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Sex differences in the relationship between short sleep duration and obesity among koreans

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This cross-sectional study examined the relationship between short sleep duration and obesity by analysing data from 3,950 participants aged 40–69 years who took part in the 2003–2004 follow-up survey of the Korean Genome and Epidemiologic Study. Based on the subjective experience of morning fatigue, short sleep duration was defined as < 5 h of sleep. Short sleep duration was significantly associated with general obesity, as measured by body mass index (adjusted odds ratios [confidence intervals], 1.246 [1.016–1.529]); these associations became stronger as the severity of general obesity worsened. Analysing data separately by sex, we detected a relationship between short sleep duration and general obesity in females only. Considering the impact of age, the relationship was detected only in females aged 40–59 years old. In females aged 40–59 years, both general obesity (1.518 [1.110–2.075]) and neck obesity (1.425 [1.045–1.945]) were associated with short sleep duration. Our study established a correlation between short sleep duration and general obesity, specifically in females and those aged 40–59 years. This finding highlights the importance of adequate sleep to treat and prevent obesity in this demographic group.

Keywords Obesity, Sleep disorders, Age, Asian, Women

It is estimated that by 2035, overweight and obesity will impact more than 4 billion individuals worldwide, in contrast to the over 2.6 billion recorded in 2020, signifying an increase from 38% of the world's population in 2020 to more than 50% by 2035[1]. Sleep disorders are an emerging global health challenge. Globally, 16.6% of individuals experience severe or extreme nocturnal sleep problems, displaying a substantial variation among populations, ranging from 1.6% to over 56.0%[2,3].

Is there a connection between these two epidemics? The association between short sleep duration and obesity has been one of the most extensively researched aspects in this context. As reported in several meta-analyses, the relationship between short sleep duration and obesity remains controversial. While numerous prospective and cross-sectional studies have shown that short sleep duration contributes to the development of obesity, many other studies have found no such relationship[4–6]. This could be attributed to methodological constraints, such as the absence of a standardised definition for short sleep, the use of different obesity measures in various studies, and oversight of aspects related to sleep quality[7]. Furthermore, the association between short sleep duration and obesity can vary based on demographic variables, such as sex and age, and studies that have comprehensively explored these aspects are currently lacking.

In the current study, we investigated the relationship between short sleep duration and obesity in Korean adults using a well-validated national cohort. We objectively defined short sleep duration, assessed the relationship between obesity and short sleep duration using various definitions, and examined the relationship based on sex and age.

Results

Baseline characteristics of the study participants

Table 1 summarises the baseline characteristics of participants according to sex. In addition, Supplement Table 1 shows the baseline characteristics of participants according to the presence and absence of general obesity. In total, this study included 2048 males and 1902 females, with mean ages of 50.2 ± 7.4 and 51.1 ± 8.0 years,

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respectively. Most participants were married and primarily belonged to the 3rd quartile of household income (both males and females). Unlike females, the majority of males were smokers and drinkers.

The mean BMI values were 24.5 ± 2.7 and 24.6 ± 3.0 in males and females, respectively. Based on BMI, the prevalence of general obesity was 41.9 and 42.3% in males and females, respectively,

indicating no significant difference. The prevalence of central obesity, as determined using WC, was 17.1% in males and 13.6% in females, revealing a statistically significant difference ($p = 0.002$). The prevalence of neck obesity was 46.6% in males and 49.5% in females, indicating the absence of a statistically significant difference. Therefore, among the obesity indices, only central obesity showed a significant difference based on sex.

The mean sleep duration was 6.2 ± 1.2 h in males and 5.9 ± 1.3 h in females, and the difference was statistically significant ($p < 0.001$). The proportion of < 5 h of sleep was significantly higher in females (13.6%) than that in males (8.9%) ($p < 0.001$). However, the proportion of waking up tired in the morning was significantly lower in females (8.7%) than in males (12.1%) ($p < 0.001$).

Based on laboratory data, haemoglobin A1C > 6.5% was detected in 8.8% of males and 6.9% of females ($p = 0.031$). Additionally, low-density lipoprotein (LDL) cholesterol ≥ 150 mg/dL was detected in 17.4% of males and 26.6% of females ($p < 0.001$), while 30.5% of males and 59.4% of females had low high-density lipoprotein (HDL) cholesterol values ($p < 0.001$). In both males and females, hypertension was identified as the most common comorbidity. Diabetes, arthritis, and gastritis or gastric ulcers were also detected as common comorbidities. Gastritis or gastric ulcer and arthritis were significantly more common in females, while diabetes was significantly more common in males.

Associations between short sleep duration and different obesity indices

Table 2 presents the association between short sleep duration and obesity indices in the study participants. Short sleep duration was significantly associated with general obesity, as measured by BMI (aOR [CI], 1.246 [1.016–1.529]), and these associations between short sleep duration and BMI were strengthened with increasing severity of general obesity. However, short sleep duration was not related to central obesity, as measured by WC. Furthermore, neck obesity, as assessed by NC, revealed a tendency to be associated with short sleep duration (aOR [CI], 1.221 [0.995–1.499]). Notably, in cases where only neck or general obesity was present individually, no significant association was observed between short sleep duration and obesity. However, the coexistence of neck and general obesity revealed a significant relationship between short sleep duration and obesity (aOR [CI], 1.304 [1.039–1.637]). Accordingly, the relationship between short sleep duration and general obesity was only evident when general obesity was associated with neck obesity.

Table 3 shows the association between short sleep duration and different obesity indices according to sex. Among females, short sleep duration was significantly associated with general obesity (aOR [CI], 1.435 [1.088–1.892]), and this association strengthened with higher BMI values. Neck obesity tended to be associated with short sleep duration (aOR [CI], 1.307 [0.991–1.722]). In participants with neck or general obesity alone, no association between short sleep duration and obesity was detected. However, the coexistence of types of neck and general obesity revealed a significant relationship between short sleep duration and obesity among female participants (aOR [CI], 1.496 [1.096–2.042]). In addition, there was no statistically significant association between short sleep duration and central obesity, as assessed by WC, among females. As shown in Supplementary Table 2, there was no association between these short sleep duration and obesity in males. Figure 1 summarises these findings and presents the association between short sleep duration and different types of obesity.

BMI, body mass index.

Various factors associated with short sleep duration other than obesity among the study participants

Supplementary Table 3 presents the various factors other than obesity associated with short sleep duration in all study participants. No variable was positively associated with short sleep duration, but higher monthly income was negatively associated with short sleep duration.

Analysing factors exclusively among female participants, university level or higher education (aOR [CI], 1.556 [1.042–2.324]) was the only factor associated with short sleep duration (Supplementary Table 4). Among male participants, higher monthly income was negatively associated with shorter sleep duration (Supplementary Table 5).

Impact of age on the relationship between short sleep duration and obesity

Table 4 presents the effect of age on the relationship between short sleep duration and obesity according to sex. Females aged 40–59 years exhibited a significant association between obesity, both general (aOR [CI], 1.518 [1.110–2.075]) and neck (aOR [CI], 1.425 [1.045–1.945]) obesity and short sleep duration. Moreover, this group showed a tendency towards a correlation between central obesity and short sleep duration (aOR [CI], 1.476 [0.930–2.342]). In contrast, females aged ≥ 60 years did not.

display any significant association between obesity and short sleep duration. However, the *p*-values for interactions between age groups were not significant. Among males, age did not impact the association between obesity and short sleep duration (Supplementary Table 6).

Discussion.

In the current study, we investigated the correlation between short sleep duration, defined as < 5 h of sleep, and obesity among adult Koreans. Obesity was categorised into general, central, and neck obesity, and the association was analysed with respect to sex.

The baseline characteristics of the study participants can be summarised as follows (Table 1 and Supplementary Table 1). Considering the study included participants, the prevalence of general obesity based on BMI was 41.9% in males and 42.3% in females. The prevalence of central obesity based on WC was 17.1% in males and 13.6% in

Characteristics	Male No. (%) or Mean ± SD	Female No. (%) or Mean ± SD	*p*-value
N	2,048 (51.8)	1,902 (48.2)	
Age (years), Mean ± SD	50.2 ± 7.4	51.1 ± 8.0	< 0.001
Age (years) (%)			
40–59	1749 (85.4)	1554 (81.7)	0.002
≥60	299 (14.6)	348 (18.3)	
Education (%)			
≤High school	1395 (68.1)	1689 (88.8)	< 0.001
University or higher	650 (31.7)	209 (11.0)	
BMI (kg/m^2), Mean ± SD	24.5 ± 2.7	24.6 ± 3.0	0.204
Waist Circumference (3 times mean, cm), Mean ± SD	83.2 ± 7.2	76.8 ± 7.6	< 0.001
Neck Circumference (cm), Mean ± SD	37.7 ± 2.1	33.0 ± 1.8	< 0.001
BMI (kg/m^2) (%)			
Non-obese (< 25)	1190 (58.1)	1098 (57.7)	0.811
Obese (≥ 25)	858 (41.9)	804 (42.3)	
Waist Circumference (cm) (%)			
Non-obese (< 90 for male,<85 for female)	1698 (82.9)	1644 (86.4)	0.002
Obese (≥ 90 for male, ≥ 85 for female)	350 (17.1)	258 (13.6)	
Neck circumference (cm) (%)			
Non-obese (< 38 for male, < 33 for female)	1093 (53.4)	960 (50.5)	0.069
Obese (≥ 38 for male, ≥ 33 for female)	955 (46.6)	942 (49.5)	
Currently married (%)			
Yes	1989 (97.1)	1653 (86.9)	< 0.001
No (including divorced, separated, never married)	59 (2.9)	249 (13.1)	
Occupation (%)			
Office worker	847 (41.4)	231 (12.1)	< 0.001
Service workers/Sellers	278 (13.6)	271 (14.2)	
Agriculture/Fishery/Labour	677 (33.1)	126 (6.6)	
None	245 (12.0)	1274 (67.0)	
Household income (quartiles)			
1st (lowest)	196 (9.6)	401 (21.1)	< 0.001
2nd	497 (24.3)	488 (25.7)	
3rd	979 (47.8)	784 (41.2)	
4th (highest)	375 (18.3)	228 (12.0)	
Smoking (pack-years) (%)			
Non-smoker	442 (21.6)	1828 (96.1)	< 0.001
< 10 pack-years	339 (16.6)	57 (3.0)	
≥10, < 20 pack-years	400 (19.5)	13 (0.7)	
≥20, < 30 pack-years	428 (20.9)	3 (0.2)	
≥30 pack- years	438 (21.4)	1 (0.1)	
Drinking amount (%)			
Non-drinker	340 (16.6)	1199 (63.0)	< 0.001
<20 g/day for males (< 10 g/day for females)	832 (40.6)	553 (29.1)	
≥20 g/day for males (≥ 10 g/day for females)	862 (42.1)	141 (7.4)	
Sleep			
Sleep duration (hours/day), Mean ± SD	6.2 ± 1.2	5.9 ± 1.3	< 0.001
Sleep duration (< 5 h) (%)	183 (8.9)	259 (13.6)	< 0.001
Waking-up tired			
No	1800 (87.9)	1737 (91.3)	< 0.001
Yes	248 (12.1)	165 (8.7)	
Regular exercise (%)	1160 (56.6)	1048 (55.1)	0.330
Laboratory data (%)			
HbA1c% >6.5	180 (8.8)	132 (6.9)	0.031
FBS (mg/dL) ≥ 126	74 (3.6)	46 (2.4)	0.015
TC (mg/dL) ≥ 200	951 (46.4)	1001 (52.6)	< 0.001
HDL-C (mg/dL) < 40 for male, < 50 for female	624 (30.5)	1130 (59.4)	< 0.001
Continued			

Characteristics	Male No. (%) or Mean ± SD	Female No. (%) or Mean ± SD	*p*-value
LDL-C (mg/dL) ≥ 150	357 (17.4)	505 (26.6)	< 0.001
Comorbidities (%)			
Hypertension	164 (8.0)	174 (9.1)	0.200
Diabetes	79 (3.9)	46 (2.4)	0.010
Arthritis	8 (0.4)	53 (2.8)	< 0.001
Gastritis or gastric ulcer	39 (1.9)	55 (2.9)	0.042

Table 1. Baseline characteristics of the participants according to sex ($N = 3,950$). Regular exercise was defined as exercising more than twice a week, regardless of intensity; comorbidities were considered only if participants were receiving active therapy. *FBS* fasting blood sugar, *HbA1c* haemoglobin A1C, *HDL-C* high-density lipoprotein cholesterol, *LDL-C* low-density lipoprotein cholesterol. *SD* standard deviation, *TC* total cholesterol.

	Total No. (%)	Sleep ≥ 5 h No. (%)	Sleep < 5 h No. (%)	*p*-value	OR	95% CI	*p*-value	aOR	95% CI	*p*-value
N	3950 (100.0)	3508 (88.8)	442 (11.2)							
General obesity										
Non-obese	2288 (57.9)	2057 (58.6)	231 (52.3)	0.011	Ref			Ref		
Obese	1662 (42.1)	1451 (41.4)	211 (47.7)		1.295	1.062–1.579	0.011	1.246	1.016–1.529	0.035
BMI group (kg/m^2)										
<18.5	39 (1.0)	33 (1.0)	6 (1.0)	0.014	1.843	0.754–4.502	0.180	1.871	0.754–4.642	0.176
18.5–22.9	1147 (29.0)	1044 (31.4)	103 (16.5)		Ref		0.015	Ref		0.061
23.0–24.9	1102 (27.9)	980 (29.5)	122 (19.6)		1.262	0.957–1.664	0.099	1.285	0.970–1.702	0.080
25.0–29.9	1510 (38.2)	1324 (39.8)	186 (29.8)		1.424	1.105–1.836	0.006	1.407	1.083–1.828	0.011
≥ 30	152 (3.8)	127 (3.8)	25 (4.0)		1.995	1.242–3.206	0.004	1.711	1.052–2.784	0.030
Central obesity										
Non-obese	3342 (84.6)	2973 (84.7)	369 (83.5)	0.487	Ref			Ref		
Obese	608 (15.4)	535 (15.3)	73 (16.5)		1.099	0.841–1.436	0.488	1.026	0.776–1.357	0.855
Neck obesity										
Non-obese	2053 (52.0)	1847 (52.7)	206 (46.6)	0.0165	Ref			Ref		
Obese	1897 (48.0)	1661 (47.3)	236 (53.4)		1.274	1.045–1.553	0.017	1.221	0.995–1.499	0.055
General vs. Neck obesity										
Non-obese	1776 (45.0)	1598 (48.0)	178 (28.5)	0.0317	Ref		0.0317	Ref		0.092
General obesity only	277 (7.0)	249 (7.5)	28 (4.5)		1.010	0.663–1.537	0.965	0.973	0.636–1.489	0.899
Neck obesity only	512 (13.0)	459 (13.8)	53 (8.5)		1.037	0.750–1.433	0.828	0.996	0.718–1.384	0.983
Both obesity	1385 (35.1)	1202 (36.1)	183 (29.3)		1.367	1.098–1.702	0.005	1.304	1.039–1.637	0.022

Table 2. Associations between short sleep duration and different obesity indices in the study participants ($N = 3,950$). General obesity was defined as body mass index (BMI) ≥ 25 kg/m^2; central obesity was defined as a waist circumference of ≥ 90 cm in males and ≥ 85 cm in females; neck obesity was defined as a neck circumference of ≥ 38 cm in males and ≥ 33 cm in females. Adjusted for age, sex, education, marital status, income, smoking, alcohol consumption, baseline HbA1c, arthritis treatment, and gastrointestinal disease treatment. *aOR* adjusted odds ratio, *BMI* body mass index, *CI* confidence interval, *OR* odds ratio, *Ref* reference.

females. The prevalence of neck obesity based on NC was 46.6% in males and 49.5% in females. The prevalence of general obesity among the study participants appears to reflect the global prevalence[1]. However, compared to recent data on obesity prevalence among Korean adults, the obesity prevalence in men in our study was slightly lower (41.9% vs. 49.2%), while the prevalence in women was notably higher (42.3% vs. 27.8%)[8]. This.

likely reflects the regional characteristics of the cohort and suggests that our study population included a higher proportion of obese women compared to the national average for Korean women.

To the best of our knowledge, no comprehensive study has reported the global prevalence of neck obesity. Nevertheless, the prevalence of general and neck obesity seemed to coincide among the study participants. Intriguingly, the prevalence of central obesity was lower than that of both general and neck obesity. Notably, Asians appear to have a lower prevalence of central obesity than the recently reported global prevalence of central obesity of 41.5% [9]. The mean sleep duration for our participants was 6.2 ± 1.2 and 5.9 ± 1.3 h in males and females, respectively. The prevalence of short sleep duration, defined as a sleep duration of < 5 h in the current study, was significantly higher in females (13.6%) than in males (8.9%). Reportedly, Korean adults sleep for shorter durations than individuals worldwide[10].

	Total No. (%)	Sleep ≥ 5 h No. (%)	Sleep < 5 h No. (%)	*p*-value	OR	95% CI	*p*-value	aOR	95% CI	*p*-value
N	1902 (100.0)	1643 (86.4)	259 (13.6)							
General obesity										
Non-obese	1098 (57.7)	972 (59.2)	126 (48.6)	0.002	Ref			Ref		
Obese	804 (42.3)	671 (40.8)	133 (51.4)		1.529	1.176–1.989	0.002	1.435	1.088–1.892	0.011
BMI (kg/m^2)										
<18.5	13 (0.7)	10 (0.6)	3 (1.2)	0.001	2.784	0.745–10.410	0.128	2.392	0.628–9.106	0.201
18.5–22.9	586 (30.8)	529 (32.2)	57 (22.0)		Ref		0.002	Ref		0.019
23.0–24.9	499 (26.2)	433 (26.4)	66 (25.5)		1.415	0.971–2.061	0.071	1.376	0.938–2.019	0.103
25.0–29.9	707 (37.2)	596 (36.3)	111 (42.9)		1.728	1.230–2.429	0.002	1.631	1.142–2.330	0.007
≥ 30	97 (5.1)	75 (4.6)	22 (8.5)		2.722	1.574–4.710	< 0.001	2.343	1.324–4.144	0.003
Central obesity										
Non-obese	1644 (86.4)	1431 (87.1)	213 (82.2)	0.034	Ref			Ref		
Obese	258 (13.6)	212 (12.9)	46 (17.8)		1.458	1.027–2.068	0.035	1.200	0.821–1.752	0.347
Neck obesity										
Non-obese	960 (50.5)	848 (51.6)	112 (43.2)	0.012	Ref			Ref		
Obese	942 (49.5)	795 (48.4)	147 (56.8)		1.400	1.075–1.823	0.013	1.307	0.991–1.722	0.058
General vs. Neck obesity										
Non-obese	822 (43.2)	727 (44.2)	95 (36.7)	0.005	Ref		0.006	Ref		0.032
General obesity only	138 (7.3)	121 (7.4)	17 (6.6)		1.075	0.620–1.865	0.797	1.008	0.575–1.767	0.978
Neck obesity only	276 (14.5)	245 (14.9)	31 (12.0)		0.968	0.630–1.489	0.883	0.922	0.595–1.427	0.714
Both obesity	666 (35.0)	550 (33.5)	116 (44.8)		1.614	1.204–2.163	0.001	1.496	1.096–2.042	0.011

Table 3. Associations between short sleep duration and different obesity indices among females (N = 1902). General obesity was defined as body mass index (BMI) ≥ 25 kg/m^2; central obesity was defined as a waist circumference of ≥ 90 cm in males and ≥ 85 cm in females; neck obesity was defined as a neck circumference of ≥ 38 cm in males and ≥ 33 cm in females. Adjusted for age, sex, education, marital status, income, smoking, alcohol consumption, baseline HbA1c, arthritis treatment, and gastrointestinal disease treatment. *aOR* adjusted odds ratio, *BMI* body mass index, *CI* confidence interval, *OR* odds ratio, *Ref* reference.

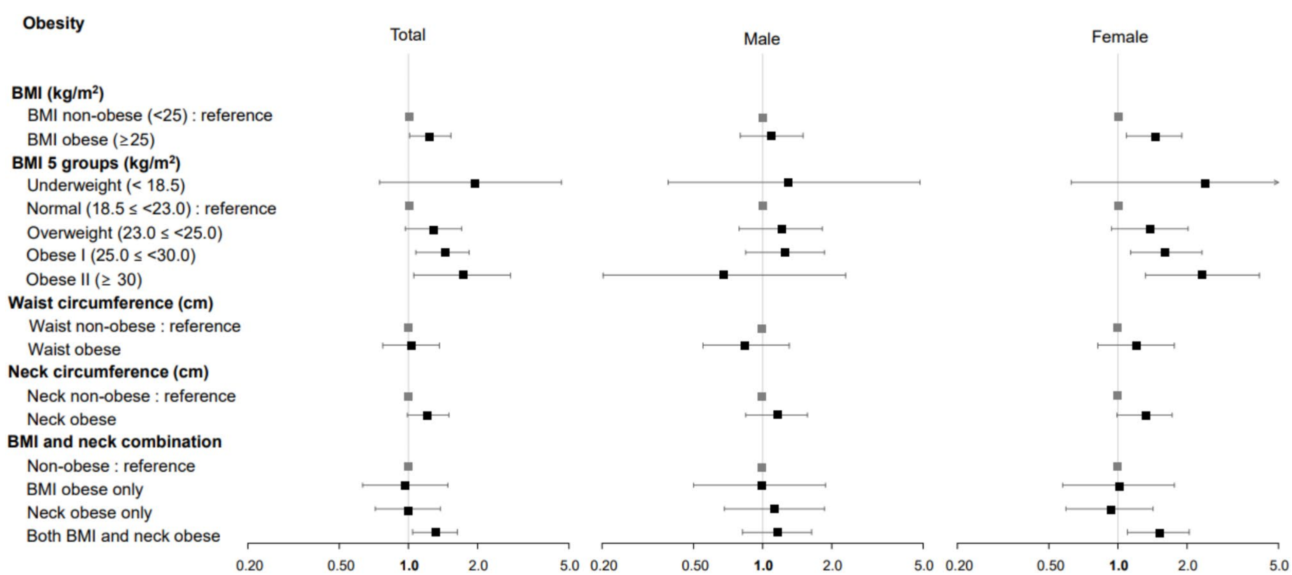

Fig. 1. Associations between short sleep duration and different types of obesity.

On examining the association between short sleep duration and different obesity indices, we found that short sleep duration was significantly associated with general obesity, and this association became stronger as the severity of general obesity worsened. Short sleep duration was not related to central or neck obesity; however, neck obesity tended to be associated with short sleep duration. Intriguingly, an association between short sleep duration and general obesity was observed only in the presence of neck obesity. In other words, in cases in which only general obesity existed without the presence of neck obesity, this association disappeared (Table 2).

	Age 40–59 years (N = 1554)			Age ≥ 60 years (N = 348)			
	aOR	95% CI	p-value	aOR	95% CI	p-value	p-for interaction
General Obesity							
Non-obese	Ref			Ref			
Obese	1.518	1.110–2.075	0.009	1.054	0.593–1.872	0.859	0.273
Central Obesity							
Non-obese	Ref			Ref			
Obese	1.476	0.930–2.342	0.098	0.812	0.439–1.50	0.506	0.124
Neck Obesity							
Non-obese	Ref			Ref			
Obese	1.425	1.045–1.945	0.025	0.899	0.504–1.603	0.718	0.166

Table 4. Effect of age on the association between obesity and sleep deprivation among female participants (N = 1902). General obesity was defined as body mass index (BMI) ≥ 25 kg/m^2; central obesity was defined as a waist circumference of ≥ 90 cm in males and ≥ 85 cm in females; neck obesity was defined as a neck circumference of ≥ 38 cm in males and ≥ 33 cm in females. Adjusted for age, sex, education, marital status, income, smoking, alcohol consumption, baseline HbA1c, arthritis treatment, and gastrointestinal disease treatment. *aOR* adjusted odds ratio, *CI* confidence interval, *Ref* reference.

Neck obesity, assessed using NC, has recently gained acceptance as an obesity index and has also been shown to be associated with metabolic syndrome, insulin resistance, and cardiovascular disease[11,12]. In addition, neck obesity is a well-recognised indicator of the presence and severity of obstructive sleep apnoea (OSA) because individuals with a thicker neck might have a narrower airway, which could hinder smooth airflow from the throat to the lungs during sleep[13–16]. Considering the high prevalence of OSA among individuals with obesity and its potential to impair sleep quality, it can be inferred that OSA might have contributed to the observed associations between general obesity and short sleep duration to a certain extent in this study. However, given the absence of data regarding whether the participants had sleep apnoea, we were unable to delve deeper into this possibility. Notably, we did not detect a relationship between short sleep duration and central obesity, which could be attributed to the low prevalence of central obesity in our study participants. Moreover, the low prevalence of central obesity among Asians has been well-documented[9]. Considering that several studies have reported an association between short sleep duration and central obesity, as reviewed in a recent meta-analysis, our findings warrant further investigation[17].

Considering another intriguing discovery in the current study, the relationship between short sleep duration and general obesity was only noticeable among females, as determined by conducting a further analysis based on sex (Table 3). Our findings imply that the correlation between short sleep duration and obesity could potentially differ based on sex in Korean adults. This observation has not been previously documented, thereby warranting further clarification.

Here, women appeared to be more susceptible to obesity resulting from sleep deprivation; however, we were unable to explain this. As shown in Table 1, there were a few differences in baseline characteristics, such as education, income, occupation, smoking, alcohol consumption, and comorbidities, between men and women. However, since our analysis controlled for all these baseline characteristics, these differences cannot account for the observed sex disparity. Further research is warranted to explore this issue, and most importantly, to investigate whether the association between short sleep duration and obesity is also more pronounced in women in non-Korean populations.

The mechanisms underlying the relationship between short sleep duration and obesity primarily involve disrupted eating habits and unhealthy lifestyle choices linked to endocrine shifts in response to inadequate sleep[17–22]. Inadequate sleep may lead to increased tendencies for disinhibited eating behaviours, heightened susceptibility to hunger, decreased engagement in vigorous physical activities, elevated consumption of dietary fats, and increased alcohol intake, all of which collectively contribute to the development of overweight and obesity[18–21]. Furthermore, elevated concentrations of the appetite-inducing hormone ghrelin, reduced levels of the appetite-suppressing hormone leptin, and compromised glucose tolerance associated with experimentally restricted sleep are deemed potential underlying endocrine mechanisms contributing to the development of overweight due to insufficient sleep[17,22]. As no previous study has examined the relationship between sleep deprivation and obesity by sex, as in this study, we speculate that females experiencing shorter sleep durations could be more vulnerable to the aforementioned changes.

Next, we examined the influence of age (40–59 years vs. ≥60 years) on the relationship between obesity and short sleep duration. Herein, we found that 40–59 years of age could contribute to the association between short sleep duration and general obesity among female participants (see Table 4). Notably, females aged 40–59 years demonstrated a significant relationship not only between general obesity and short sleep duration but also between neck obesity and short sleep duration. Moreover, we observed a tendency towards a correlation between central obesity and short sleep duration within this group. Therefore, middle-aged females with short sleep duration appear to be the most vulnerable to developing obesity. This finding potentially indicates that female hormones may play a role in the association between short sleep duration and obesity. However, given that the age-based analysis failed to reveal a significant p-value for interaction, the interpretation should be approached carefully. Therefore, the role of age in the association between short sleep duration and obesity needs to be further explored. Notably, a 10-year follow-up study has reported the role of age in the relationship between sleep duration and obesity in females. The authors investigated the association between obesity and either short or long sleep duration, and only females were studied. Short sleep duration was defined as < 6 h of sleep and long sleep duration as ≥ 9 h of sleep. Only females < 40 years of age, including both habitual short sleepers and habitual long sleepers, had a higher prevalence of central obesity than habitual normal sleepers[23]. Given that our study participants were ≥ 40 years of age, a direct comparison with the above-discussed study was not possible. Taken together, young and middle-aged females may be more susceptible to developing obesity in response to inadequate sleep duration.

Furthermore, we explored the relationship between short sleep duration and diverse variables. Apart from obesity, few significant relationships were observed in either the total group or subgroups of females and males (Supplementary Tables 3–5). It should be noted that short sleep duration had a minimal impact on other variables. Particularly among female participants, short sleep duration was not correlated with metabolic abnormalities related to obesity, such as diabetes and high cholesterol levels, despite the association between general obesity and short sleep duration. This may be explained by the low prevalence of central obesity in our study group.

This study has a few limitations that need to be addressed. Information on sleep duration was self-reported through a questionnaire; thus, the accuracy of sleep duration data cannot be ensured. In addition, sleep quality can vary substantially among individuals, even at similar sleep durations. These differences in sleep quality may have influenced the results of our study. Our definition of short sleep duration was based on not only the number of sleep hours but also the subjective experience of morning fatigue. Thus, we believe that potential biases in this regard were minimised in our study. In conclusion, short sleep duration was associated with general obesity, and this association was strengthened when the severity of general obesity worsened. Individual analyses based on sex and age revealed that this association was maintained only in females, particularly in middle-aged females aged 40–59 years. Therefore, our study underscores the critical importance of acquiring an adequate amount of sleep to prevent and treat obesity, with particular emphasis on the demographics of middle-aged females. Additionally, the cross-sectional study design prevents the establishment of causal relationships. Consequently, reverse causation or bidirectional associations are possible; for example, short sleep duration might be a consequence of obesity.

Methods

Study population, design, and ethical consideration

This cross-sectional study analysed data from the Korean Genome and Epidemiology Study (KoGES). KoGES was launched by the Korean Center for Disease Control and Prevention in 2001 and is based on two distinct communities in South Korea: the Ansung cohort, which represents a rural community, and the Ansan cohort, which represents an urban community. Individuals aged 40–69 years were recruited from the national health examination registry of each community. The primary objective of the KoGES was to investigate the epidemiological characteristics, prevalence, and factors influencing chronic diseases among Koreans. Participants in the cohort underwent a thorough health examination and questionnaire-based interviews. The health examination included anthropometric and clinical assessments, and the questionnaire collected data on demographic characteristics, lifestyle, and medical history. Follow-up examinations were conducted biennially during scheduled site visits[24].

Our study targeted the Ansan cohort, given that neck circumference (NC) data were required and were available for this cohort only. The Ansan cohort began in 2001–2002 with a total of 5,015 participants; however, NC measurements were initiated from 2003 to 2004. Therefore, the current study included data on the 4,023 participants from the 2003–2004 cohort. Of the 4,023 participants, we included 3,950 individuals in the analysis, excluding 6 participants with missing sleep-related data and 67 participants with missing obesity-related data (Fig. 2).

Definition and measurement of important variables

General obesity was defined as BMI ≥ 25 kg/m^2 according to the Asian-specific cutoffs[25,26]. In accordance with a Korean guideline, central obesity was defined as waist circumference (WC) ≥ 90 cm in males and ≥ 85 cm in females[27]. Neck obesity was defined by NC ≥ 38 cm in males and ≥ 33 cm in females, as recommended in Korean adults[28]. WC was measured at the midpoint between the.

lower rib margin and the iliac crest in the standing position. NC was measured by placing the superior border of a tape measure immediately below the laryngeal prominence and applying it perpendicularly to the long axis of the neck.

Accumulated evidence has suggested an association between short sleep duration, indicating insufficient sleep, and obesity. However, the definition of short sleep duration varied considerably across different studies[4–6,23]. Thus, to establish an appropriate definition for short sleep duration, we first surveyed all participants regarding their average sleep duration and how they felt upon waking up in the morning. Among the respondents, 2,563 (64.9%) reported an average sleep duration of ≥ 6 h but < 7 h; 1,237 (31.3%) reported an average sleep duration of ≥ 5 h but < 6 h; and 442 (11.2%) reported a sleep duration of < 5 h. Participants who were asleep for < 5 h reported experiencing fatigue upon waking up in the morning, accounting for 88.8% of those involved. Among participants, 68.7% of those with an average sleep duration of ≥ 5 h but < 6 h reported feeling fatigued upon waking up in the morning, while 35.1% of those with an average sleep duration of ≥ 6 h but < 7 h reported the same. Accordingly, we defined short sleep duration as having less than 5 h of sleep.

Blood was drawn for biochemical analyses after overnight fasting. Comorbidities were considered only when participants were receiving active therapy. Regular exercise was defined as exercising more than twice a week, regardless of the intensity.

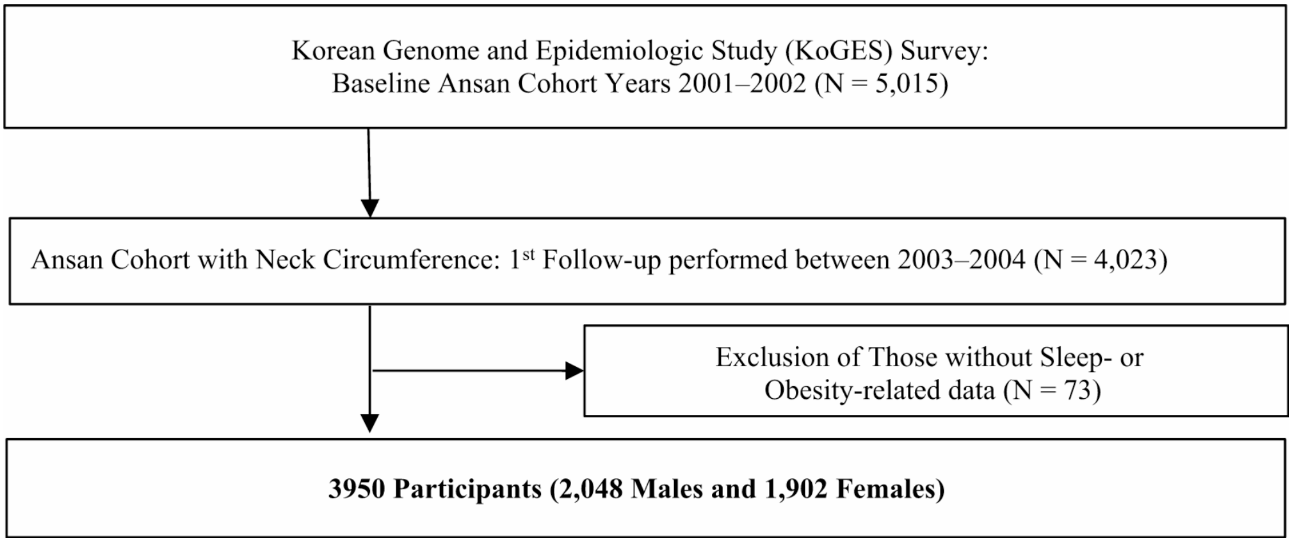

Fig. 2. Flow diagram depicting participant selection and the number of participants.

Statistical analysis
Baseline characteristics were compared between the groups using t-tests and chi-square tests. Data are presented as mean ± standard deviation (SD) values for continuous variables or as frequencies and proportions for categorical variables. Logistic regression analyses were conducted to explore the association between these variables and short sleep duration. All variables with p-values < 0.1 in the univariate analysis and clinically significant variables were included in a multiple logistic regression analysis. Furthermore, a subgroup analysis was conducted by performing an interaction test between the p-values and age group. The participants were stratified into two age groups: those aged 40–59 years and those aged 60 years or older (≥ 60 years). The results were reported as adjusted odds ratios (aORs) and 95% confidence intervals (CIs). To impute missing values, a single imputation procedure was applied using the mean for numeric variables and mode for categorical variables. Data were analysed using the SAS software (version 9.4; SAS Institute, Inc., Cary, NC, USA). Statistical significance was set at $p < 0.05$.

Data availability
Data is provided within the manuscript or supplementary information files.

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Author contributions
Y Kim, Y Kim, S Kim and W Cho prepared Tables 1, 2, 3, 4 and 5 and Fibures 1-2.Y Kim and W Cho wrote the main manuscript text.All authors reviewd the munuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
All subjects voluntarily participated in the study and provided informed consent. The study protocol was approved by the Ethics Committee of KoGES at the Korean National Institute of Health and the Institutional Review Board of Asan Medical Center (IRB: 2022-0615). In addition, this study was conducted in accordance with the relevant guidelines and regulations of the Declaration of Helsinki.

Additional information
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