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Associations between self-reported sleep duration and cardiometabolic risk factors in young African-origin adults from the five-country modeling the epidemiologic transition study (METS)

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ABSTRACT

Objectives: To investigate associations between self-reported sleep duration and cardiometabolic (CM) risk factors in African-origin adults residing in five countries spanning the epidemiologic transition.
Design: Cross-sectional.
Setting and participants: Ghanaian ($n = 491$), South African ($n = 503$), Jamaican ($n = 508$), Seychellois ($n = 501$) and American ($n = 480$) men and women.
Measurements: Self-reported sleep duration was obtained using questionnaires. Sex- and site-stratified logistic regression analyses investigated relationships between sleep duration, individual CM risk factors and a binary CM risk variable (presence of ≥3 CM risk factors), adjusting for age, physical activity and education.
Results: Sleep duration distributions varied by cohort: 44.5%, 41.4%, 35.9%, 16.8% and 2.5% of American, Jamaican, Seychellois, Ghanaian and South African men reported <7 h sleep per night respectively ($p < 0.001$). Similarly, 42.6%, 28.6%, 25.2%, 12.8% and 1.5% of American, Jamaican, Seychellois, Ghanaian and South African women reported <7 h sleep respectively ($p < 0.001$). American men reporting ≤6 h sleep were more likely to be in the elevated CM risk group (OR: 2.52, 95%CI: 1.02, 6.22, $p = 0.045$) and to have a high waist circumference (OR: 2.44, 95%CI: 1.07, 5.57, $p = 0.034$) compared to those reporting 8 h sleep. Jamaican women reporting ≤6 h sleep (OR: 2.53, 95%CI: 1.19, 5.36, $p = 0.016$) and American women reporting 7 h sleep (OR: 2.71, 95%CI: 1.17, 6.26, $p = 0.002$) were more likely to be obese than those reporting 8 h sleep.
Conclusions: Associations between short sleep and CM risk factors were only evident in the American men and women and Jamaican women. Future interventions to address CM risk and sleep health may need to be country-specific when targeting high-risk populations.

Introduction

Traditional risk factors for cardiovascular disease (CVD) and type 2 diabetes mellitus include obesity, hypertension, elevated blood glucose levels, dyslipidemia, poor diet, physical inactivity and tobacco smoking. Poor sleep, characterized by insufficient, too much, mistimed or

Abbreviations: METS, Modeling the Epidemiologic Transition Study; HDI, Human Development Index; PA, Physical activity

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low-quality sleep, is now also recognized as a risk factor for cardiometabolic (CM) diseases.[1–3]

Several prospective cohort studies show that both short and long sleep are associated with higher all-cause and CVD mortality in a U-shaped manner.[4–6] In the United States (US), the National Health Interview Survey data indicate that relative to sleeping 7 and 8 h per night, self-reported short (≤6 h) and long (>9 h) sleep duration are independently associated with obesity, type 2 diabetes mellitus, hypertension and CVD.[1] Sleep restriction in healthy volunteers leads to several metabolic alterations, including increased inflammatory markers and sympathetic activity, alterations in appetite regulating hormones and increased hunger/food intake, adipocyte dysfunction, altered growth hormone and cortisol profiles, and reduced insulin sensitivity; all of which may increase risk for CM diseases.[7–9] Indeed, current guidelines from the National Sleep Foundation in the US recommend adults (26–64 year) sleep 7–9 h per night,[10] and a consensus statement from the American Academy of Sleep Medicine and Sleep Research Society recommends that adults (18–60 year) sleep 7 h or more for optimal health.[11]

African-origin populations may be particularly vulnerable to CM diseases. In the US, African American men, for example, have a higher incidence of fatal coronary heart disease and African American women a higher incidence of both fatal and non-fatal coronary heart disease compared to men and women of European-origin.[12] Similarly, there also appear to be distinct differences in sleep parameters between European- and African-origin populations.[13] For example, individuals of African-origin in the United Kingdom (UK) Biobank cohort were more than three times as likely to report short nocturnal sleep (≤6 h) than propensity-matched participants of European-origin.[14] In another study, actigraphy-derived sleep duration in adults of African-origin was shorter and of poorer quality than those of European-origin in the Chicago area study (6.65 h v 7.45 h), even when adjusted for education, which was used as a proxy for socio-economic status.[15] Similarly, polysomnographic studies have observed less slow-wave (non-rapid eye movement stage 3, NREM3) sleep and more stage NREM2 sleep in African Americans compared to European Americans.[16,17] Although very little sleep-related research exists on African-origin populations living outside of the US or the UK, there is some evidence to suggest that South Africans of African-origin have unusually long sleep durations (8–10 h) compared to South Africans of European- or Indian-origin or of mixed ancestry.[16–19] Recent evidence suggests that the relationship between sleep and CM risk may vary by ethnicity.[18] For example, adjusted data from the US National Health and Nutrition Examination Survey indicated that 7 h of sleep was associated with the lowest CM risk score in non-Hispanic Americans compared to 8 h of sleep in African Americans.[18] Caution should be taken, however, not to over generalize these results, given that multiple biopsychosocial, environmental and cultural factors which modify sleep may in fact diminish some ethnic differences in sleep.

Improving our understanding of the etiology and associated risk factors for non-communicable diseases (NCD) is important to guide policies and interventions aimed at reducing their prevalence. This almost certainly needs to take into account the unique characteristics of any given population. For example, since the distribution of NCD-related deaths varies as countries span the epidemiologic, and particularly the demographic, transition, with the burden of NCDs growing at a faster rate in developing compared to developed countries,[19] between country comparisons are needed. One way to account for a country's stage of development is to use the Human Development Index (HDI). This composite statistic was developed by the United Nations to measure a country's social and economic development, and takes into account life expectancy at birth, mean and expected years of education and gross national income per capita. Furthermore, it is becoming clear that since some risk factors for NCDs may be population specific (e.g. insulin resistance in Indian populations), applying a Eurocentric approach to NCD prevention in individuals of African-origin may be inappropriate. Therefore, the aim of this study was to investigate associations between self-reported sleep duration and CM risk factors in five African-origin cohorts spanning the epidemiologic transition.

Participants and methods

Study design and overview

The Modeling the Epidemiologic Transition Study (METS, R01DK80763) is a prospective study exploring associations between physical activity (PA) levels, relative weight change and CM risk factors in young adults of African-origin from five countries (Ghana, South Africa, Jamaica, Seychelles, the United States).[20,21] These countries were chosen as they represent a broad range of social and economic development as captured by the United Nations' HDI 2010 report, the year in which METS began. Ghana was ranked as a low human development country (HDI rank 130), South Africa low-medium (110), Jamaica medium-high (80), Seychelles high (52) and the US very high (4). The Ghanaians were from a rural community while the others were all considered urban and peri-urban dwellers. Full details of the methods employed, including a detailed description of the sampling procedures, have been published previously.[20] Briefly, at each of the sites, the samples were initially generated using age- and sex-stratified random sampling, followed by door-to-door recruitment until the study sample number was met ($n = 500$).

Participants

Approximately 2506 (~500 from each site) young adults of African-origin between the ages of 25 and 45 years were recruited into METS. Persons with obvious infectious diseases (including active malaria or HIV), who were pregnant or lactating or had any condition preventing them from engaging in normal physical activities (such as severe osteo- or rheumatoid arthritis, lower extremity disability) were excluded. Of the 2506 original participants, only those with valid sleep questionnaire data were included in this analysis and those taking sleeping medications or psychoactive medications were also excluded ($n = 2473$; Ghana: $n = 492$; South Africa: $n = 503$; Jamaica: $n = 497$; Seychelles: $n = 501$ US: $n = 480$).

The protocol for METS was approved by the Institutional Review Board of Loyola University, Chicago, IL, US (the coordinating center for this international study); the Committee on Human Research Publication and Ethics of Kwame Nkrumah University of Science and Technology, Kumasi, Ghana; the Human Research Ethics Committee of the University of Cape Town, South Africa; the Board for Ethics and Clinical Research of the University of Lausanne, Switzerland; the Ethics Committee of the Ministry of Health of Seychelles; and the Ethics Committee of the University of the West Indies, Kingston, Jamaica. Written informed consent was obtained from all participants.

Procedures

All procedures were standardized across the five sites, and research study staff were centrally trained and certified prior to the initiation of the study. Questionnaires were administered in participants' home language by trained staff.

Questionnaires

The study-specific questionnaires captured participants' demographic information, basic health history, medication and dietary supplement use, tobacco and alcohol use, general household socioeconomic (SES) characteristics, occupation and education as previously described.[20] Relevant for the current study, participants were

asked "Approximately how many hours do you sleep each night?" and current employment status was assessed by the question "Did you do any type of work for pay in the last month?" Asset index was based on possession of 19 items reflecting individual and household wealth.[22] Day length was calculated for each individual by determining time elapsed between sunrise and sunset on the date he/she completed the questionnaire.

Anthropometry

Weight (kg) height (cm), and waist and hip circumferences (cm) were measured according to the METS standard procedures**.** Body mass index (BMI) was calculated as weight/height^2 (kg/m^2), and participants were classified as normal weight (BMI: <25 kg/m^2), overweight (BMI: ≥25 kg/m^2 but <30 kg/m^2) or obese (BMI: ≥30 kg/m^2).

Moderate and vigorous levels of physical activity

Physical activity (PA) was assessed over 8 days using waist-worn Actical accelerometers (Phillips Respironics, Bend, OR, USA) as previously described.[20,23,24] For the current analysis, we assessed PA between the hours of 07h00 and 23h00 daily and estimated daily moderate- to vigorous-intensity PA (MVPA) in 1 min bouts using a previously described protocol.[25]

Clinical and biochemical measurements

Resting systolic and diastolic blood pressure (SBP and DBP) were measured twice, in triplicate (Omron HEM-747Ic, Omron Healthcare, Bannockburn, IL, USA) as previously described.[20] Following an overnight fast, venous blood samples were drawn for subsequent analyses of insulin and lipid concentrations as previously described.[20] Fasting capillary plasma glucose was determined using finger stick (Accu-check Aviva, Roche). Triglycerides (TG) and high-density lipoprotein-cholesterol (HDL) were calculated using the Friedewald equation[26]

CM risk

The following five CM risk factors were defined according to the Adult Treatment Panel III criteria: (i) waist circumference ≥102 cm in men and ≥88 cm in women; (ii) elevated blood pressure (≥130/85 mmHg), or receiving treatment; (iii) hypertriglyceridemia (≥150 mg/dL or ≥1.7 mmol/L), or receiving treatment; (iv) low high-density lipoprotein (HDL) cholesterol (<40 mg/dL or <1.03 mmol/L in men and <50 mg/dL or 1.29 mmol/L in women), or receiving treatment; and (v) elevated fasting plasma glucose (≥100 mg/dL or ≥5.6 mmol/L) or receiving treatment.[27] Individuals with at least 3 of the 5 risk factors were classified as elevated CM risk.

Data and statistical analyses

Data are presented as mean ± standard deviation, median with the interquartile range, proportions, relative risk ratios or odds ratios with 95% confidence intervals. The Shapiro-Wilk test was used to test for normality. Descriptive variables between groups were compared using one-way analysis of variance or covariance, or Kruskal-Wallis tests. Frequency differences between groups were analyzed using Chi-Squared or Fisher's Exact tests. Pairwise correlations were performed using Pearson's correlation. Binary logistic regressions examined associations between self-reported sleep duration (predictor) and high waist circumference, triglycerides, blood pressure and glucose, low HDL, obesity and high CM risk (all outcome variables in separate models). For regression analyses, sleep duration was binned hourly. Based on the sleep duration distribution observed in this study (Fig. 1) and the current sleep duration recommendations for optimal health in adults,[10] the reference sleep duration was 8 h, 3–6 h were collapsed into one group and 10–14 h were collapsed into a single group. All models were stratified by sex and site, adjusted for age, with total minutes of MVPA and education as covariates. Day length was also covaried for when necessary. Data were analyzed using Stata (v.12, StataCorp, Texas, USA) and significance accepted using an alpha value of $p < 0.05$.

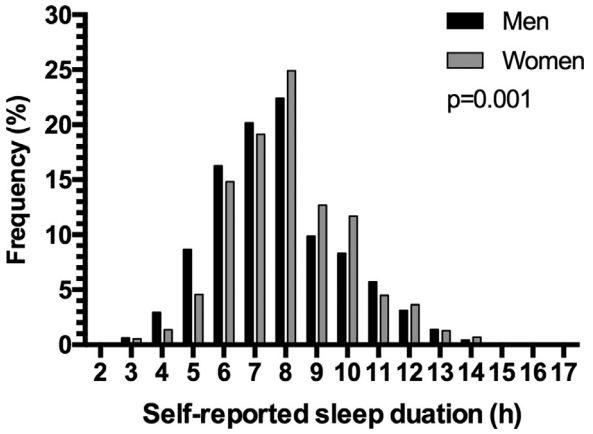

Fig. 1. Comparison of self-reported sleep length distributions between the men ($n = 1163$) and women ($n = 1334$) from all five sites combined. Significance was determined using a Chi-squared test.

Results

Participant characteristics

The characteristics of the participants from the five sites are presented separately for men (Table 1) and women (Table 2). For both sexes, all participant characteristics differed by site. Among the men, post hoc analyses indicated that Seychellois and American men were older than the other three cohorts. BMI, waist circumference and obesity prevalence was highest among American and Seychellois men and obesity lowest among Ghanaian and South African men. TG concentration was lowest among the Jamaicans, while HDL concentration was lowest among the Ghanaians and highest in the South Africans. Both South African and American men presented with the highest SBP and DBP measurements. Fasting glucose concentration was highest in Seychellois and Ghanaian men and lowest among the South Africans. More American and Seychellois and fewer Jamaican men had elevated CM risk (3 out of 5 risk factors). Ghana and South African reported the lowest years of education and men from the US reported the highest. Employment was lowest in South Africa and highest in Ghana and Seychelles. Minutes of MVPA were highest in Ghana and South Africa, and lowest in Jamaica and the US.

Among the women, South Africans were the youngest and Seychellois and Americans were the oldest. BMI, waist circumference and obesity were highest in American women, followed by South African women and lowest among Ghanaian women. TG concentration was highest among American and lowest among Seychellois women. HDL concentration was lowest in South African and highest in American women. SBP and DBP were highest in South African and American women and lowest among Ghanaian women. Fasting glucose concentration was highest in Ghanaian and lowest in South African women. More American and fewer Ghanaian and Jamaican women presented with elevated CM risk. Ghanaian women reported fewest and American women most education years. Employment was lowest in South African and highest in Seychellois women. Minutes of MVPA were highest in Ghana and Seychelles and lowest in the USA.

Self-reported sleep duration

Self-reported sleep duration distributions differed by sex (Fig. 1, $p < 0.001$) with women (8.05 ± 1.95 h) reporting longer sleep

Table 1
Characteristics of the men from all five sites, presented from lowest to highest HDI ($n = 1156$)

	Ghana ($n = 202$)	South Africa ($n = 236$)	Jamaica ($n = 249$)	Seychelles ($n = 231$)	United States ($n = 238$)	p-value
Sleep duration (h)	7.8 ± 1.5	10.3 ± 1.8	7.0 ± 1.9	7.0 ± 1.3	6.7 ± 1.3	<0.001
Age (y)	35 (28–41)	34 (29–39)	33 (29–39)	37 (33–41)	36 (30–41)	<0.001
BMI (kg·m^{-2})	21.8 (20.3–23.8)	21.5 (19.9–24.2)	22.4 (20.3–26.0)	26.0 (22.9–29.1)	27.8 (24.1–32.9)	<0.001
WC (cm)	76.8 (72.3–80.7)	78.0 (73.1–86.2)	76.9 (71.8–87.3)	89.0 (80.5–97.0)	93.7 (81.3–106.5)	<0.001
TG (mmol·L^{-1})*	0.9 (0.7–1.2)	0.9 (0.6–1.2)	0.7 (0.6–1.0)	0.9 (0.6–1.3)	0.9 (0.6–1.3)	<0.001
HDL (mmol·L^{-1})*	1.1 (0.9–1.4)	1.3 (1.0–1.6)	1.2 (1.0–1.4)	1.2 (1.0–1.4)	1.2 (1.0–1.5)	<0.001
SBP (mmHg)	118.6 ± 12.6	129.0 ± 17.1	121.5 ± 12.8	122.6 ± 14.5	127.9 ± 14.6	<0.001
DBP (mmHg)	68.2 ± 11.0	79.6 ± 13.1	71.22±11.1	74.9 ± 11.4	80.9 ± 12.1	<0.001
Glucose (mmol·L^{-1})*	5.61 (5.22–6.00)	4.72 (4.33–5.17)	5.28 (4.94–5.67)	5.61 (5.33–6.22)	5.56 (5.11–6.06)	<0.001
Obese (count,%)	3 (1.5)	13 (5.5)	24 (9.6)	48 (20.8)	96 (40.3)	<0.001
High WC (count,%)	3 (1.5)	13 (5.5)	11 (4.4)	34 (14.7)	82 (34.5)	<0.001
High TG (count,%)*	24 (11.9)	35 (14.9)	5 (3.2)	35 (15.2)	33 (14.2)	0.003
Low HDL (count,%)*	92 (46.0)	62 (26.5)	53 (34.4)	46 (36.2)	73 (31.5)	0.001
High BP (count,%)	31 (15.4)	113 (47.9)	44 (17.7)	74 (32.0)	110 (46.2)	<0.001
High glucose (count,%)*	114 (56.4)	28 (12.1)	85 (34.6)	139 (60.2)	124 (52.8)	<0.001
Elevated CM risk (count,%)*	23 (11.4)	18 (7.6)	9 (4.3)	39 (18.1)	68 (28.2)	<0.001
Education (y)*	9 (9–10)	10 (8–12)	11 (9–11)	13 (11–15)	12 (12–14)	<0.001
Employed (count,%)*	178 (93.7)	64 (27.7)	201 (82.7)	214 (97.3)	144 (61.8)	<0.001
Asset index	9 (6–11)	9 (6–10)	12 (10–15)	13 (12–15)	16 (15–17)	<0.001
MVPA (min·day^{-1})*	45.3 (26.7–62.3)	48.2 (30.9–75.7)	24.5 (11.7–41.4)	32.2 (17.4–50.4)	20.6 (10.1–42.9)	<0.001
Smoker (count,%)	13 (6.4)	152 (64.4)	107 (43.0)	87 (37.7)	171 (71.9)	<0.001
Day length (h)	12.32 (11.93–12.48)	12.60 (10.87–13.48)	12.00 (11.35–12.82)	12.22 (11.98–12.33)	12.97 (10.50–14.45)	<0.001

Data are presented as mean ± standard deviation, median (interquartile range) or count (%). HDI: Human Development Index, BMI: body mass index, WC: waist circumference, TG: triglyceride HDL: high density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, CM: cardiometabolic, MVPA: moderate-to-vigorous intensity physical activity.

* TG: $n = 1057$, HDL: $n = 947$, Glucose: $n = 1146$, High glucose: $n = 1154$, High CM risk: $n = 1099$, Education: $n = 1118$, Currently employed: $n = 1117$, MVPA: $n = 1079$. p-values represent between site comparisons using either one-way ANOVA, Kruskal-Wallis, Chi-squared or Fishers Exact tests.

durations than men (7.73 ± 2.06 h, $p < 0.001$). Simple correlations indicated that being employed was associated with shorter sleep durations in both men ($r^2 = 0.10$, $p < 0.001$) and women ($r^2 = 0.12$, $p < 0.001$). Furthermore, sleep duration was weakly, but negatively associated with day length in women ($r^2 = 0.01$, $p < 0.001$), but not men ($r^2 = 0.00$, $p = 0.658$).

Self-reported sleep duration differed between the sites for men (Table 1, Fig. 2A, $p < 0.001$) and women (Table 2, Fig. 2B, $p < 0.001$). Specifically, South African men reported longer sleep durations than men from the other cohorts (all $p < 0.001$), followed by Ghanaian men, who slept longer sleep than Jamaican ($p < 0.001$), Seychellois ($p < 0.001$) and American ($p < 0.001$) men. Similarly, South African women reported longer sleep durations than all other cohorts (all $p < 0.001$), and Ghanaian women reported longer sleep durations than Jamaican ($p = 0.001$), Seychellois ($p = 0.001$) and American ($p < 0.001$) women. American women reported shorter sleep durations than Jamaican ($p < 0.001$) and Seychellois ($p = 0.001$) women. Being employed was weakly associated with shorter sleep duration

Table 2
Characteristics of the women from all five sites, presented from lowest to highest HDI ($n = 1317$)

	Ghana ($n = 290$)	South Africa ($n = 267$)	Jamaica ($n = 248$)	Seychelles ($n = 270$)	United States ($n = 242$)	p-value
Sleep duration (h)	8.0 ± 1.4	10.4 ± 1.7	7.5 ± 1.7	7.3 ± 1.2	6.8 ± 1.4	<0.001
Age (y)	34 (28–40)	33 (27–38)	35 (29–40)	36 (31–41)	35 (30–40)	<0.001
BMI (kg·m^{-2})	24.6 (22.0–28.0)	31.6 (26.1–36.7)	29.3 (24.8–33.0)	27.1 (22.9–31.6)	33.2 (27.4–39.8)	<0.001
WC (cm)	83.5 (75.4–91.0)	95.8 (84.9–106.8)	91.0 (82.5–100.9)	87.0 (79.0–95.5)	101.1 (88.8–112.9)	<0.001
TG (mmol·L-1)*	0.8 (0.6–1.0)	0.8 (0.6–1.0)	0.7 (0.6–0.9)	0.6 (0.5–0.9)	0.8 (0.6–1.3)	<0.001
HDL (mmol·L-1)*	1.2 (1.0–1.4)	1.1 (0.9–1.3)	1.2 (1.0–1.3)	1.2 (1.0–1.4)	1.3 (1.0–1.6)	<0.001
SBP (mmHg)	110.4 ± 15.0	118.2 ± 18.6	115.2 ± 14.7	110.8 ± 12.7	117.5 ± 16.2	<0.001
DBP (mmHg)	66.2 ± 11.4	76.3 ± 11.8	72.1 ± 11.4	71.2 ± 9.9	79.1 ± 13.0	<0.001
Glucose (mg·dL-1)*	5.50 (5.11–5.89)	4.50 (3.94–4.94)	5.06 (4.72–5.39)	5.17 (4.78–5.56)	5.22 (4.72–5.67)	<0.001
Obese (count,%)	46 (15.9)	149 (55.8)	113 (45.6)	84 (31.1)	153 (63.2)	<0.001
High WC (count,%)	88 (30.3)	176 (65.9)	141 (57.1)	123 (45.6)	181 (74.8)	<0.001
High TG (count,%)*	14 (4.9)	10 (3.8)	11 (4.6)	8 (3.0)	34 (14.7)	<0.001
Low HDL (count,%)*	155 (54.0)	176 (66.2)	155 (54.0)	96 (53.9)	105 (45.5)	<0.001
High BP (count,%)	29 (10.0)	73 (27.3)	42 (16.9)	52 (19.3)	81 (33.5)	<0.001
High glucose (count,%)*	138 (47.9)	24 (9.0)	36 (14.6)	76 (28.3)	75 (31.4)	<0.001
Elevated CM risk (count,%)*	39 (13.6)	47 (17.7)	33 (13.7)	46 (17.8)	76 (32.2)	<0.001
Education (y)*	9 (5–9)	11 (9–12)	11 (9–11)	13 (11–14)	14 (12–15)	<0.001
Employed (count,%)*	206 (74.6)	40 (15.2)	134 (54.0)	236 (92.2)	150 (62.2)	<0.001
Asset index	8 (5–10)	8 (7–10)	12 (9–13)	13 (11–15)	16 (15–17)	<0.001
MVPA (min·day^{-1})*	22.2 (14.4–33.9)	19.7 (8.8–29.7)	16.3 (7.4–28.0)	22.0 (12.5–30.5)	9.6 (4.4–19.3)	<0.001
Smoker (count,%)	0 (0.0)	25 (9.4)	43 (17.3)	17 (6.3)	79 (32.6)	<0.001
Daylength (h)	12.12 (11.85–12.48)	11.82 (10.48–13.47)	11.73 (11.35–12.23)	12.03 (11.90–12.22)	13.48 (11.00–14.65)	<0.001

Data are presented as mean ± standard deviation, median (interquartile range) or count (%). HDI: Human Development Index, BMI: body mass index, WC: waist circumference, TG: triglyceride, HDL: high density lipoprotein cholesterol, SBP: systolic blood pressure, DBP: diastolic blood pressure, CM: cardiometabolic, MVPA: moderate-to-vigorous intensity physical activity.

* TG: $n = 1292$, HDL: $n = 1203$, Glucose: $n = 1310$, High glucose: $n = 1329$, High CM risk: $n = 1288$, Education: $n = 1296$, Currently employed: $n = 1285$, MVPA: $n = 1244$. p-values represent between site comparisons using either one-way ANOVA, Kruskal-Wallis, Chi-squared or Fishers Exact tests.

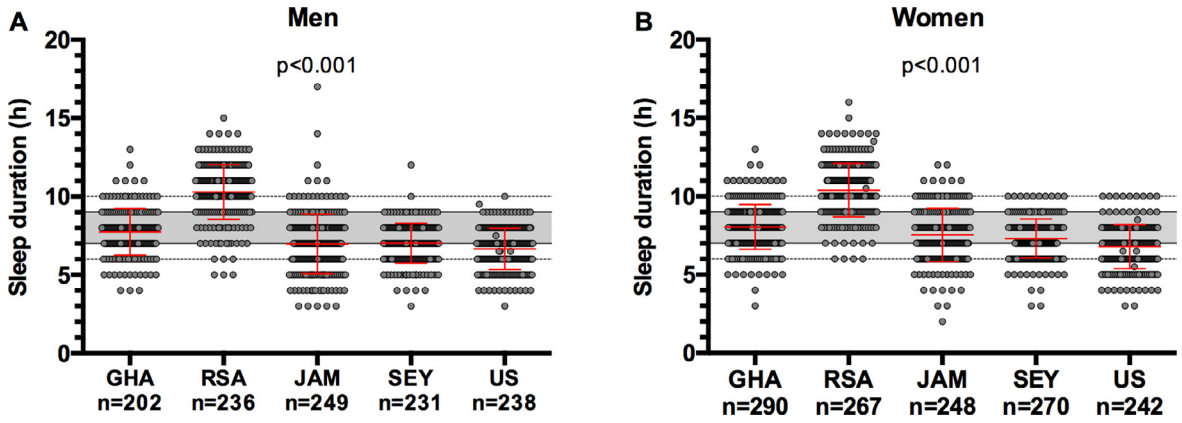

Fig. 2. Self-reported sleep duration comparison between sites for the men (A) and women (B). Individual data points are plotted together with mean and SD. The grey area (7–9 h) indicates the recommended sleep duration for adults in this age group and the dotted lines (6–10 h) are the upper and lower recommended duration limits (i.e. 6 h and 10 h).[10] Significance was determined using a one-way ANOVA.

in Ghanaian men ($r^2 = 0.03$, $p = 0.021$), Ghanaian women ($r^2 = 0.02$, $p = 0.020$), South African women ($r^2 = 0.06$, $p < 0.001$) and Seychellois women ($r^2 = 0.02$, $p = 0.044$). Day length was weakly but negatively associated with sleep duration in Ghanaian men ($r^2 = 0.02$, $p = 0.036$) and Jamaican women ($r^2 = 0.02$, $p = 0.022$), but did not reach significance among any of the other groups (data not shown).

Among the men, 44.5% of the Americans, 41.4% of the Jamaicans, 35.9% of the Seychellois, 16.8% of the Ghanaians and 2.5% of the South Africans reported sleeping less than the recommended 7–9 h per night.[38] In contrast, 73.7%, 11.9%, 7.6%, 0.9% and 0.4% of South African, Ghanaian, Jamaican, Seychellois and American men respectively reported long sleep durations (i.e. >9 h per night). A similar picture is observed among women whereby 42.6%, 28.6%, 25.2% 12.8% and 1.5% of American, Jamaican, Seychellois, Ghanaian and South African women respectively reported less than 7 h of sleep per night. On the other hand, 72.7%, 14.5%, 13.8%, 3.7% and 3.7% of South African, Jamaican, Ghanaian, Seychellois and American women respectively reported 9 h or more of sleep each night. These distributions differed significantly for men ($p < 0.001$) and women ($p < 0.001$).

Self-reported sleep durations of participants with and without individual CM risk factors are presented in Appendix Tables A1 (Men) and A2 (Women). Age-adjusted analyses indicate that Ghanaian men with high TG concentrations had shorter self-reported sleep durations than those with normal TG concentrations ($p = 0.042$) and American men with high waist circumferences reported shorter sleep durations than those with normal measurements ($p = 0.034$). Obese American women had shorter sleep than their non-obese counterparts ($p = 0.020$).

Relationship between self-reported sleep duration and obesity for pooled data

The age-adjusted relationship between self-reported sleep duration bins and obesity for all sites combined is presented in Fig. 3. Among the men, those who reported ≤6 h of sleep per night had 1.54 times the odds of being obese (95% CI: 1.00–2.37, $p = 0.049$) compared to those who reported 8 h of sleep (Fig. 3A, $p < 0.001$). Similarly, men who reported sleeping ≥10 h had 0.34 times the odds of presenting with obesity (95% CI: 0.17, 0.67, $p = 0.002$) compared to those who reported 8 h. After adjusting for site, minutes of MVPA and education, however, none of the obesity models remained statistically significant (Table 3).

Among women, the age-adjusted relationship between self-reported sleep duration bins and obesity was also significant (Fig. 3B, $p < 0.001$). Women who reported sleeping ≤6 h per night were 1.87 times the odds of being obese (95% CI: 1.35, 2.60, $p = 0.001$) and those who reported sleeping ≥10 h per night were 1.82 times the odds of being obese (95% CI: 1.31–2.52, $p < 0.001$) compared to women who report 8 h of sleep per night. After including site, minutes of MVPA, education and day length in the model, only the short-sleep association remained significant such that women who reported ≤6 h of sleep per night were 1.47 times the odds of being

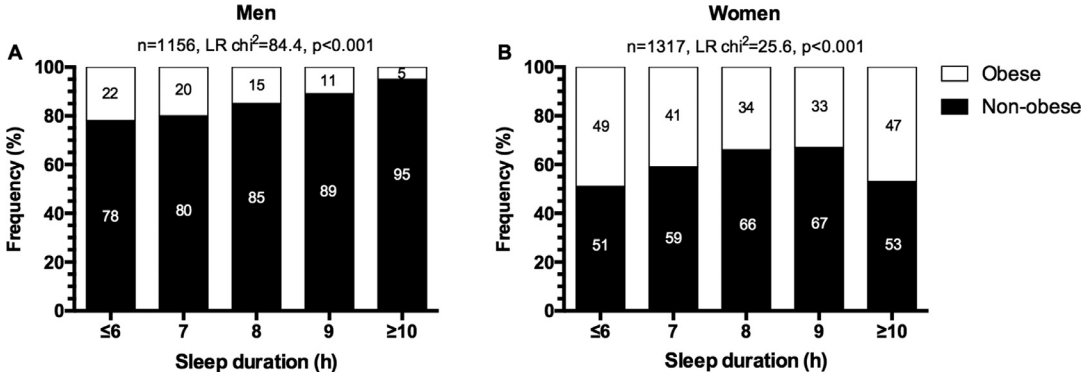

Fig. 3. Relationships between obesity and self-reported sleep duration for men (A) and women (B). Significance was determined using binary logistic regression and adjusted for age.

Table 3
Fully-adjusted binary logistic regression models assessing associations between obesity (outcome) and self-reported sleep duration (predictor) in the men and women from all sites

		Men		Women	
		OR (95% CI)	P-value	OR (95% CI)	*p*-value
Sleep duration	≤6 h v 8h	1.29 (0.78, 2.13)	0.328	1.47 (1.01, 2.13)	0.045
	7 h v 8h	1.20 (0.69, 2.07)	0.523	1.34 (0.91, 1.97)	0.135
	9 h v 8h	1.11 (0.50, 2.47)	0.799	0.99 (0.63, 1.54)	0.967
	≥10 h v 8h	1.07 (0.35, 3.23)	0.904	0.99 (0.63, 1.54)	0.955
Site	Ghana v US	0.04 (0.01, 0.12)	<0.001	0.14 (0.08, 0.24)	<0.001
	South Africa v US	0.13 (0.04, 0.36)	<0.001	1.07 (0.65, 1.78)	0.783
	Jamaica v US	0.14 (0.76, 0.25)	<0.001	0.56 (0.37, 0.86)	0.007
	Seychelles v US	0.38 (0.25, 0.60)	<0.001	0.26 (0.17, 0.39)	<0.001
	Age (y)	1.03 (1.00–1.07)	0.062	1.03 (1.01, 1.05)	0.003
	MVPA (min/d)	0.99 (0.98. 1.00)	0.001	0.99 (0.98. 1.00)	0.022
	Education (y)	1.05 (0.97, 1.15)	0.239	1.00 (0.95, 1.05)	0.968
	Day length (h)	–	–	1.05 (0.95, 1.16)	0.314
	Model	n = 1061, LR chi^2=182.4, p<0.001		n = 1218, LR chi^2=185.3, p<0.001	

OR: odds ratio, CI: confidence interval, MVPA: moderate- to vigorous-intensity physical activity.

obese compared to those who reported 8 h of sleep (95% CI: 1.01, 2.12, p = 0.045, Table 3).

Relationship between self-reported sleep duration and CM risk factors for each of the five sites

Tables A3–A9 in the Appendix show the results from the regression models exploring the relationships between self-reported sleep duration (predictor) and elevated CM risk, obesity, high waist circumference, high triglycerides, low HDL-cholesterol, high blood pressure and high glucose for men and women at each of the five sites. All models were adjusted for age, minutes of MVPA and education years. Day length was only included as a covariate in the Ghanaian men and Jamaican women analyses, since these were the only two groups in whom day length was associated with sleep duration. American men who reported ≤6 h of sleep per night were 2.52 times the odds of having elevated CM risk (Fig. 4A, 95% CI: 1.02, 6.22, p = 0.045, Table A3) and 2.44 times the odds of having a high WC (Fig. 4B, 95% CI: 1.07, 5.57, p = 0.034, Table A5) compared to those who reported 8 h sleep per night.

Among the women, Jamaicans who reported that they slept ≤6 h per night had 2.64 times the odds of being obese (Fig. 4C, 95% CI: 1.24, 5.63, p = 0.012, Table A4) while women from the USA who reported sleeping 7 h per night had 2.71 times the odds of being obese (Fig. 4D, 95% CI: 1.17, 6.26, p = 0.002, Table A4) compared to those reporting 8 h per night. Both men and women from Ghana reporting 7 h of sleep were more likely to have high HDL concentrations compared to those reporting 8 h of sleep (Men: Fig. 4E, OR: 0.30, 95% CI: 0.13, 0.70, p = 0.005, Table A7; Women: Fig. 4F, OR: 0.39, 95% CI: 0.19, 0.79, p = 0.009, Table A7). In contrast, men from the Seychelles who reported sleeping 7 h per night had 3.39 times the odds of having low HDL levels compared to those who reported 8 h of sleep per night (95% CI: 1.07, 10.73, p = 0.037, Table A7).

Discussion

Our study presents data from an international study exploring the risk factors for obesity and CM risk in five African-origin populations spanning the epidemiologic transition. The first finding is that pooled data from all five cohorts demonstrates an approximately linear relationship between self-reported sleep duration and obesity in men, such that those reporting longer sleep were less likely to be obese. This was in contrast to the women, where the relationship was U-shaped, i.e. women reporting either shorter or longer sleep being more likely to be obese compared to those sleeping 7–9 h. Therefore our study extends the well-established association between sleep duration and obesity,[28] by demonstrating that within a geographically diverse population of young adults of African-origin, the relationship between sleep duration and obesity differs between sexes. After adjusting for site and potential confounders such as physical activity levels education and day length, only women who reported ≤6 h sleep per night were more likely to be obese compared to those who reported 8 h of sleep. This suggests that there is an ecological relationship between sleep and obesity between the five cohorts and prompted us to explore further the associations between sleep duration, obesity and CM risk factors stratified by geographical site and sex.

Our second observation is that while previous studies report that the sleep duration-CM risk relationship varies by ethnicity,[18,29] we provide evidence that within young adults of African-origin, this relationship also varies by geographical location and sex. Specifically, our data showed that only short-sleeping (≤6 h) men from America had higher CM risk and larger waist circumferences than those reporting 8 h of sleep per night. Similarly, compared to their respective 8 h reference groups, only women from America reporting 7 h of sleep were more likely to be obese, men from the Seychelles reporting 7 h of sleep were more likely to have low HDL-cholesterol levels, while Ghanaian men and women reporting 7 h of sleep were more likely to have higher HDL cholesterol levels.

It is likely that sleep duration and quality (not measured in this study) interact with socioeconomic and environmental factors in modifying CM risk. The neighborhood and home environment, including factors such as crime and safety, housing density, home type, noise and temperature and the physical sleeping arrangements might impact sleep quality. Since low-income African-origin South African women reported better sleep quality in the laboratory than at home[30] and a meta-analysis found that ethnic differences in sleep duration between African Americans and Caucasian Americans disappeared when sleep was recorded in the laboratory,[13] a role for the neighborhood and home environment on sleep seems likely. Given that sleep duration and quality are potentially modifiable[31] and since early studies suggested beneficial effects of sleep extension on appetite and glucose regulation,[32,33] the home sleep environment should be further investigated as an intervention target to improve sleep and reduce CM risk. Furthermore, the extent to which current sleep guidelines advocated to promote optimal health are applicable to different countries may need to be addressed.

We next observed differences in self-reported sleep duration by HDI categories. Men and women from the two lowest ranked HDI countries (Ghana and South Africa) reported longer sleep than those from the higher HDI countries, and amongst the women, those from

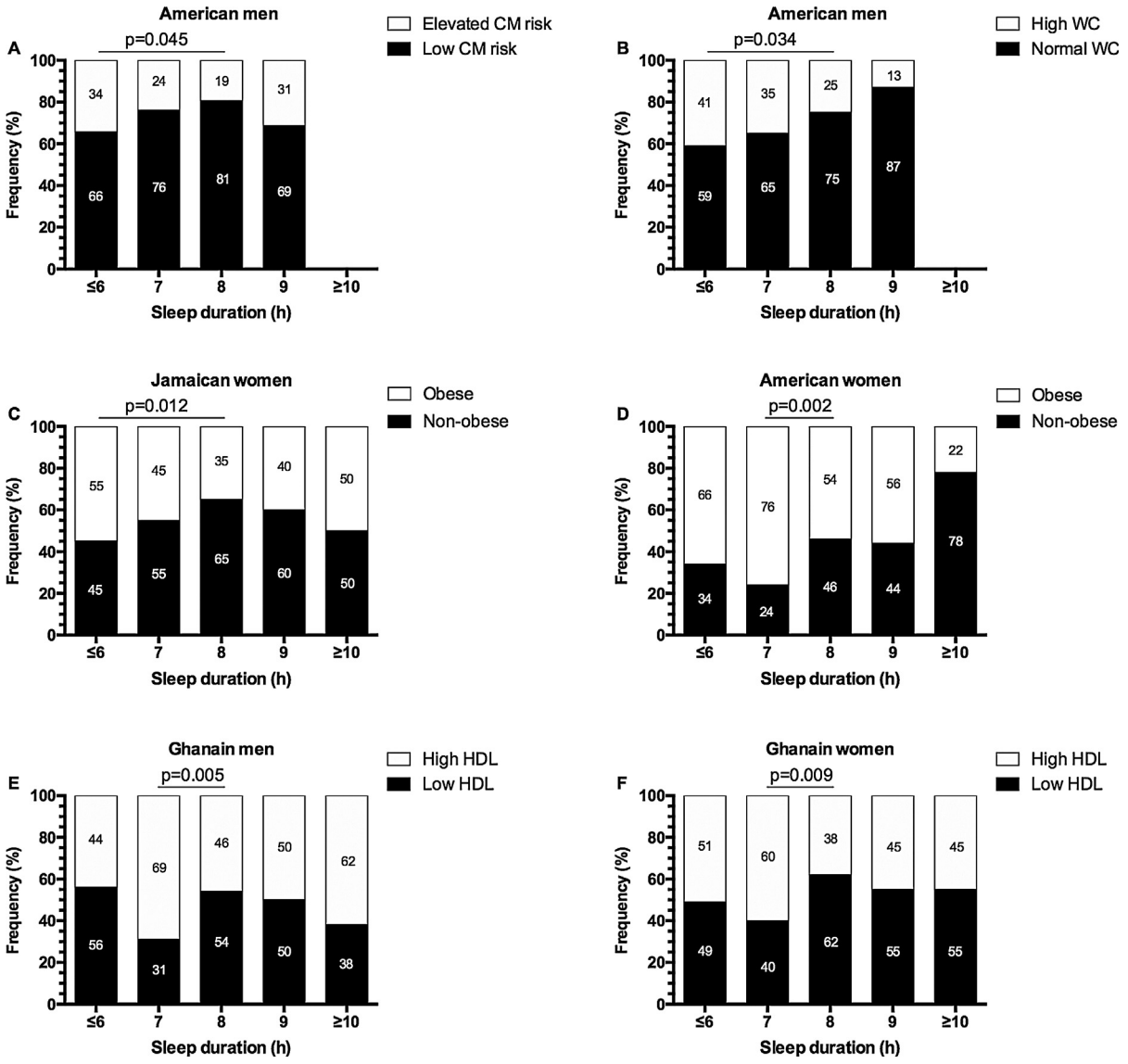

Fig. 4. Relationships between CM risk in the American men (A), high waist circumference in the American men (B), obesity in the Jamaican women (C), obesity in the American women (D), high HDL in the Ghanaian men (E) and women (F) and self-reported sleep duration. Significance was determined using multinomial or binary logistic regression adjusting for age, MVPA and education.

the highest HDI country (US) reported the shortest sleep durations. To the best of our knowledge, only one other study has compared sleep duration between countries at varying stages of human development, and ours is the first to explore this relationship in young adults. Manyanga et al. found no differences between objectively measured sleep duration and sleep efficiency in 10-year old children from 12 countries of varying HDI.[34] It is likely that downstream effects of environmental or societal risk factors on sleep duration may only manifest in adulthood. Alternatively, the different methods of sleep measurement (accelerometry versus self-report) used in these two studies may partially account for the contrasting outcomes. It may also be that other local factors, many of which were not measured or adjusted for in this study, contributed to the HDI-associated differences in sleep duration observed in this study.

One might argue that employment status accounts for the cohort-specific variation in sleep duration observed in this study. Employed individuals typically have shorter sleep durations than unemployed persons[35] as do those working longer hours[35,36] or with lengthy commutes.[36,37] Indeed, we found that unemployed South African women, but not men, reported significantly longer sleep durations. Contrary to this, however, is our observation that the Ghanaians, who had higher employment rates than the Americans, also reported longer sleep durations. Thus, employment status may be too crude a measure in this context; perhaps working hours, commute time to work or daily time utilization (none of which were measured in this study) play a larger role and should be investigated in future. Alternatively, type of employment should be considered, Indeed the Ghanaians in this study reported significantly higher levels of manual labor compared to the Americans.

It is possible that the shorter sleep durations reported by the Americans compared to the longer sleep durations of the Ghanaians living in a more rural environment may reflect the effect of urbanization. Shorter sleep durations have been reported in urban Chinese adults,[38] Peruvian adults,[39] Canadian high-school children,[40] and Thai primary-school children[41] compared to their respective rural-dwelling counterparts. Potentially there may be fewer environmental barriers to good sleep (noise, light, crowding, safety) in some rural settings. In contrast, however, no differences were observed in objectively measured sleep duration between rural and urban communities in Mozambique. Rather, sleep timing was later in the urban setting and sleep quality

was worse in the rural group, associated with less comfortable beds and more high intensity physical activity during the day.[42]

Certainly, we cannot ignore the effect that cultural factors may have on sleep duration differences between population groups. Previously, Ong et al. explored sleep durations among Australians, New Zealanders and Asians living in Singapore, Hong Kong and South Korea. Despite living in the same cities, almost two thirds of Australians and New Zealanders slept more than 7 h per night compared to only a quarter of the Asians, who also had later bedtimes and earlier rise-times.[43] Similarly, findings indicate that Asians living in East Asia[43] or in the US have shorter sleep than non-Asians in the US,[44] that non-Hispanic blacks have shorter sleep than non-Hispanic whites and Hispanics living in the US[18] and that African Americans have shorter sleep than European Americans.[45]

Similarly, it is tempting to speculate that the unusually long sleep duration reported by the South African participants in this study is at least in part attributable to cultural factors. First, it is similar to four previously published datasets (8–10 h sleep per night) in African-origin South African participants.[16–19] Second, it is longer than what has been reported in South Africans of other ethnicities (Mixed ancestry, Indian/Asian-origin or European-origin).[46,47] Third it appears to transcend urbanization or age since these long sleep durations has been reported in both rural[48] and urban[47,49] settings, and in older[46,48] and younger[47] South African participants of African-origin. Perhaps there is an interpretation or understanding bias towards the question asked or a mismatch between self-reported and actual sleep obtained, or possibly environmental or social factors are important. The South Africans of African-descent described in these studies have typically been of a low socioeconomic status with low levels of employment and limited education, they often live in communities with high crime rates, and in homes with over-crowding, noise, poor ventilation and inadequate heating or cooling. Since many of these factors have been associated with poor sleep quality,[50–54] we speculate as to whether the longer sleep reported by this South African cohort may to some extent reflect poor sleep quality.[55,56] Thus future research which objectively measures sleep duration, incorporating measures of sleep quality as well as data on potential biopsychosocial contributors to sleep sufficiency such as work duration, commuting time, housing density, neighborhood noise and safety, in these long-sleeping South Africans is needed to better understand this phenomenon.

Finally, we consistently observed that men in our study reported shorter sleep durations than women, and that this is similar to what has previously been observed in other populations,[43,49,57] but not all.[35] There is some debate as to what might drive apparent sex-based differences in sleep duration, with factors such as health, sociodemographic factors, flexibility to nap during the day or have an earlier bedtime being some proposed as determinants.[57]

Our study is not without limitations, first and foremost being that sleep duration is self-reported as opposed to objectively measured. Although we were able to measure physical activity through waist-worn Actical accelerometers, we could not use these to objectively measure sleep. It is possible that individuals may over- or under-estimate their sleep duration. Moreover, we did not have the ability to distinguish between sleep duration on work and non-work days, nor did we collect data on home sleep environment which may impact sleep duration differences between the sites. We are now addressing this limitation in our recently funded study, in the same cohort, using actigraphy-derived sleep measurements through METS-Sleep (R01HL148271). Secondly, we were unable to assess sleep quality or mental health, and it is well-established that there is a bidirectional association between sleep and disorders such as depression, bipolar disorder and schizophrenia.[58] Similarly, the presence of sleep disorders may have influenced the nature of the sleep duration CM risk relationships assessed in this study. While we controlled for this as best as we could by excluding individuals on medication for sleeping problems or mood disorders such as depression, anxiety, bipolar disorder, this is something that needs to be included in futures studies. Finally, our data are cross-sectional, and we are therefore not able to infer any cause and effect between self-reported sleep duration and CM health outcomes.

Conclusion

We found that young adults of African-origin residing in communities from low HDI countries are more likely to report longer sleep than those in higher HDI countries. We also found that there is an ecological relationship for the association between sleep duration and CM risk factors dependent on the country in which participants reside. This indicates that factors specific to the country, and more specifically the community, likely modify this association and future research in larger cohorts using standardized measurement tools and accounting for additional biopsychosocial factors is needed. Finally, while it appears that while short sleep is associated with increased CM risk in the higher HDI countries in this study, neither the unusually long sleep nor short sleep observed in the South Africans were associated with CM risk.

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Supplementary data

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