

# BMJ Open Joint effects of self-reported sleep and modifiable physical activity on risk of dyslipidaemia in women aged 45–55 years: a cross-sectional study

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## ABSTRACT

**Objectives** Modifiable physical activity (PA) plays an important role in dyslipidaemia risk in middle-aged women with sleep problems, especially perimenopausal women. We aimed to explore the joint effects of sleep and PA on the risk of dyslipidaemia in women aged 45–55 years, and the extent to which PA moderated the effect of sleep on the risk of dyslipidaemia.

**Design** A cross-sectional study.

**Setting** This study was based on the survey of Chronic Disease and Nutrition Monitoring in Adults in Inner Mongolia in 2015.

**Participants** 721 women aged 45–55 years were included.

**Outcome measurement** PA was measured by the Global Physical Activity Questionnaire. Sleep was measured by questionnaire formulated by the Chinese Center for Disease Control and Prevention. Multivariate logistic regression analyses were performed to determine the joint effects of sleep and PA on dyslipidaemia risk. OR and 95% CI were reported.

**Results** Among all participants, 60.6% had sleep problems, 29.0% had low PA and 41.1% had dyslipidaemia. Women with sleep problems had higher dyslipidaemia risk than women without sleep problems, irrespective of low, moderate or high PA, with OR (95% CI) of 4.24 (2.40 to 7.49), 3.14 (1.80 to 5.49) and 2.04 (1.20 to 3.48), respectively. PA could not completely attenuate the negative association between sleep and dyslipidaemia risk. With PA increased from low to high, the OR of dyslipidaemia decreased by 2.20. Women with sleep problems and low PA had higher risks of high total cholesterol, high triglyceride, low high-density lipoprotein cholesterol and high low-density lipoprotein cholesterol than women without sleep problems and high PA, with OR (95% CI) of 2.51 (1.18 to 5.35), 2.42 (1.23 to 4.74), 2.88 (1.44 to 5.74) and 2.52 (1.12 to 5.70), respectively.

**Conclusions** Among women aged 45–55 years, the joint effects of self-reported sleep and PA on dyslipidaemia risk were more marked for sleep than for PA. Modifiable PA is a widely accessible and effective intervention to reduce the dyslipidaemia risk in women with sleep problems, particularly among perimenopausal women.

## Strengths and limitations of this study

- This study was based on the survey of Chronic Disease and Nutrition Monitoring in Adults, covered urban, agricultural and pastoral areas in Inner Mongolia. The participants were recruited consecutively used multistage stratified cluster random sampling, which were generally representative.
- The study explored the joint effects of sleep and physical activity (PA) on the risk of dyslipidaemia in women aged 45–55 years, and the extent to which PA moderated the effect of sleep on the risk of dyslipidaemia.
- Due to the cross-sectional design of the study, associations between self-reported sleep, PA and the risk of dyslipidaemia can be inferred but not causality.

## INTRODUCTION

Dyslipidaemia is a major risk factor for cardiovascular disease.<sup>1,2</sup> Elevated low-density lipoprotein cholesterol (LDL-C) accounted for 4.32 million deaths and 94.9 million disability-adjusted life years worldwide in 2017.<sup>3</sup> Furthermore, elevated total cholesterol (TC) and triglyceride (TG) can increase the risk of type 2 diabetes mellitus,<sup>4</sup> and reduced high-density lipoprotein cholesterol (HDL-C) can worsen the outcomes of patients with coronary heart disease.<sup>5</sup>

Dyslipidaemia includes elevated TC, elevated TG, elevated LDL-C and low HDL-C.<sup>6</sup> Risk factors of dyslipidaemia includes age,<sup>7</sup> low oestrogen levels,<sup>8</sup> sleep disorder,<sup>9</sup> smoking<sup>10</sup> and insufficient aerobic exercise.<sup>11</sup> Among perimenopausal women, aged 45–55 years,<sup>12,13</sup> with decreasing oestrogen levels, the incidence of dyslipidaemia has increased significantly.<sup>14,15</sup> The prevalence of dyslipidaemia was reported to be 38.7% among middle-aged and elderly women in China.<sup>16</sup> Thus, identifying modifiable risk factors for dyslipidaemia is very important for public health.

Sleep problems tend to become more common in middle-aged and elderly women, and include difficulty in falling asleep, early awakening and awakening during the night.<sup>17–20</sup> Poor sleep quality was significantly associated with an increased risk of dyslipidaemia.<sup>21–22</sup> Poor sleep quality was also correlated with high TG and TC,<sup>23</sup> but negatively correlated with HDL-C.<sup>24</sup> A potential mechanism for the associations may be that women in the perimenopausal period, had gradually decreasing hormone levels when their sleep problems occurred, leading to dyslipidaemia.<sup>25</sup>

Physical activity (PA) is a modifiable and conventional influencing factor for dyslipidaemia. Several studies demonstrated that low PA had adverse effects on prevalence of dyslipidaemia.<sup>16–26</sup> HDL-C was found to increase after PA intervention.<sup>27</sup> PA led to high energy consumption, which reduced the level of TG.<sup>28</sup> For patients with dyslipidaemia, increased PA significantly reduced their risk of death.<sup>29</sup>

There is some evidence that the association between sleep and PA is bidirectional. Moderate-to-vigorous intensity PA was associated with better sleep quality.<sup>30–31</sup> Poor sleep quality limited PA,<sup>32</sup> and sleep problems were associated with insufficient PA.<sup>33</sup> Therefore, the mechanism for the effects of sleep and PA on dyslipidaemia is very complex.

PA is a modifiable lifestyle factor, but sleep problems are important symptoms of neurological diseases that are difficult to regulate.<sup>34</sup> Casas *et al*<sup>35</sup> reported significant linear trends in TG and HDL-C among leisure-time activity and sleep quality categories in middle-aged women. However, little is known about the associations of PA, including occupational, transition and leisure-time activity, and sleep with risk of dyslipidaemia in women aged 45–55 years. This study aimed to explore the joint effects of sleep and PA on the risk of dyslipidaemia in women aged 45–55 years, and the extent to which PA moderated the effect of sleep on the risk of dyslipidaemia to provide some effective suggestions for the management of dyslipidaemia in perimenopausal women.

## METHODS

### Design and setting of the study

The data for this cross-sectional study were collected from the survey of Chronic Disease and Nutrition Monitoring in Adults in Inner Mongolia in 2015, conducted by the Chinese Center for Disease Control and Prevention (CDC). The survey was conducted across eight monitoring sites, covered urban, agricultural and pastoral areas in Inner Mongolia. Participants, aged  $\geq 18$  years were selected by multistage-stratified cluster random sampling. All participants received on-site investigations that included questionnaires, anthropometric measurements and fasting blood sample collections.

Women aged 45–55 years were enrolled in the present study (n=821). Subsequently, 100 women were excluded for missing weight, height or waist circumference data

(n=25), missing serum lipid testing data (n=8), missing alcohol drinking data (n=1), reporting that they did not drink but indicating alcohol intake (n=32) and having mean total PA time exceeding 1440 min/day (n=34). Finally, a total of 721 women were included in the study.

### Data collection

The questionnaire used in the study was from Chinese CDC and evaluated by experts, with high reliability and validity. General information including age, ethnicity, educational level, marital status and residence, lifestyle variables including smoking status, alcohol drinking status, sleep and PA, and history of dyslipidaemia were obtained by trained investigators through face-to-face interviews.

Anthropometric data including height, weight and waist circumference were measured by trained investigators. Fasting venous blood samples were collected by trained laboratory staff members.<sup>36</sup>

### Measurements

#### Dyslipidaemia definition

Dyslipidaemia was defined as having any one of the following: high TC (serum TC  $\geq 240$  mg/dL), high TG (serum TG  $\geq 200$  mg/dL), high LDL-C (serum LDL-C  $\geq 160$  mg/dL), low HDL-C (serum HDL-C  $< 40$  mg/dL) and self-reported dyslipidaemia diagnosis.<sup>37</sup>

#### Sleep assessment

Self-reported sleep was measured by the following questions: during the past 30 days, for more than 3 days per week (including 3 days), did you have any one of the following problems: (1) snoring, asphyxiating or suffocating; (2) difficulty in falling asleep (more than 30 min); (3) midway wakefulness twice or more; (4) medication for at least 1 day to help sleep; and (5) waking up early and difficulty in falling asleep again. Participants could respond 'yes' or 'no'. We defined sleep problems as at least one answer of 'yes'. These similar questions of sleep assessment have used in previous studies.<sup>17–38</sup>

#### Assessment of PA

PA was collected using the Global Physical Activity Questionnaire (GPAQ).<sup>39</sup> Different domain-specific PAs (work, transportation and recreational activities) were classified into moderate and vigorous intensity. For assessment of total PA, we calculated the metabolic equivalent (MET) minutes per week according to the GPAQ analysis guide<sup>40</sup>: MET-min/week = (moderate minutes  $\times 4.0$  METs) + (vigorous minutes  $\times 8.0$  METs). Total PA was categorised as low (0–1908 MET-min/week), moderate (1909–5129 MET-min/week) and high ( $\geq 5130$  MET-min/week).<sup>41</sup>

#### Covariates

Covariates included age, ethnicity (Han/Mongolian/other minority), educational level (primary school or lower/junior high school/senior high school and above), marital status (single/married/others) and residence (rural/urban). Lifestyle variables included smoking

**Table 1** Characteristics of sleep and physical activity in women

	Sleep problems			Physical activity			
	No (n=284)	Yes (n=437)	P value	Low (n=209)	Moderate (n=215)	High (n=297)	P value
Age (years)	49.8 (2.8)	50.5 (2.8)	0.001**	50.1 (2.9)	50.5 (2.9)	50.1 (2.8)	0.285
Ethnicity							
Han	230 (38.8)	363 (61.2)	0.757	169 (28.5)	173 (29.2)	251 (42.3)	0.423
Mongolian	37 (41.6)	52 (58.4)		28 (31.5)	26 (29.2)	35 (39.3)	
Other minority	17 (43.6)	22 (56.4)		12 (30.8)	16 (41.0)	11 (28.2)	
Educational level							
Primary school or lower	127 (40.1)	190 (59.9)	0.068	75 (23.7)	87 (27.4)	155 (48.9)	0.002**
Junior high school	87 (34.5)	165 (65.5)		79 (31.4)	78 (31.0)	95 (37.6)	
Senior high school and above	70 (46.1)	82 (53.9)		55 (36.2)	50 (32.9)	47 (30.9)	
Marital status							
Single	2 (66.7)	1 (33.3)	0.578	1 (33.3)	2 (66.7)	0 (0)	0.097
Married	275 (39.4)	423 (60.6)		205 (29.4)	203 (29.1)	290 (41.5)	
Others	7 (35.0)	13 (65.0)		3 (15.0)	10 (50.0)	7 (35.0)	
Smoking status							
No	273 (40.4)	402 (59.6)	0.026*	197 (29.2)	204 (30.2)	274 (40.6)	0.440
Yes	11 (23.9)	35 (76.1)		12 (26.1)	11 (23.9)	23 (50.0)	
Alcohol drinking status							
No	253 (41.4)	358 (58.6)	0.009**	185 (30.3)	180 (29.5)	246 (40.3)	0.190
Yes	31 (28.2)	79 (71.8)		24 (21.8)	35 (31.8)	51 (46.4)	
Residence							
Rural	188 (42.7)	252 (57.3)	0.022*	121 (27.5)	120 (27.3)	199 (45.2)	0.020*
Urban	96 (34.2)	185 (65.8)		88 (31.3)	95 (33.8)	98 (34.9)	
Body mass index							
Normal or underweight	94 (39.7)	143 (60.3)	0.723	69 (29.1)	67 (28.3)	101 (42.6)	0.966
Overweight	132 (40.5)	194 (59.5)		93 (28.5)	101 (31.0)	132 (40.5)	
Obese	58 (36.7)	100 (63.3)		47 (29.8)	47 (29.8)	64 (40.4)	
Waist circumference (cm)							
<85	163 (38.4)	262 (61.6)	0.495	119 (28.0)	132 (31.1)	174 (40.9)	0.639
≥85	121 (40.9)	175 (59.1)		90 (30.4)	83 (28.0)	123 (41.6)	
Sleep problems							
No	—	—		83 (29.2)	82 (28.9)	119 (41.9)	0.902
Yes	—	—		126 (28.8)	133 (30.4)	178 (40.7)	

\*p&lt;0.05, \*\*p&lt;0.01.

status (yes/no) and alcohol drinking status (yes/no). Anthropometric data included height, weight and waist circumference (<85 cm, ≥85 cm). Body mass index was calculated as weight (kg)/height<sup>2</sup> (m<sup>2</sup>) and categorised as normal or underweight (<24.0 kg/m<sup>2</sup>), overweight (24.0–27.9 kg/m<sup>2</sup>) or obese (≥28.0 kg/m<sup>2</sup>).<sup>42</sup>

### Statistical analysis

Continuous variables were shown as mean±SD. Categorical variables were expressed as rate or proportion. The t-test, analysis of variance and  $\chi^2$  test were used to analyse differences in sleep, PA and dyslipidaemia in the participants with different characteristics. Multivariate logistic

regression analyses were conducted to examine the associations of sleep and PA with risk of dyslipidaemia. The results were reported as OR with 95% CI. We defined  $\alpha=0.05$  as the significance level, and two-tailed p<0.05 was considered to indicate statistical significance. All data analyses were performed using IBM SPSS Statistics V.19.0 (IBM Corp).

### Patient and public involvement

This research was done without patient involvement. Patients were not invited to comment on the study design and were not consulted to develop patient-relevant outcomes or interpret the results. Patients were not

**Table 2** Prevalence of dyslipidaemia and its components in women

	All	Sleep problems			Physical activity			P value
		No	Yes	P value	Low	Moderate	High	
<b>Dyslipidaemia</b>								
No	425 (58.9)	195 (68.7)	230 (52.6)	<0.001***	105 (50.2)	121 (56.3)	199 (67.0)	0.001**
Yes	296 (41.1)	89 (31.3)	207 (47.4)		104 (49.8)	94 (43.7)	98 (33.0)	
<b>High TC</b>								
No	673 (88.3)	262 (92.3)	375 (85.8)	0.008**	177 (84.7)	188 (87.4)	272 (91.5)	0.052
Yes	84 (11.7)	22 (7.7)	62 (14.2)		32 (15.3)	27 (12.6)	25 (8.5)	
<b>High TG</b>								
No	574 (79.6)	239 (84.2)	335 (76.7)	0.015*	160 (76.7)	168 (78.1)	246 (82.8)	0.184
Yes	147 (20.4)	45 (15.8)	102 (23.3)		49 (23.3)	47 (21.9)	51 (17.2)	
<b>Low HDL-C</b>								
No	558 (77.4)	229 (80.6)	329 (75.3)	0.093	151 (72.3)	165 (76.7)	242 (81.5)	0.049*
Yes	163 (22.6)	55 (19.4)	108 (24.7)		58 (27.7)	50 (23.3)	55 (18.5)	
<b>High LDL-C</b>								
No	655 (90.8)	264 (93.0)	391 (89.5)	0.113	183 (87.6)	196 (91.2)	276 (92.9)	0.117
Yes	66 (9.2)	20 (7.0)	46 (10.5)		26 (12.4)	19 (8.8)	21 (7.1)	

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.

invited to contribute to the writing or editing of this document for readability or accuracy.

## RESULTS

### Demographic characteristics of the participants

Seven hundred and twenty-one women were included in this study and the mean age was 50.2 years (SD=2.8 years). Among all participants, 593 (82.2%) were Han ethnicity, 430 (61.0%) were from rural areas, 317 (44.0%) had primary school or lower educational level and the majority were married (96.8%). Six hundred and eleven (84.7%) were non-drinkers, 675 (93.6%) were non-smokers, 237 (32.9%) were normal or underweight and 425 (58.9%) had waist circumference <85 cm.

Four hundred and thirty-seven (60.6%) had sleep problems and 209 (29.0%) had low PA. There were significant differences in sleep among people with different age, smoking status, alcohol drinking status and residence status, and significant differences in PA among people with different educational level and residence (all p<0.05, [table 1](#)). There was no significant difference in PA between the different sleep groups (p>0.05, [table 1](#)).

### Prevalence of dyslipidaemia and its components

The prevalence of dyslipidaemia in women with sleep problems was significantly higher than that of women without sleep problems (47.4% vs 31.3%; p<0.001). Women with sleep problems also had higher prevalence of high TC, high TG than women without sleep problems (14.2% vs 7.7%, 23.3% vs 15.8%; all p≤0.05). Women with low PA had a higher prevalence of dyslipidaemia (49.8%

vs 43.7% vs 33.0%; p=0.001), and low HDL-C (27.7% vs 23.3% vs 18.5%; p=0.049) compared with moderate or high PA. ([table 2](#)).

### Independent effect of PA and sleep on dyslipidaemia and its components

In the multivariate logistic analyses, the effects of PA and sleep on risk of dyslipidaemia remained evident. Compared with women without sleep problems, the adjusted OR (95% CI) for dyslipidaemia, high TC and high TG in women with sleep problems were 2.15 (1.54 to 2.99), 1.81 (1.08 to 3.04) and 1.64 (1.10 to 2.46), respectively. Furthermore, compared with women with high PA, the adjusted OR (95% CI) for dyslipidaemia in women with low PA was 1.94 (1.32 to 2.84) ([table 3](#)).

### Joint effects of sleep and PA on the risk of dyslipidaemia and its components

The participants were categorised into six subgroups according to their joint PA and sleep characteristics. After adjustment for confounders, the joint effects of PA and sleep on dyslipidaemia were significant. Women with sleep problems had higher risk of dyslipidaemia than women without sleep problems, irrespective of low, moderate or high PA, with OR (95% CI) of 4.24 (2.40 to 7.49), 3.14 (1.80 to 5.49) and 2.04 (1.20 to 3.48), respectively, ([figure 1](#)). PA could not completely attenuate the negative association between sleep problems and risk of dyslipidaemia. With PA increased from low to high, the OR of dyslipidaemia decreased by 2.20 ([table 4](#)).

Likewise, women with sleep problems and low PA had higher risks of high TC, high TG, low HDL-C and high

**Table 3** Independent effect of physical activity and sleep on dyslipidaemia and its components

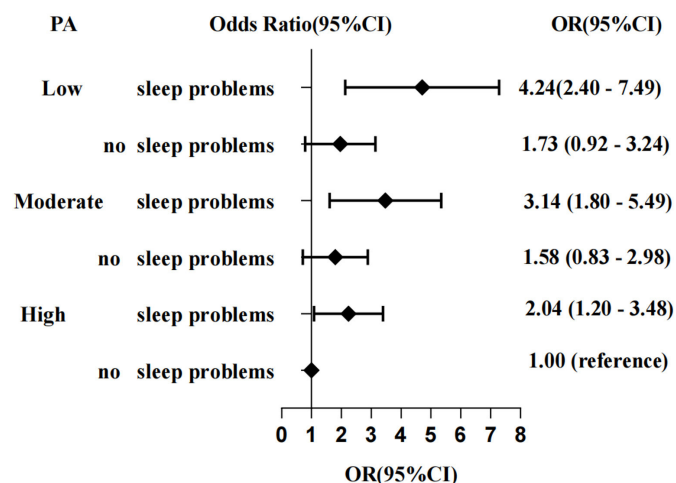
	Model 1†		Model 2‡	
	OR (95% CI)	P value	OR (95% CI)	P value
<b>Dyslipidaemia</b>				
Physical activity				
High	1.00 (reference)	<0.001***	1.00 (reference)	0.002**
Moderate	1.58 (1.10 to 2.27)		1.55 (1.06 to 2.27)	
Low	2.01 (1.40 to 2.89)		1.94 (1.32 to 2.84)	
Sleep problems				
No	1.00 (reference)	<0.001***	1.00 (reference)	<0.001***
Yes	1.97 (1.44 to 2.70)		2.15 (1.54 to 2.99)	
<b>High TC</b>				
Physical activity				
High	1.00 (reference)	0.017*	1.00 (reference)	0.059
Moderate	1.56 (0.88 to 2.78)		1.48 (0.83 to 2.65)	
Low	1.97 (1.13 to 3.43)		1.98 (1.13 to 3.47)	
Sleep problems				
No	1.00 (reference)	0.009**	1.00 (reference)	0.025*
Yes	1.97 (1.18 to 3.28)		1.81 (1.08 to 3.04)	
<b>High TG</b>				
Physical activity				
High	1.00 (reference)	0.076	1.00 (reference)	0.348
Moderate	1.35 (0.88 to 2.10)		1.30 (0.82 to 2.06)	
Low	1.48 (0.95 to 2.29)		1.37 (0.87 to 2.17)	
Sleep problems				
No	1.00 (reference)	0.015*	1.00 (reference)	0.015*
Yes	1.62 (1.10 to 2.38)		1.64 (1.10 to 2.46)	
<b>Low HDL-C</b>				
Physical activity				
High	1.00 (reference)	0.014*	1.00 (reference)	0.083
Moderate	1.33 (0.87 to 2.05)		1.32 (0.84 to 2.07)	
Low	1.69 (1.11 to 2.58)		1.65 (1.06 to 2.57)	
Sleep problems				
No	1.00 (reference)	0.094	1.00 (reference)	0.073
Yes	1.37 (0.95 to 1.97)		1.43 (0.97 to 2.10)	
<b>High LDL-C</b>				
Physical activity				
High	1.00 (reference)	0.043*	1.00 (reference)	0.092
Moderate	1.27 (0.67 to 2.43)		1.38 (0.72 to 2.65)	
Low	1.87 (1.02 to 3.42)		1.98 (1.07 to 3.65)	
Sleep problems				
No	1.00 (reference)	0.115	1.00 (reference)	0.064
Yes	1.55 (0.90 to 2.69)		1.69 (0.97 to 2.95)	

\*p<0.05, \*\*p<0.01, \*\*\*p<0.001.

†Model 1: Unadjusted.

‡Model 2: Adjusted for age, ethnicity, education level, marital status, residence, smoking status, alcohol drinking status, waist circumference and physical activity (association of sleep problems) or sleep problems (association of physical activity).

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.



**Figure 1** The simple effect of sleep with dyslipidaemia. PA, physical activity.

LDL-C than women without sleep problems and high PA, with OR (95% CI) of 2.51 (1.18 to 5.35), 2.42 (1.23 to 4.74), 2.88 (1.44 to 5.74) and 2.52 (1.12 to 5.70), respectively. With PA increased from low to high, the OR of low HDL-C decreased by 0.91 (table 4). Sleep problems were associated with increased risks of dyslipidaemia (OR=3.14; 95% CI: 1.80 to 5.49) and low HDL-C (OR=2.08; 95% CI: 1.03 to 4.20) among women with moderate PA. In addition, high PA was associated with increased risk of low HDL-C (OR=1.97; 95% CI: 1.01 to 3.84) among women with sleep problems (figure 2A–D).

## DISCUSSION

In the present study, the prevalence of dyslipidaemia was 41.1% in women aged 45–55 years, 60.6% of participants had sleep problems and 29.0% participants had low PA. The prevalence of dyslipidaemia was 47.4% in women with sleep problems, and significantly higher than that in women without sleep problems.

Low PA and sleep problems were interactively associated with an increased risk of dyslipidaemia in women aged 45–55 years. Furthermore, the effects on dyslipidaemia were more marked for sleep than for PA. We found that PA attenuated but did not eliminate the excess risk of dyslipidaemia associated with sleep problems. With PA increased from low to high, the OR of dyslipidaemia and low HDL-C decreased by 2.20 and 0.91, respectively.

## Comparisons with other studies

Among middle-aged and older people, PA had significant positive associations with several health conditions, including reduced risks of cardiovascular disease,<sup>43</sup> diabetes<sup>44</sup> and hypertension.<sup>45</sup> Our study showed that high PA was associated with lower risk of dyslipidaemia and its components, included high TC and high TG in women aged 45–55 years. In our study, self-reported sleep was measured by a questionnaire that contained all dimensions of the widely employed Pittsburgh Sleep Quality Index (PSQI), and clearly distinguished whether women had sleep problems. Consistent with our results, previous studies reported that sleep problems measured by the PSQI were associated with the increased risk of dyslipidaemia and its components.<sup>23 24</sup>

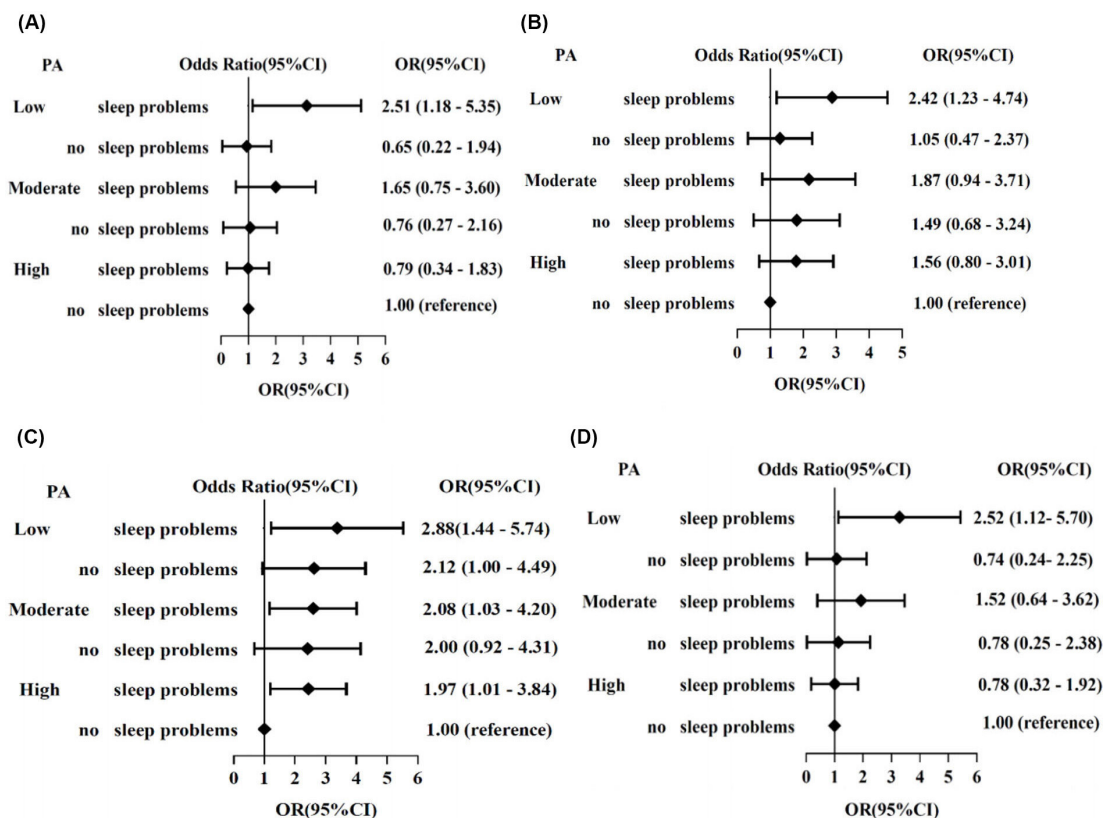
To date, epidemiological evidence regarding the joint effects of PA and sleep on dyslipidaemia has been limited. Casas *et al*<sup>35</sup> reported that low leisure-time activity was negatively associated with high TC and low HDL-C. The study pointed out that the joint effects on serum lipids were more marked for leisure-time activity than for sleep quality. Contrary to their results, the effect on risk of dyslipidaemia were more marked for sleep than for PA in the present study. These discrepancies among the findings may be partly explained by differences in the measurement methods for PA and sleep quality. In our study, we measured PA by the GPAQ, which included occupational, transition and leisure-time PA, and used a questionnaire to assess sleep quality. Whereas Casas, *et al*

**Table 4** The  $\Delta$ OR of the dyslipidaemia and its components in women with sleep problems

	Sleep problems	Physical activity			$\Delta$ OR
		Low OR (95% CI)	Moderate OR (95% CI)	High OR (95% CI)	
Dyslipidaemia	Yes	4.24 (2.40 to 7.49)*	3.14 (1.80 to 5.49)*	2.04 (1.20 to 3.48)*	2.20
	No	1.73 (0.92 to 3.24)	1.58 (0.83 to 2.98)	1.00 (reference)	
High TC	Yes	2.51 (1.18 to 5.35)*	1.65 (0.75 to 3.60)	0.79 (0.34 to 1.83)	1.72
	No	0.65 (0.22 to 1.94)	0.76 (0.27 to 2.16)	1.00 (reference)	
High TG	Yes	2.42 (1.23 to 4.74)*	1.87 (0.94 to 3.71)	1.56 (0.80 to 3.01)	0.86
	No	1.05 (0.47 to 2.37)	1.49 (0.68 to 3.24)	1.00 (reference)	
Low HDL-C	Yes	2.88 (1.44 to 5.74)*	2.08 (1.03 to 4.20)*	1.97 (1.01 to 3.84)*	0.91
	No	2.12 (1.00 to 4.49)	2.00 (0.92 to 4.31)	1.00 (reference)	
High LDL-C	Yes	2.52 (1.12 to 5.70)*	1.52 (0.64 to 3.62)	0.78 (0.32 to 1.92)	1.74
	No	0.74 (0.24 to 2.25)	0.78 (0.25 to 2.38)	1.00 (reference)	

\*p<0.05.

HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triglyceride.



**Figure 2** The simple effect of sleep with the components of dyslipidaemia; (A) TC, total cholesterol; (B) TG, triglyceride; (C) HDL-C, high-density lipoprotein cholesterol; (D) LDL-C, low-density lipoprotein cholesterol. PA, physical activity.

only analysed the leisure-time PA, and measured sleep quality by PSQI. What is more, the women participants were aged 45–55 years, who were in the perimenopausal period accompanied by changes in hormone levels. Previous study showed that daily PA and energy expenditure significantly decreased during the perimenopausal period.<sup>46</sup> Santoro showed that poor sleep quality became more common in perimenopausal women associated with the hormonal changes.<sup>47</sup> Furthermore, with decreasing oestrogen levels, the risk of dyslipidaemia of perimenopausal women has increased significantly.<sup>15</sup>

There are several potential factors to address for the difference between the simple effects of sleep and PA on the risk of dyslipidaemia. Age was positively associated with risk of dyslipidaemia.<sup>9 48</sup> In our study, women with sleep problems were older, and women with dyslipidaemia were also older. Alcohol drinking has been suggested as a possible risk factor for dyslipidaemia.<sup>49 50</sup> In our study, women with sleep problems were more likely to drink alcohol, which may be another reason why sleep problems had a greater effect on dyslipidaemia.

Our results were consistent with previous studies regarding the interactive associations of sleep and PA with chronic pain,<sup>51</sup> somatic symptoms,<sup>52</sup> insulin resistance<sup>53</sup> and depressive symptoms.<sup>54</sup> All of these studies highlighted the health benefits of PA and suggested that any adverse effects of sleep problems on those outcomes may be reduced by regular PA. In our study, with PA increased from low to high, the OR of dyslipidaemia decreased by

2.20. Meanwhile, contrary to other studies,<sup>32 33</sup> there was no significant association between PA and sleep problems, suggesting that increasing PA may not improve sleep quality in middle-aged women.

Modifiable PA has an effective protection on human's health against chronic diseases<sup>55–57</sup> especially in participants with sleep problems, even if PA did not completely counteract the risk among sleep problems individuals. Modifiable PA are widely accessible and effective intervention to reduce the risk of dyslipidaemia and other chronic diseases in women with sleep problems, especially in perimenopausal women.

### Strengths and limitations

Our study has some strengths and limitations. To our knowledge, there were relatively few studies on the joint effects of sleep and PA on risk of dyslipidaemia. This study was based on a survey of chronic disease and nutrition in Chinese adults, covered urban, agricultural and pastoral areas in Inner Mongolia. The participants were recruited consecutively used multistage cluster random sampling, which were generally representative. However, our study was a cross-sectional study, which only showed the relationship between sleep, PA and the risk of dyslipidaemia, not the causal association. In our study, self-reported sleep was measured by a questionnaire that included five questions. Although, these five questions consist all dimensions of the widely employed PSQI, there were some biases in our results due to no special scale used.

Therefore, it is necessary to conduct more prospective and experimental research on the joint effects of sleep and PA on the risk of dyslipidaemia in women in the perimenopausal period.

## CONCLUSIONS

In women aged 45–55 years, the joint effects of self-reported sleep and PA on risk of dyslipidaemia were more marked for sleep than for PA. Women aged 45–55 years with sleep problems and low PA should be given more attention. Modifiable PA is a widely accessible and effective intervention to reduce the risk of dyslipidaemia in women with sleep problems, particularly among women during the perimenopausal period. The study can provide some effective suggestions for the management of dyslipidaemia in perimenopausal women. Further research is warranted to identify available services for perimenopausal women to improve their quality of life.

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**Patient consent for publication** Not applicable.

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## REFERENCES

- Baigent C, Keech A, Kearney PM, *et al*. Efficacy and safety of cholesterol-lowering treatment: prospective meta-analysis of data from 90,056 participants in 14 randomised trials of statins. *Lancet* 2005;366:1267–78.
- Nelson RH. Hyperlipidemia as a risk factor for cardiovascular disease. *Prim Care* 2013;40:195–211.
- GBD 2017 Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet* 2018;392:1923–94.
- Zhang M, Zhou J, Liu Y, *et al*. Risk of type 2 diabetes mellitus associated with plasma lipid levels: the rural Chinese cohort study. *Diabetes Res Clin Pract* 2018;135:150–7.
- Zhao Q, Li J, Yang J, *et al*. Association of total cholesterol and HDL-C levels and outcome in coronary heart disease patients with heart failure. *Medicine* 2017;96:e6094.
- National cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III). third report of the National cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III) final report. *Circulation* 2002;106:3143–421.
- Ebrahimi H, Emamian MH, Hashemi H, *et al*. Dyslipidemia and its risk factors among urban middle-aged Iranians: a population-based study. *Diabetes Metab Syndr* 2016;10:149–56.
- Stevenson JC, Chines A, Pan K, *et al*. A pooled analysis of the effects of conjugated estrogens/bazedoxifene on lipid parameters in postmenopausal women from the selective estrogens, menopause, and response to therapy (SMART) trials. *J Clin Endocrinol Metab* 2015;100:2329–3238.
- Wu H, Xiong L, Xu Q, *et al*. Higher serum triglyceride to high-density lipoprotein cholesterol ratio was associated with increased cardiovascular mortality in female patients on peritoneal dialysis. *Nutr Metab Cardiovasc Dis* 2015;25:749–55.
- Wang Z, Wang D, Wang Y. Cigarette smoking and adipose tissue: the emerging role in progression of atherosclerosis. *Mediators Inflamm* 2017;2017:3102737.
- Donley DA, Fournier SB, Reger BL, *et al*. Aerobic exercise training reduces arterial stiffness in metabolic syndrome. *J Appl Physiol* 2014;116:1396–404.
- Nelson HD. Menopause. *Lancet* 2008;371:760–70.
- Li L, Wu J, Pu D, *et al*. Factors associated with the age of natural menopause and menopausal symptoms in Chinese women. *Maturitas* 2012;73:354–60.
- Chinese College of Cardiovascular Physician Women Physician Committee, Chinese Society of Cardiology Women's Heart Health Group. [Chinese expert consensus on management of dyslipidemia in postmenopausal women]. *Zhonghua Xin Xue Guan Bing Za Zhi* 2014;42:279–83.
- Cortez-Dias N, Robalo Martins S, Belo A, *et al*. Em nome DOS Investigadores do Estudo VALSIM. Characterization of lipid profile in primary health care users in Portugal. *Rev Port Cardiol* 2013;32:987–96.
- Li Y, Zhao L, Yu D, *et al*. The prevalence and risk factors of dyslipidemia in different diabetic progression stages among middle-aged and elderly populations in China. *PLoS One* 2018;13:e0205709.
- Sagayadevan V, Abidin E, Binte Shafie S, *et al*. Prevalence and correlates of sleep problems among elderly Singaporeans. *Psychogeriatrics* 2017;17:43–51.
- Bruyneel M. Sleep disturbances in menopausal women: aetiology and practical aspects. *Maturitas* 2015;81:406–9.
- Boyle A, Melville CA, Morrison J, *et al*. A cohort study of the prevalence of sleep problems in adults with intellectual disabilities. *J Sleep Res* 2010;19:42–53.
- Harvey MT, Baker DJ, Horner RH, *et al*. A brief report on the prevalence of sleep problems in individuals with mental retardation living in the community. *J Posit Behav Interv* 2003;5:195–200.
- Hung C-M, Li Y-C, Chen H-J, *et al*. Risk of dementia in patients with primary insomnia: a nationwide population-based case-control study. *BMC Psychiatry* 2018;18:38.
- Medic G, Wille M, Hemels ME. Short- and long-term health consequences of sleep disruption. *Nat Sci Sleep* 2017;9:151–61.
- Wan Mahmood WA, Draman Yusoff MS, Behan LA, *et al*. Association between sleep disruption and levels of lipids in caucasians with type 2 diabetes. *Int J Endocrinol* 2013;2013:341506.
- Hung H-C, Yang Y-C, Ou H-Y, *et al*. The association between self-reported sleep quality and metabolic syndrome. *PLoS One* 2013;8:e54304.
- Takahashi TA, Johnson KM. Menopause. *Med Clin North Am* 2015;99:521–34.
- Liu X, Yu S, Mao Z, *et al*. Dyslipidemia prevalence, awareness, treatment, control, and risk factors in Chinese rural population: the Henan rural cohort study. *Lipids Health Dis* 2018;17:119.
- Nybo L, Sundstrup E, Jakobsen MD, *et al*. High-intensity training versus traditional exercise interventions for promoting health. *Med Sci Sports Exerc* 2010;42:1951–8.



- 28 LeMura LM, von Duvillard SP, Andreacci J, *et al.* Lipid and lipoprotein profiles, cardiovascular fitness, body composition, and diet during and after resistance, aerobic and combination training in young women. *Eur J Appl Physiol* 2000;82:451–8.
- 29 Kokkinos PF, Faselis C, Myers J, *et al.* Interactive effects of fitness and statin treatment on mortality risk in veterans with dyslipidaemia: a cohort study. *Lancet* 2013;381:394–9.
- 30 Christie AD, Seery E, Kent JA. Physical activity, sleep quality, and self-reported fatigue across the adult lifespan. *Exp Gerontol* 2016;77:exger.2016.02.001:7–11.
- 31 Borges-Cosic M, Aparicio VA, Estévez-López F, *et al.* Sedentary time, physical activity, and sleep quality in fibromyalgia: the al-Ándalus project. *Scand J Med Sci Sports* 2019;29:266–74.
- 32 Štefan L, Vrgoč G, Rupčić T, *et al.* Sleep duration and sleep quality are associated with physical activity in elderly people living in nursing homes. *Int J Environ Res Public Health* 2018;15:2512.
- 33 Štefan L, Sporiš G, Krističević T, *et al.* Associations between sleep quality and its domains and insufficient physical activity in a large sample of Croatian young adults: a cross-sectional study. *BMJ Open* 2018;8:e021902.
- 34 Porter VR, Buxton WG, Avidan AY. Sleep, cognition and dementia. *Curr Psychiatry Rep* 2015;17:97.
- 35 Casas RS, Pettee Gabriel KK, Kriska AM, *et al.* Association of leisure physical activity and sleep with cardiovascular risk factors in postmenopausal women. *Menopause* 2012;19:413–9.
- 36 Pang SJ. Associations of lipid parameters and phospholipid profiles with insulin resistance among adults. *Chinese Center for Diseases Control and Prevention* 2018.
- 37 Kopin L, Lowenstein C. Dyslipidemia. *Ann Intern Med* 2017;167:ITC81–96.
- 38 Olinto MTA, Garcez A, Henn RL, *et al.* Sleep-related problems and minor psychiatric disorders among Brazilian shift workers. *Psychiatry Res* 2017;257:412–7.
- 39 World Health Organization. Global physical activity questionnaire (GPAQ). Available: [https://www.who.int/ncds/surveillance/steps/GPAQ\\_EN.pdf](https://www.who.int/ncds/surveillance/steps/GPAQ_EN.pdf)
- 40 World Health Organization. Global physical activity questionnaire (GPAQ) analysis guide. Available: [https://www.who.int/ncds/surveillance/steps/resources/GPAQ\\_Analysis\\_Guide.pdf](https://www.who.int/ncds/surveillance/steps/resources/GPAQ_Analysis_Guide.pdf)
- 41 Yu ZM, Parker L, Dummer TJB. Depressive symptoms, diet quality, physical activity, and body composition among populations in nova Scotia, Canada: report from the Atlantic partnership for tomorrow's health. *Prev Med* 2014;61:106–13.
- 42 Xu W, Zhang H, Paillard-Borg S, *et al.* Prevalence of overweight and obesity among Chinese adults: role of adiposity indicators and age. *Obes Facts* 2016;9:17–28.
- 43 de Souto Barreto P, Cesari M, Andrieu S, *et al.* Physical activity and incident chronic diseases: a longitudinal observational study in 16 European countries. *Am J Prev Med* 2017;52:373–8.
- 44 Marques A, Peralta M, Sarmento H, *et al.* Associations between vigorous physical activity and chronic diseases in older adults: a study in 13 European countries. *Eur J Public Health* 2018;28:950–5.
- 45 Huai P, Xun H, Reilly KH, *et al.* Physical activity and risk of hypertension: a meta-analysis of prospective cohort studies. *Hypertension* 2013;62:1021–6.
- 46 Kim J-S, Choe J-P, Park J-H, *et al.* The comparison of physical activity, sedentary behavior, and mental health between early menopausal women and age-matched General middle-aged women. *Int J Environ Res Public Health* 2021;18:7256.
- 47 Santoro N. Perimenopause: from research to practice. *J Women Health* 2002;25:332–9.
- 48 Florez H, Silva E, Fernández V, *et al.* Prevalence and risk factors associated with the metabolic syndrome and dyslipidemia in white, black, Amerindian and mixed Hispanics in Zulia state, Venezuela. *Diabetes Res Clin Pract* 2005;69:63–77.
- 49 Pintó X, Valdivielso P, Perez de Juan JM, *et al.* Predictive factors of achieving therapeutic goals of hypertriglyceridemia. *Curr Med Res Opin* 2014;30:19–26.
- 50 Yang J, Ye J, Guo Q, *et al.* The joint effects of smoking and alcohol drinking on lipid-related indices among Chinese males-comparing exercise and non-exercise groups. *Subst Use Misuse* 2018;53:2431–8.
- 51 Mork PJ, Vik KL, Moe B, *et al.* Sleep problems, exercise and obesity and risk of chronic musculoskeletal pain: the Norwegian HUNT study. *Eur J Public Health* 2014;24:924–9.
- 52 Ablin JN, Clauw DJ, Lyden AK, *et al.* Effects of sleep restriction and exercise deprivation on somatic symptoms and mood in healthy adults. *Clin Exp Rheumatol* 2013;31:S53–9.
- 53 Zuo H, Shi Z, Yuan B, *et al.* Interaction between physical activity and sleep duration in relation to insulin resistance among non-diabetic Chinese adults. *BMC Public Health* 2012;12:247.
- 54 Kaseva K, Dobewall H, Yang X, *et al.* Physical activity, sleep, and symptoms of depression in Adults-Testing for mediation. *Med Sci Sports Exerc* 2019;51:1162–8.
- 55 Dao-Tran T-H, Seib C. Prevalence and correlates of sleep disturbance among older women in Vietnam. *J Clin Nurs* 2018;27:3307–13.
- 56 Andersson C, Lyass A, Larson MG, *et al.* Physical activity measured by accelerometry and its associations with cardiac structure and vascular function in young and middle-aged adults. *J Am Heart Assoc* 2015;4:e001528.
- 57 Goto C, Higashi Y, Kimura M, *et al.* Effect of different intensities of exercise on endothelium-dependent vasodilation in humans: role of endothelium-dependent nitric oxide and oxidative stress. *Circulation* 2003;108:530–5.