolicznego (MetS) i jego komponentów u mężczyzn i u kobiet.
Materiał i metody: W badaniu wzięło udział 10 367 osób w wieku od 37 do 66 lat. Przyjęto definicję zespołu metabolicznego opracowaną przez Międzynarodową Federację Diabetologiczną (IDF). Do oceny ryzyka (OR) MetS i jego komponentów zastosowano regresję logistyczną. Jako poziom referencyjny przyjęto sen trwający 7–8 godzin w nocy.
Wyniki: Nie stwierdzono zależności między krótkim czasem snu (≤ 6 h) a ryzykiem wystąpienia MetS. Długi czas snu (≥ 9 h) wiązał się z większym ryzykiem rozwoju MetS jedynie w modelu nieadiustowanym (OR = 1,12). Po adiustacji na zmienne zakłócające odnotowano istotną zależność między długim trwaniem snu a większym ryzykiem wystąpienia otyłości brzusznej u ogółu badanych (OR = 1,16) oraz u mężczyzn (OR = 1,22). U kobiet większe ryzyko wystąpienia podwyższonego stężenia glukozy wiązało się zarówno z krótkim (OR = 1,08), jak i z długim czasem snu (OR = 1,12).
Wnioski: Badanie nie potwierdziło istnienia zależności między nieadekwatnym czasem snu a ryzykiem wystąpienia MetS zdefiniowanym wg kryteriów IDF. Długość snu była jednak związana z niektórymi komponentami MetS. Niezbędne jest przeprowadzenie dalszych, najlepiej długofalowych badań w tym zakresie.

Introduction

Metabolic disorders, although highly dependent on genetic factors, can be significantly modified by environmental factors. It has been stated in recent years that besides the traditional elements of lifestyle such as diet and physical activity, an additional factor, namely sleep, is involved in metabolic processes, hormonal functions, and energy homeostasis [1]. Tests have shown that sleep duration is associated with adverse health outcomes, such as obesity [2, 3], type 2 diabetes [3–5], cardiovascular disease [3, 6], and all-cause mortality [7, 8]. Inadequate sleep duration may also be a risk factor of metabolic syndrome (MetS) [9–11]. However, tests results in this domain vary. Some of them show a U-shaped relationship between sleep duration and the prevalence of MetS [10]. It has been shown in some papers that MetS is only associated with short sleep duration [12–15] or long sleep duration [16–18]. In another paper, however, there was no relationship found between sleep duration and the risk of MetS [19]. So far, the influence of sex on shaping the association between sleep duration and metabolic profile [20–24] has not been found. Some tests suggest that in the case of women, sleep disorders happen more frequently due to psychological factors, in comparison with men [25–27], which may result in different effects resulting from inadequate sleep duration and the incidence of metabolic disorders in both sexes.

Aim of the research

The aim of the paper was to examine relationships between self-reported sleep duration and the risk of metabolic syndrome and its components, both for men and women.

Material and methods

Research material was collected within the framework of the PONS project (Polish-Norwegian Study) on the health condition of the inhabitants of the Świętokrzyskie Province in Poland. The study was approved by the Ethics Committee within the Cancer Centre and Institute of Oncology in Warsaw and by the Committee on Bioethics at the Faculty of Medicine and Health Sciences, Jan Kochanowski University in Kielce, Poland. The studies included blood pressure measurements and analyses of collected fasting-blood samples, on the basis of which the concentration of cholesterol, glucose, and triglycerides was determined, anthropometric measurements (waist circumference) were taken, and a questionnaire interview conducted. Detailed information regarding the project, research procedures and group selection were described in previously published papers [28–30]. In brief: 13,172 individuals were examined (4447 men), aged between 37 and 66 years, permanently residing in the Kielecki region in Poland. Individuals with incomplete data were excluded from the study (n = 2609), as well as people with a history of cardiovascular disease, stroke, cancer, or diabetes (n = 196). In further analysis of the data, 10,367 participants were used.

The socio-demographic variables included: sex (men; women), age (37–46; 47–56; 57–66 years), place of residence (city; country), education (university; lower than university), and marital status (married or in a stable relationship; single or a widow/widower).

Sleep duration was assessed with the question: "on average, how many hours do you sleep each night?" Answers were recorded in whole hours. We created the following three categories of sleeping duration: ≤ 6 h, 7–8 h, and ≥ 9 h per night. We refer to these three groups as short, normal, and long sleepers, respectively. Physical activity (PA) was evaluated with the use of the International Physical Activity Questionnaire (IPAQ) – the long form. The analysis included the most frequent forms of activity, i.e. moderate PA and walking PA. Due to the small number of participants declaring vigorous PA, we did not include it in our analysis. Moderate PA included the time devoted to activities of moderate intensity, related to the domains: sport, recreational, and leisure time; job-related PA; housework, house maintenance, and caring for family. Walking PA during the last week involved walking for 10 or more minutes every day, in all domains subject to assessment: job-related PA, transportation PA, recreation, sport, and leisure-time PA. The scores are presented as time in minutes per day. Sitting time (ST) during the last week was determined on the basis of time spent in a sitting position on working days and at weekends. Next, the average number of minutes spent sitting during a week was calculated. The respondents who smoked cigarettes on a daily basis during the study were classified as current smokers, and those who had not smoked for longer than 6 months, as former smokers; the rest were regarded as non-smokers. The data concerning alcohol and coffee consumption were collected by means of the Food Frequency Questionnaire (FFQ). The answers relating to the consumption frequency of products from the questionnaire were transformed into daily consumption doses and then standardised by z-score. As far as coffee is concerned, the portion consisted of one cup (250 ml). The frequencies of consumption were classified based on the following answers: 6 times a day or more, 4–5 times a day, 2–3 times a day, once a day, 5–6 times a week, 2–4 times a week, 1–3 times a month, once a week, less frequently than once a month or not at all, I don't know, and I refuse to answer the question. Alcohol consumption was evaluated on the basis of the frequency of alcoholic drink consumption during the preceding 30 days in the following categories: every day, 4–5 times a week, 2–3 times a week, once a week, 2–3 times in the last 30 days, once during the

last 30 days, not at all in the last 30 days, I don't know, refusal to answer. The prevalence of MetS was defined based on the recommendations of the International Diabetes Federation Task Force on Epidemiology and Prevention (joint interim statement in 2009) [31].

Statistical analysis

The normality of distribution of quantitative characteristics was evaluated: age, coffee and alcohol consumption, moderate physical activity, and walking and sitting time. Arithmetic means and standard deviations as well as medians and quartile range were calculated (95% CI) in the groups distinguished, based on the time devoted to sleep. A structure indicator was calculated for qualitative characteristics: education, place of residence, marital status, and smoking. The χ^2 test was used to test the structure indicator, and in the case of quantitative variables Kruskal-Wallis one-way analysis of variance was applied, depending on the type of distribution and the significance of variance (Table 1). Logistic regression was used for risk assessment (OR) of the prevalence of MetS and its components in individual groups of sleep duration. Sleep of 7–8 h per night was adopted as a reference level. Two models were analysed: unadjusted and adjusted for socio-demographic variables (gender, age, education, place of residence, marital status); and health-related behaviour (moderate physical activity, walking, sitting time, smoking, coffee and alcohol consumption). The statistical analysis was carried out with the use of the Statistica program, version 12.0. The *p*-values less than 0.05 were considered statistically significant.

Table 1. The characteristic of the study participants in three categories of sleep duration

Factors	≤ 6 h of sleep	7–8 h of sleep	≥ 9 h of sleep	*P*-value
Age: 37–46 years, *n* (%)	154 (5.55)	494 (6.60)	39 (4.97)	< 0.001[A]
Age: 47–57 years, *n* (%)	1533 (55.28)	4256 (56.88)	373 (47.52)	< 0.001[A]
Sex: women, *n* (%)	1843 (66.46)	4886 (65.29)	582 (74.14)	< 0.001[A]
Place of living: city, *n* (%)	1877 (67.69)	4569 (61.06)	458 (58.34)	< 0.001[A]
Education: university, *n* (%)	737 (28.38)	1942 (27.55)	145 (20.14)	0.001[A]
Marital status: single, *n* (%)	652 (23.51)	1435 (19.18)	157 (20.00)	0.001[A]
Former smokers, *n* (%)	907 (32.71)	2457 (32.85)	266 (33.89)	0.01[A]
Current smokers, *n* (%)	630 (22.72)	1494 (19.98)	139 (17.71)	0.01[A]
Coffee [servings/day] *x* (SD); Me (95% CI)	1.29 (1.09); 1.00 (90.00–4.50)	1.25 (0.99); 1.00 (0.0–2.50)	1.2 (1.02); 1.00 (0.00–2.50)	0.05[B]
Alcohol [servings/day] *x* (SD); Me (95% CI)	0.09 (0.15); 0.03 (0.00–0.64)	0.10 (0.15); 0.03 (0.00–0.64)	0.08 (0.16); 0.03 (0.00–0.64)	< 0.05[B]
ST [min/day] *x* (SD); Me (95% CI)	579.61 (347.57); 540.00 (120.00–1260.00)	560.42 (781.21); 540.00 (180.00–1200.00)	560.42 (363.53); 480.00 (120.00–1200.00)	< 0.05[B]
Walking [min/day] *x* (SD); Me (95% CI)	89.38 (78.14); 60.00 (90.00–300.00)	88.93 (77.08); 65.00 (0.00–300.00)	82.23 (71.99); 60.00 (0.00–270.00)	NS[B]
Moderate PA [min/day] *x* (SD); Me (95% CI)	133.51 (97.64); 120.00 (0.00–360.00)	141.69 (100.71); 120.00 (90.00–360.00)	138.99 (95.63) 120 (0.00–360.00)	0.002[B]
Metabolic syndrome, *n* (%)	1349 (48.65)	3567 (47.67)	417 (53.12)	0.05[A]
Abdominal obesity, *n* (%)	1989 (71.73)	5423 (72.47)	627 (79.87)	0.001[A]
Elevated blood pressure, *n* (%)	2161 (77.93)	5747 (76.80)	603 (76.82)	NS[A]
Increased glucose concentration, *n* (%)	972 (35.05)	2448 (32.71)	292 (37.20)	0.05[A]
Decreased HDL cholesterol concentration, *n* (%)	866 (31.23)	2328 (31.11)	245 (31.21)	NS[A]
Increased triglycerides concentration, *n* (%)	995 (35.88)	2713 (36.36)	307 (39.11)	NS[A]

NS – non significant, ST – sitting time, PA – physical activity, [A]χ^2 test, [B]Kruskal-Wallis test.

Table 2. The risk of MetS and the prevalence of its components depending on sleep duration (OR (95% CI))

Variable	Gender	≤ 6 h		7–8 h	≥ 9 h	
		Unadjusted	Adjusted	1.0	Unadjusted	Adjusted
MetS	Total	1.02 (0.98–1.06)	1.00 (0.95–1.05)	1.0	**1.11 (1.03–1.20)**	1.04 (0.95–1.27)
	Men	0.99 (0.92–1.08)	0.99 (0.91–1.07)	1.0	**1.18 (1.01–1.38)**	1.14 (0.97–1.35)
	Women	1.04 (0.98–1.10)	1.00 (0.94–1.07)	1.0	**1.16 (1.06–1.26)**	1.05 (0.95–1.16)
Abdominal obesity	Total	0.98 (0.93–1.03)	1.00 (0.94–1.05)	1.0	**1.23 (1.12–1.34)**	**1.16 (1.04–1.28)**
	Men	0.99 (0.92–1.08)	1.03 (0.94–1.12)	1.0	**1.29 (1.08–1.53)**	**1.22 (1.02–1.47)**
	Women	0.97 (0.91–1.03)	0.97 (0.91–1.04)	1.0	**1.19 (1.07–1.32)**	1.10 (0.98–1.27)
Elevated blood pressure	Total	1.03 (0.98–1.09)	1.03 (0.97–1.09)	1.0	1.00 (0.92–1.09)	0.97 (0.88–1.07)
	Men	1.09 (0.96–1.23)	1.11 (0.97–1.26)	1.0	1.05 (0.84–1.33)	1.08 (0.83–1.40)
	Women	1.03 (0.97–1.09)	1.00 (0.93–1.07)	1.0	1.04 (0.95–1.15)	0.99 (0.88–1.10)
Increased glucose concentration	Total	**1.05 (1.01–1.10)**	1.03 (0.98–1.09)	1.0	**1.10 (1.02–1.19)**	1.03 (0.94–1.12)
	Men	0.99 (0.93–1.08)	0.98 (0.91–1.06)	1.0	1.15 (0.99–1.33)	1.07 (0.92–1.24)
	Women	**1.10 (1.03–1.17)**	**1.08 (1.02–1.25)**	1.0	**1.16 (1.06–1.28)**	**1.12 (1.02–1.23)**
Decreased HDL cholesterol concentration	Total	1.00 (0.95–1.05)	0.98 (0.93–1.03)	1.0	1.00 (0.92–1.08)	0.96 (0.88–1.05)
	Men	0.99 (0.91–1.07)	1.02 (0.87–1.19)	1.0	1.00 (0.86–1.16)	0.98 (0.90–1.06)
	Women	1.01 (0.95–1.07)	0.98 (0.92–1.05)	1.0	1.02 (0.93–1.12)	0.96 (0.86–1.07)
Increased triglycerides concentration	Total	0.99 (0.95–1.04)	0.98 (0.93–1.04)	1.0	1.06 (0.98–1.14)	1.03 (0.95–1.12)
	Men	0.96 (0.89–1.04)	0.96 (0.87–1.04)	1.0	1.07 (0.93–1.24)	1.09 (0.94–1.27)
	Women	1.00 (0.94–1.08)	0.99 (0.93–1.06)	1.0	**1.19 (1.08–1.32)**	1.07 (0.96–1.14)

*Numbers in **bold** indicate statistically significant results.*

Results

Individuals who had the shortest sleep duration were more likely to be men than women, they were more often people living in urban areas in comparison to those living in rural areas, and more often people with higher education and living alone in comparison with those in long-term relationships (Table 1). The shortest sleep duration was also connected with those who smoked cigarettes, had longer sitting time, and who drank greater amounts of coffee. Participants declaring 7–8 h of sleep devoted the largest amount of time to moderate physical activity. The longest sleep duration was declared by individuals from the oldest age group, and drinking the least amount of alcohol. In the group of participants sleeping the longest, the highest number of MetS cases was found, as well as abdominal obesity and an increased concentration of glucose. Sleep duration was found not to significantly influence blood pressure or concentration of HDL-cholesterol and triglycerides. The characteristics of the test material divided into sexes was presented in a different paper [30].

In the unadjusted model, short sleep duration (≤ 6 h) was only connected with a higher glucose concentration in the case of women and in the whole group (Table 2). Longer sleep duration (≥ 9 h) was connected with abdominal obesity in all the analysed groups. There were significant connections found between long sleep duration and a higher concentration of glucose in the case of women and in the whole tested group, while a higher level of triglycerides was found only in the women. After adjusting for confounders, a significant relationship was found between a long sleep period and higher risk of abdominal obesity in the whole group, as well as in the group of men. In the case of women, however, both for short and long sleep, there was a higher risk for an occurrence of an increased concentration of glucose.

Discussion

To the best of our knowledge this paper is the first in which the relationship between sleep duration and the risk of MetS and its components is analysed in the population of Poland. The results of the conducted tests show no dependency between short sleep duration (≤ 6 h) and the risk of MetS, despite the fact that many authors have confirmed the presence of such dependencies [9, 12–15, 21, 32]. It should be mentioned, however, that most of these papers applied different definitions of MetS

[9, 12–14, 32], and in some there were also definitions of short sleep duration applied which was less than 6 h per night [15, 21]. Long sleep duration (≥ 9 h) was connected with a higher risk of MetS, but only in the unadjusted model. The dependencies disappear, though, after adjusting for confounders such as age, sex, place of residence, education, marital status, smoking cigarettes, coffee and alcohol consumption, physical activity, and sitting time. Rao *et al.* [33] showed that adhering to physical activity guidelines may mitigate the associations of non-movement behaviours (including sleep time) with MetS, underlining the beneficial role of physical activity to prevent chronic disease risk. The participants of our study, who declared the number of hours of their sleep to be optimal, really devoted more time to moderate physical activities in comparison to those declaring non-adequate sleep duration, which would confirm the above-mentioned suggestions. The analysis of particular components of MetS has shown an association between sleep duration ≥ 9 h and higher risk of abdominal obesity among all the group members and among men. In the group of women, there was a higher risk of increased concentration of glucose in both the short and long sleep duration groups. A similar tendency observed in the whole group did not reach the level of statistical importance. In available publications, the relationships between sleep duration and particular components of MetS are ambiguous. Hairston *et al.* [34] showed that extremes of sleep duration are related to increases in subcutaneous and visceral adipose tissue in persons younger than 40 years old. In younger women (< 40 years), both habitual short and long sleep duration was a risk factor for abdominal obesity, whereas no such relationship was seen in older women [35]. The study of Celis-Morales *et al.* [36] showed that the association between a genetic risk for obesity and phenotypic adiposity measures (including abdominal obesity) is exacerbated by adverse sleeping characteristics. A U-shaped relationship between sleep duration and the risk of impaired fasting glucose, found by us in the group of women, is in accordance with the results of other studies. Lou *et al.* [37] stated that both short (< 6 h) and long (> 8 h) sleep duration increased the risk of impaired fasting glucose in the Chinese population, after adjusting for confounders. Similar U-shaped relationships were noted in both cross-sectional and longitudinal tests in reference to increased risk of impaired glucose tolerance and/or type 2 diabetes [5, 38–42]. Saleh and Jansen [19], however, did not show significant associations between sleep duration and any of the MetS components. It was not confirmed in other papers that there is any connection between sleep duration and increased blood pressure [18, 39] or abnormal concentration of HDL-cholesterol [43], and in the case of triglycerides, such a connection was found only in the group of men [43]. Similarly, in the group tested by us, after adjusting to covariates, there was no relationship found between sleep duration and blood pressure, as well as the concentration of HDL-cholesterol and triglycerides.

The small number of associations between sleep duration and the risk of MetS and its components, which was observed in the participants of our study, does not allow for a more precise determination of whether such dependencies differ according to sex. In the available publications, the problem was seldom analysed separately for men and for women. Contrary to our results, Kim *et al.* [44] found an association between sleep duration and impaired fasting glucose in men but not in women. However, Tuomilehto *et al.* [45] showed that short (≤ 6 h) or long (≥ 8 h) sleep duration is related to an increased risk of type 2 diabetes in middle-aged women, but not in men, which was in accordance with our analyses. Do and Kim [24] noted that only women with short sleep duration (< 7 h/day) exhibited elevated risk factors, such as systolic and diastolic blood pressures and the proportion of hypertension treatments, but not men. Among the participants tested by us, the relationship between sleep duration and blood pressure was not significant for men and for women.

This study has several limitations. First of all, due to the cross-sectional character of the paper, the causal connection between sleep duration and the risk of MetS could not be fully explained. Secondly, sleep duration was assessed by self-report. However, Taheri *et al.* [46] found that self-reported sleep duration and polysomnographic measurement are both stable and highly correlated. Thirdly, we could not assess sleep quality in this study, which, similarly to inadequate duration of sleep, can influence metabolism. Fourthly, we could not take into account the important distracting factor of the caloric value of diets of test participants, which can also be connected with the risk of MetS and its components.

The strengths of this paper are the large number of tested participants and the fact that it was a homogenous group in terms of age and ethnic origin. The analysis took into account many confounding factors such as socio-demographic variables, physical activity, sitting time, smoking, and consumption of coffee and alcohol.

Conclusions

Our research did not confirm the presence of an association between short sleep duration (≤ 6 h) and the risk of MetS, defined in accordance with IDF criteria [31]. Longer sleep duration, ≥ 9 h, was connected with a higher risk of MetS only in the unadjusted model. Sleep duration, however, was associated with some of the MetS components. There was a significant

connection found between sleep duration ≥ 9 h and higher risk of abdominal obesity in the whole group and in men, and a U-shaped relationship between sleep duration and the risk of higher concentration of glucose in women. Therefore, it is necessary to perform further studies in this domain.

Connections between sleep duration and the risk of MetS and its components may vary in the case of men and women, but the achieved results did not allow for the explanation of the role of sex in the formation of these relationships.

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Conflict of interest

The authors declare no conflict of interest.

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