· 临床研究 ·

基于智能穿戴设备探讨睡眠时长与高血压关系的真实世界研究

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【摘 要】 目的 基于智能穿戴设备测量睡眠时长与家庭血压,明确睡眠时长与高血压的关联性。**方法** 本研究数据资料来自由中国医疗保健国际交流促进会发起的"血压健康研究",由中国人民解放军总医院执行。本研究采用在线招募方式,招募来自全国 34 个省、自治区、直辖市的受试者。根据纳入与排除标准,2021 年 12 月至 2023 年 1 月共纳入 1 706 例既往无高血压病史的成年受试者,采用华为智能血压手表测量睡眠数据及家庭血压数据,通过填写电子问卷收集受试者人口学资料和病史等信息。按照基线时血压测量数值将受试者分为高血压组[收缩压(SBP)≥135 mmHg(1 mmHg=0.133 kPa),和(或)舒张压(DBP)≥85 mmHg,n=851]和非高血压组(SBP<135 mmHg,且 DBP<85 mmHg,n=855)。采用 SPSS 26.0 统计软件进行数据分析。根据数据类型,分别采用 t 检验或 χ^2 检验进行组间比较。采用多因素 logistic 回归分析睡眠时长与高血压之间的横断面关系。**结果** 1 706 例受试者中男性 1 519 例(89.04%),女性 187 例(10.96%);年龄(44.87±11.52)岁;体质量指数(BMI)为(24.99±3.33)kg/m^2;睡眠时长(7.35±1.10)h;收缩压(125.97±11.75)mmHg,舒张压(84.66±8.45)mmHg;心率(77.43±9.63)次/min。在不同睡眠时长(≥9 h、7~<9 h、5~<7 h、<5 h)受试者中,高血压患病率比较(45.26%、48.16%、52.63%和 67.65%),差异有统计学意义(P=0.046)。随着睡眠时长缩短,高血压患病率有增高趋势。未校正混杂因素的多因素 logistic 回归分析结果显示,与睡眠时长 7~<9 h 组比较,睡眠时长≥9 h 组(OR=0.890,95%CI 0.583~1.358;P=0.589)及睡眠时长 5~<7 h 组(OR=1.196,95%CI 0.974~1.469;P=0.088)高血压风险无统计学差异;睡眠时长<5 h 组(OR=2.250,95%CI 1.086~4.665;P=0.029)的受试者高血压风险增加。校正了所有可获取混杂因素(年龄、性别、BMI、高盐饮食习惯、吸烟/饮酒史、呼吸睡眠暂停综合征史、糖尿病史、慢性肾脏病史等)后,与睡眠时长 7~<9 h 组的受试者比较,睡眠时长≥9 h 组(OR=0.952,95%CI 0.606~1.495;P=0.831)及睡眠时长 5~<7 h 组(OR=1.056,95%CI 0.848~1.315;P=0.625)高血压风险无统计学差异;睡眠时长<5 h 组(OR=2.238,95%CI 1.026~4.884;P=0.043)受试者的高血压风险依然增加。**结论** 睡眠时长过长及睡眠时长轻度不足与高血压风险无显著关联,睡眠时长过短与高血压风险增加显著关联。

【关键词】 睡眠时长;高血压;家庭血压监测;智能穿戴设备

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A real-world study on relationship between sleep duration and hypertension based on smart wearable devices

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【Abstract】 Objective To investigate the correlation between sleep duration and hypertension based on the data collected through smart wearable devices. **Methods** The data in this study were from Blood Pressure Health Study (initiated by China International Exchange and Promotive Association for Medical and Health Care and executed by Chines PLA General Hospital). All participants were recruited online from 34 provinces, autonomous regions, and municipalities. Based on our inclusion/exclusion criteria, a total of 1 706 adult participants with no history of hypertension were recruited to this study from December, 2021 to January, 2024. Huawei smart blood pressure watches were employed to measure and collect sleep and home blood pressure data, and their demographic information and medical history were collected through electronic questionnaires. Based on their baseline blood pressure, they were divided into hypertensive group [SBP ≥135 mmHg (1 mmHg=0.133 kPa) and/or DBP ≥85 mmHg, n=851] and non-hypertensive group (SBP <135 mmHg and DBP<85 mmHg). SPSS statistics 26.0 was used for data analysis. Data comparison between the two groups was

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performed using student's *t* test or *Chi*-square test depending on data type. Multivariate logistic regression analysis was used to examine the cross-sectional relationship between sleep duration and hypertension. **Results** Among the 1 706 participants, there were 1 519 males (89.04%) and 187 females (10.96%), with an average age of (44.87±11.52) years, a body mass index (BMI) of (24.99±3.33) kg/m^2, a sleep duration of (7.35±1.10) h, SBP of (125.97±11.75) mmHg, DBP of (84.66±8.45) mmHg, and a heart rate of (77.43±9.63) beats/min. In the participants with different sleep durations (≥9, 7-<9, 5-<7 and <5 h), there was a significant difference in the prevalence of hypertension (45.26% *vs* 48.16% *vs* 52.63% *vs* 67.65%; $P=0.046$), indicating an increasing trend in hypertension prevalence with shorter sleep duration. Multivariate logistic regression analysis without adjusting for confounding factors showed that compared to the group with a sleep duration of 7-<9 h, the group with a duration of ≥9 h (*OR*=0.890, 95%*CI* 0.583-1.358; $P=0.589$) and the group of 5-<7 h (*OR*=1.196, 95%*CI* 0.974-1.469; $P=0.088$) showed no statistical difference in hypertension risk, and the group with a duration of <5 h (*OR*=2.250, 95%*CI* 1.086-4.665; $P=0.029$) had an increased risk of hypertension. After adjusting for all available confounding factors (age, gender, BMI, high-salt diet habits, smoking/alcohol history, history of sleep apnea syndrome, diabetes history, history of chronic kidney disease, *etc.*), compared to the participants with a sleep duration of 7-<9 h, the group with a sleep duration of ≥9 h (*OR*=0.952, 95%*CI* 0.606-1.495; $P=0.831$) and the group with a sleep duration of 5-<7 h (*OR*=1.056, 95%*CI* 0.848-1.315; $P=0.625$) showed no statistically significant difference in hypertension risk, whereas those with a sleep duration of <5 h (*OR*=2.238, 95%*CI* 1.026-4.884; $P=0.043$) still had an increased risk of hypertension. **Conclusion** There is no significant correlation between mild shortfall and excessive sleep duration and hypertension risk, but obvious association is found between excessively short sleep duration and an increased risk of hypertension.

【Key words】 sleep duration; hypertension; home blood pressure monitoring; smart wearable devices

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高血压是一个重要的公共卫生问题,中国高血压调查数据显示,我国18岁及以上居民高血压患病率为27.9%[1]。美国心脏协会(American Heart Association)最新定义了生活8要素的理念[饮食、活动、吸烟、睡眠、体质量指数(body mass index, BMI)、血脂、血糖和血压],首次将睡眠作为影响心血管健康的生活8要素之一[2]。近年来睡眠时长不足已经越发被认为是心血管疾病的一个重要危险因素[3]。部分观察性研究报道了睡眠时长与高血压病之间的关联[4-6],但也有研究有不一致的结论,如Katano等[7]发现短睡眠时长人群高血压风险并未增加。既往研究中,睡眠时长的检测方法大多采用填写睡眠问卷等自我报告的主观测量方法,可能存在回忆偏倚,且相关研究采用的是诊室血压数据,未能考虑"白大衣高血压"及"隐蔽性高血压"等情况[8-10],从而可能会影响研究结果。

近年来,以智能手环、手表为代表的可穿戴设备在健康医疗领域的应用逐渐兴起,为健康与疾病管理提供新手段[11]。本研究利用智能穿戴设备测量睡眠时长和家庭血压,分析睡眠时长与高血压的关联,为完善高血压防控策略提供依据。

1 对象与方法

1.1 研究对象

选择2021年12月至2023年1月加入血压健康研究的受试者为研究对象。血压健康研究由中国医疗保健国际交流促进会发起,中国人民解放军总医院执行。纳入标准:(1)年龄≥18岁;(2)具备使用华为血压手表及《血压健康研究》APP的能力;(3)自愿填写完整健康问卷;(4)加入研究后2周内,非同日血压测量≥3次,睡眠测量≥1次。排除标准:(1)正服用降压药物;(2)妊娠期;(3)腕部有损伤或深色纹身等;(4)不具备正常的行为理解及控制能力、无法签署知情同意书。针对46 871名血压健康研究的受试者,按照上述纳入与排除标准,剔除健康问卷填写不完整者38 657例,血压测量数据不完整者4 669例,正在服用降压药物者1 839例,最终共有1 706例纳入研究进行数据分析。本研究采用家庭血压标准,根据中国高血压防治指南(2018年修订版)[1],高血压病定义为家庭收缩压≥135 mmHg(1 mmHg=0.133 kPa)和(或)舒张压≥85 mmHg。按照基线时血压测量数值,将受试者分为高血压组($n=851$)和非高血压组($n=855$)。本研究获得中国人民解放军总医院医学伦理委员会批准(伦理批件号:S2021-567),在中国临床研究注册中心完成注册(注册号 ChiCTR2200057354)。受试者对研究内容知情同意,签订知情同意书。

1.2 受试者信息采集

(1)一般资料:包括性别、年龄、身高、体质量,根据身高和体质量计算BMI。BMI=体质量(kg)/身高(m)^2,将BMI由连续性变量转化为"<24 kg/m^2、≥24 kg/m^2"的分类变量。(2)健康问卷:主要包括是否服用降压药、是否抽烟或饮酒、是否患有慢性肾脏疾病、是否患有糖尿病、是否患有睡眠呼吸暂停综合征等。(3)睡眠时长测量:受试者加入研究后2周内,至少佩带腕表完成一次夜间睡眠测量,智能腕表通过识

别入睡开始时间及觉醒时间计算夜间睡眠时长。将睡眠时长由连续性变量转化为“<5 h、5～<7 h、7～<9 h、≥9 h”的分类变量。美国睡眠基金会推荐成人夜间睡眠时长 7～9 h[12]，本研究将 7～<9 h 作为参考值，将“<5 h、5～<7 h”定义为短睡眠时长，将“≥9 h”定义为长睡眠时长。(4)家庭血压测量：受试者每次测量前至少静坐休息 5 min，双脚平放于地面，佩戴智能血压手表的手腕放在胸前，让手腕、智能血压手表和心脏处于同一个水平(图 1)。

1.3 统计学处理

采用 SPSS 26.0 统计软件进行数据分析。计量资料以均数±标准差($\bar{x}\pm s$)表示，组间比较采用 t 检验。计数资料以例数(百分率)表示，组间比较采用 χ^2 检验。采用多因素 logistic 回归分析睡眠时长与高血压之间的横断面关系。P<0.05 为差异有统计学意义。

2 结 果

2.1 研究人群临床特征

1 706 例受试者中，男性 1 519 例(89.04%)，女性 187 例(10.96%)；年龄 18～86(44.87±11.52)岁；BMI<24 kg/m^2 共 663 例(38.86%)、≥24 kg/m^2 共 1 043 例(61.14%)；睡眠时长(7.35±1.10)h；收缩压(125.97±11.75)mmHg，舒张压(84.66±8.45)mmHg；心率(77.43±9.63)次/min。高血压组 851 例(49.88%)，非高血压组 855 例(50.11%)。

两组人群年龄、性别、BMI、吸烟或饮酒习惯、高盐饮食习惯、精神紧张生活方式、高脂血症史、收缩压、舒张压及心率比较，差异有统计学意义(P<0.05)。夜尿增多史、糖尿病史、慢性肾脏病史及呼吸睡眠暂停综合征史比较，差异无统计学意义(表 1)。

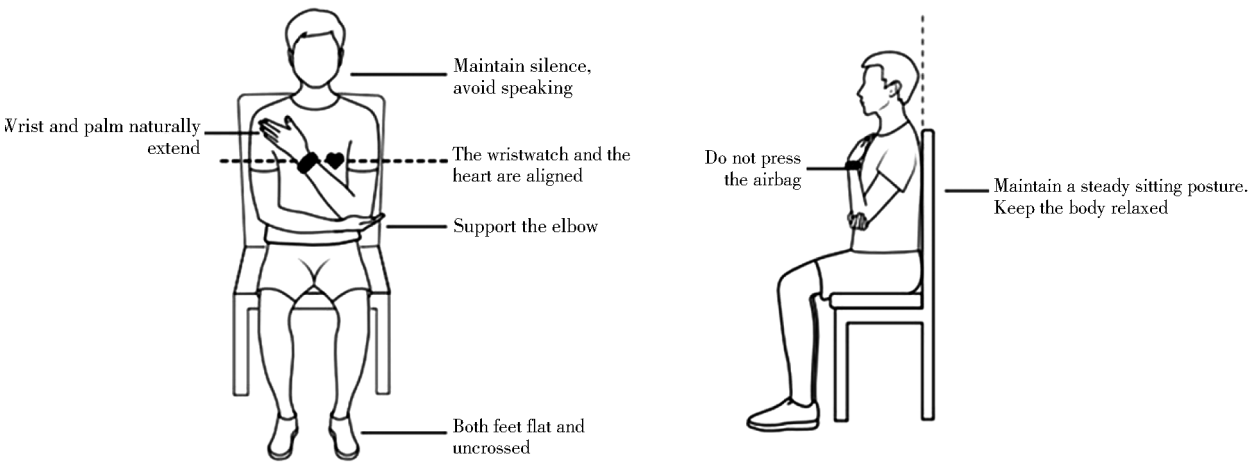

图 1 华为智能设备血压测量示意图

Figure 1 Diagram of blood pressure measurement

表 1 高血压组和非高血压组受试者临床特征比较

Table 1 Comparison of clinical characteristics between hypertension group and non-hypertension group

Item	Non-hypertension group(n=855)	Hypertension group(n=851)	P value
Male[n(%)]	719(84.09)	800(94.01)	<0.001
Age≥60 years[n(%)]	112(13.10)	66(7.76)	<0.001
BMI(kg/m^2, $\bar{x}\pm s$)	23.87±2.85	26.13±3.40	<0.001
Smoking/Alcohol drinking[n(%)]	267(31.23)	416(48.88)	<0.001
High-salt diet[n(%)]	206(24.09)	299(35.14)	<0.001
High-stress lifestyle[n(%)]	395(46.20)	454(53.35)	0.003
Nocturia[n(%)]	191(22.34)	195(22.91)	0.777
Diabetes mellitus[n(%)]	52(6.08)	45(5.29)	0.479
CKD[n(%)]	11(1.29)	9(1.06)	0.660
OSAS[n(%)]	95(11.11)	97(11.40)	0.851
Hyperlipidemia[n(%)]	253(29.59)	317(37.25)	0.001
Sleep duration(h, $\bar{x}\pm s$)	7.43±1.08	7.27±1.12	0.002
SBP(mmHg, $\bar{x}\pm s$)	117.60±7.85	134.39±8.59	<0.001
DBP(mmHg, $\bar{x}\pm s$)	78.25±4.88	91.10±6.02	<0.001
HR(beats/min, $\bar{x}\pm s$)	75.00±9.20	79.88±9.44	<0.001

BMI: body mass index; CKD: chronic kidney disease; OSAS: obstructive sleep apnea syndrome; SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate. 1 mmHg=0.133 kPa.

2.2 不同睡眠时长受试者高血压患病率比较

睡眠时长≥9 h的受试者高血压患病率为45.26%(43/95),睡眠时长7~<9 h的受试者高血压患病率为48.16%(485/1 007),睡眠时长5~<7 h的受试者高血压患病率为52.63%(300/570),睡眠时长<5 h的受试者高血压患病率为67.65%(23/34),4组受试者高血压患病率比较,差异有统计学意义(P=0.046)。

2.3 睡眠时长与高血压关联的多因素logistic回归分析

未校正混杂因素的多因素logistic回归分析显示,与睡眠时长7~<9 h组比较,睡眠时长≥9 h组(OR=0.890,95%CI 0.583~1.358;P=0.589)及睡眠时长5~<7 h组(OR=1.196,95%CI 0.974~1.469;P=0.088)高血压风险无统计学差异;睡眠时长<5 h组(OR=2.250,95%CI 1.086~4.665;P=0.029)的受试者高血压风险增加。校正"年龄、性别、BMI、高盐饮食习惯、呼吸睡眠暂停综合征史、糖尿病史、慢性肾脏病史"所有可获取的混杂因素后提示:与睡眠时长7~<9 h组的受试者比较,睡眠时长≥9 h组(OR=0.952,95%CI 0.606~1.495;P=0.831)及睡眠时长5~<7 h组(OR=1.056,95%CI 0.848~1.315;P=0.625)高血压风险无统计学差异;睡眠时长<5 h组(OR=2.238,95%CI 1.026~4.884;P=0.043)受试者的高血压风险依然增加(表2)。

3 讨 论

本研究系国内首个基于智能穿戴设备研究睡眠时长与高血压关联性的真实世界研究,研究使用智能腕式设备测量的血压及睡眠数据的准确性已在临床进行了验证[13,14]。结果显示睡眠时长过长(≥9 h)及睡眠时长轻度不足(5~<7 h)与高血压风险关联不显著,睡眠时长过短(<5 h)与高血压风险增加显著关联。睡眠过短会增加高血压风险,这可能与交感神经系统激活、钠盐排泄改变及血流动力学负荷改变有关。短睡眠时长可增加交感神经活性进而导致收缩压和舒张压升高;长期睡眠剥夺可能导致机体内压力相关激素水平升高,间接导致钠盐摄入增加及肾脏排钠量减少;长期处于短睡眠时长环境可能导致血流动力学负荷增加,引发主动脉硬化和左心室肥厚,从而使心血管系统逐渐适应高压状态[3,15,16]。

本研究以睡眠时长7~<9 h作为参照,在校正了混杂因素后,睡眠时长轻度不足(5~<7 h)的受试者高血压风险有增加趋势,但差异不显著,睡眠时长过短(<5 h)的高血压风险仍然显著增加。Grandner等[5]对美国行为风险因素监测系统数据库及全国健康访谈调查数据库进行分析,评估睡眠时长与高血压之间的横断面关系,发现睡眠≤5 h高血压风险显著增加(与>7 h睡眠组相比);Gangwisch等[4]对美国护士健康研究数据库分析,发现睡眠≤5 h组女性受试者高血压风险显著高于睡眠时长7~8 h组。本研究基于智能穿戴设备监测中国人群的客观睡眠时长与家庭血压,进一步证实睡眠不足可能是高血压的重要危险因素。然而,关于睡眠时长>9 h对于心血管风险的影响仍存在争议,有研究显示睡眠>9 h的人群心血管风险并未增加[17]。本研究校正全部混杂因素后,睡眠时长>9 h组高血压风险未增加,但是本研究中>9 h的人群共计95例,这一结果或许与样本数量较小有关,因此需要更大样本的临床研究来验证结果的稳定性。

本研究的优势之一是采用了智能穿戴设备获取睡眠时长和家庭血压测量值,相较于传统的问卷调查和医疗记录,这种客观的测量方法具有更高的准确性和客观性。另外,通过对多个混杂因素的校正,研究结果的可靠性和可信度得到了进一步增强。但本研究有一定的局限性:(1)设计类型为横断面研究,尚不能明确睡眠时长与高血压病的因果关系,进一步的纵向研究可以更好地评估睡眠时长对高血压发生的影响;(2)现实环境中,购买该智能设备消费者男性居多,故本研究性别比例不均衡;(3)智能穿戴设备近年来越发被年轻消费者接受并使用,但65岁及以上老年人群应用较少,该研究纳入人群平均年龄(44.87±11.52)岁,研究结论尚不能在老年人群中推广。

表2 睡眠时长与高血压关联的多因素logistic回归分析

Table 2 Multivariate logistic regression analysis of association between sleep duration and hypertension

Sleep duration	Model 1		Model 2		Model 3		Model 4		Model 5	
	OR	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*	*OR*	95%*CI*
≥9 h	0.890	0.583-1.358	0.921	0.603-1.408	0.974	0.633-1.500	0.951	0.608-1.488	0.952	0.606-1.495
7-<9 h	1.000	-	1.000	-	1.000	-	1.000	-	1.000	-
5-<7 h	1.196	0.974-1.469	1.193	0.971-1.466	1.175	0.954-1.447	1.079	0.868-1.341	1.056	0.848-1.315
<5 h	2.250	1.086-4.665	2.300	1.108-4.776	2.358	1.123-4.951	2.240	1.030-4.871	2.238	1.026-4.884

Model 1: unadjusted; Model 2: adjusted for age; Model 3: adjusted for age and gender; Model 4: adjusted for age, gender, BMI, high-salt diet and obstructive sleep apnea syndrome; Model 5: adjusted for age, gender, BMI, high-salt diet, smoking/alcohol drinking, obstructive sleep apnea syndrome, diabetes mellitus and chronic kidney disease. -: no datum.

综上所述,本研究结果进一步证实了睡眠时长不足与高血压之间的关联性,维持适当的睡眠时长对于预防高血压的重要性。本研究基于穿戴设备测量真实世界人群睡眠与血压数据,为探索基于睡眠干预手段的高血压防控提供可能,为数字医疗和健康大数据领域的应用拓宽前景。

【参考文献】

[1] 《中国高血压防治指南》修订委员会. 中国高血压防治指南 2018 年修订版[J]. 心脑血管病防治, 2019, 19(1): 1-44. DOI: 10.3969/j.issn.1009-816X.2019.01.001.

[2] Lloyd-Jones DM, Allen NB, Anderson CA, *et al*. Life's essential 8: updating and enhancing the American Heart Association's construct of cardiovascular health: a presidential advisory from the American Heart Association[J]. Circulation, 2022, 146(5): e18-e43. DOI: 10.1161/CIR.0000000000001078.

[3] Covassin N, Bukartyk J, Singh P, *et al*. Effects of experimental sleep restriction on ambulatory and sleep blood pressure in healthy young adults: a randomized crossover study[J]. Hypertension, 2021, 78(3): 859-870. DOI: 10.1161/HYPERTENSIONAHA.121.17622.

[4] Gangwisch JE, Feskanich D, Malaspina D, *et al*. Sleep duration and risk for hypertension in women: results from the nurses' health study[J]. Am J Hypertens, 2013, 26(7): 903-911. DOI: 10.1093/ajh/hpt044.

[5] Grandner M, Mullington JM, Hashmi SD, *et al*. Sleep duration and hypertension: analysis of > 700,000 adults by age and sex[J]. J Clin Sleep Med, 2018, 14(6): 1031-1039. DOI: 10.5664/jcsm.7176.

[6] Gangwisch JE, Heymsfield SB, Boden-Albala B, *et al*. Short sleep duration as a risk factor for hypertension: analyses of the first National Health and Nutrition Examination Survey[J]. Hypertension, 2006, 47(5): 833-839. DOI: 10.1161/01.HYP.0000217362.34748.e0.

[7] Katano S, Nakamura Y, Nakamura A, *et al*. Relationship between sleep duration and clustering of metabolic syndrome diagnostic components[J]. Diabetes Metab Syndr Obes, 2011, 4: 119-125. DOI: 10.2147/DMSO.S16147.

[8] Williams B, Mancia G, Spiering W, *et al*. 2018 practice guidelines for the management of arterial hypertension of the European Society of Hypertension and the European Society of Cardiology: ESH/ESC task force for the management of arterial hypertension[J]. J Hypertens, 2018, 36(12): 2284-2309. DOI: 10.1097/HJH.0000000000001961.

[9] Whelton PK, Carey RM, Aronow WS, *et al*. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high BP in adults: executive summary: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines[J]. Hypertension, 2018, 71(6): 1269-1324. DOI: 10.1161/HYP.0000000000000065.

[10] Yang WY, Melgarejo JD, Thijs L, *et al*. Association of office and ambulatory blood pressure with mortality and cardiovascular outcomes[J]. JAMA, 2019, 322(5): 409-420. DOI: 10.1001/jama.2019.9811.

[11] Bayoumy K, Gaber M, Elshafeey A, *et al*. Smart wearable devices in cardiovascular care: where we are and how to move forward[J]. Nat Rev Cardiol, 2021, 18(8): 581-599. DOI: 10.1038/s41569-021-00522-7.

[12] Watson NF, Badr MS, Belenky G, *et al*. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society[J]. Sleep, 2015, 38(6): 843-844. DOI: 10.5665/sleep.4716.

[13] Yi L, Lyu ZH, Hu SY, *et al*. Validating the accuracy of a multifunctional smartwatch sphygmomanometer to monitor blood pressure[J]. J Geriatr Cardiol, 2022, 19(11): 843-852. DOI: 10.11909/j.issn.1671-5411.2022.11.004.

[14] Brittany P. Using acceleration and heart rate data to classify awake, deep, and light sleep: bpine0/Sleep-Stages-Classification[EB/OL]. [2017-12-19]. https://github.com/bpine0/Sleep-Stages-Classification.

[15] Del Pinto R, Grassi G, Ferri C, *et al*. Diagnostic and therapeutic approach to sleep disorders, high blood pressure and cardiovascular diseases: a consensus document by the Italian Society of Hypertension (SIIA)[J]. High Blood Press Cardiovasc Prev, 2021, 28(2): 85-102. DOI: 10.1007/s40292-021-00436-y.

[16] St-Onge MP, Grandner MA, Brown D, *et al*. Sleep duration and quality: impact on lifestyle behaviors and cardiometabolic health: a scientific statement from the American Heart Association[J]. Circulation, 2016, 134(18): e367-e386. DOI: 10.1161/CIR.0000000000000444.

[17] Ai SZ, Zhang JH, Zhao GA, *et al*. Causal associations of short and long sleep durations with 12 cardiovascular diseases: linear and nonlinear Mendelian randomization analyses in UK Biobank[J]. Eur Heart J, 2021, 42(34): 3349-3357. DOI: 10.1093/eurheartj/ehab170.

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