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Comparison of Self-Reported Sleep Duration With Actigraphy: Results From the Hispanic Community Health Study/Study of Latinos Sueño Ancillary Study

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Most studies of sleep and health outcomes rely on self-reported sleep duration, although correlation with objective measures is poor. In this study, we defined sociodemographic and sleep characteristics associated with misreporting and assessed whether accounting for these factors better explains variation in objective sleep duration among 2,086 participants in the Hispanic Community Health Study/Study of Latinos who completed more than 5 nights of wrist actigraphy and reported habitual bed/wake times from 2010 to 2013. Using linear regression, we examined self-report as a predictor of actigraphy-assessed sleep duration. Mean amount of time spent asleep was 7.85 (standard deviation, 1.12) hours by self-report and 6.74 (standard deviation, 1.02) hours by actigraphy; correlation between them was 0.43. For each additional hour of self-reported sleep, actigraphy time spent asleep increased by 20 minutes (95% confidence interval: 19, 22). Correlations between self-reported and actigraphy-assessed time spent asleep were lower with male sex, younger age, sleep efficiency <85%, and night-to-night variability in sleep duration ≥1.5 hours. Adding sociodemographic and sleep factors to self-reports increased the proportion of variance explained in actigraphy-assessed sleep slightly (18%–32%). In this large validation study including Hispanics/Latinos, we demonstrated a moderate correlation between self-reported and actigraphy-assessed time spent asleep. The performance of self-reports varied by demographic and sleep measures but not by Hispanic subgroup.

actigraphy; Hispanic Americans; Latinos; measurement error; sleep; sleep duration; validation studies

Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; CARDIA, Coronary Artery Risk Development in Young Adults; CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; ISI, Insomnia Severity Index; SD, standard deviation.

Accumulating evidence links extremes of sleep duration with chronic diseases, including hypertension, obesity, diabetes, and cancer (1–3). Simultaneously, racial/ethnic disparities in sleep duration are gaining attention (4–6). Though a majority of studies use questionnaires to assess sleep duration, little research examines the validity of self-reporting against objective measurements such as wrist actigraphy, the objective method of choice for measuring sleep over multiple days. Even fewer studies have included ethnically diverse participants (though those that have done so have detected racial/ethnic differences in the accuracy of self-reports) (7) or have had sufficient sample sizes to explore sources of systematic bias (7–9). Yet, examining the correlation of self-reported sleep duration with objective measurements in varied populations may be essential to the interpretation of epidemiologic studies. First, prior research shows moderate correlations (Pearson's $\rho = 0.31$–0.47) between self-reported sleep duration and actigraphy-measured sleep duration and suggests the presence of both random error and systematic bias in self-reported sleep duration (7–9). Second, findings for subjective

Table 1. Characteristics[a] of the Study Sample by Self-Reported Daily Sleep Duration, HCHS/SOL Sueño ($n = 2,086$), 2010–2013

	Self-Reported Sleep Duration at Sueño Visit, hours/day								
	<7 (Short) ($n = 460$)			7–9 (Intermediate) ($n = 1,292$)			≥9 (Long) ($n = 334$)		
	Mean (SD)	No.	%	Mean (SD)	No.	%	Mean (SD)	No.	%
Age, years	48.1 (10.6)			46.9 (11.5)			46.5 (12.7)		
Body mass index[b]	31.1 (6.8)			29.8 (6.0)			29.7 (6.6)		
CES-D-10 score	8.2 (6.3)			7.2 (6.1)			7.5 (5.8)		
Female sex		283	62		849	66		219	66
Educational attainment[c]									
Less than high school/GED		137	30		387	30		140	42
High school/GED		115	25		349	27		75	22
More than high school/GED		208	45		553	43		119	36
Annual household income[c]									
<$30,000		309	67		846	65		245	73
≥$30,000		132	29		393	30		68	20
Not reported		19	4		53	4		21	6
Employment status									
Employed, non–shift worker		227	49		614	48		102	31
Shift worker		79	17		157	12		44	13
Unemployed or retired		154	33		521	40		188	56
Hispanic ethnic background[c]									
Cuban		86	19		233	18		57	17
Dominican		66	14		160	12		35	10
Mexican		102	22		366	28		93	28
Puerto Rican		97	21		241	19		90	27
Central American		67	15		172	13		45	13
South American		42	9		120	9		14	4
Nativity									
Mainland US		68	20		202	16		73	16
Outside mainland US									
Had lived in US for ≥10 years		198	59		742	58		257	56
Had lived in US for <10 years		67	20		343	27		129	28
English language preference		100	22		242	19		82	25
Current alcohol drinker		212	46		579	45		147	44
Current cigarette smoker		102	22		229	18		71	21
Physical activity level[c]									
High		45	10		119	9		20	6
Moderate		201	44		575	45		144	43
Low		214	47		595	46		169	51

Table continues

and objective measures of sleep duration do not always agree. For example, the Coronary Artery Risk Development in Young Adults (CARDIA) Study detected sex differences in the association of sleep duration with body mass index (BMI) using self-reported sleep duration (10) but not actigraphy-measured sleep duration (11).

To our knowledge, no prior study has examined the validity of self-reported sleep duration among diverse Hispanics/Latinos, the largest racial/ethnic minority group in the United States and a population heavily burdened by obesity, diabetes, and other diseases linked to sleep duration. With 2,086 participants, the current study is the largest study in any population (to our knowledge) to validate self-reported sleep duration against wrist actigraphy. This large sample enabled us to examine how well self-reports and actigraphy correlated within subgroups defined by sleep and sociodemographic

Table 1. Continued

	Self-Reported Sleep Duration at Sueño Visit, hours/day								
	<7 (Short) (*n* = 460)			7–9 (Intermediate) (*n* = 1,292)			≥9 (Long) (*n* = 334)		
	Mean (SD)	No.	%	Mean (SD)	No.	%	Mean (SD)	No.	%
Insomnia severity									
None		254	55		814	63		190	57
Subthreshold		103	22		288	22		80	24
Moderate		77	17		143	11		45	14
Severe		26	6		45	3		18	5
Caffeinated beverage[d] intake ≥3 servings/day		192	42		441	34		118	35
Use of sleep medication at least once/week		66	14		170	13		57	17
Sleep efficiency <85%		156	34		420	33		155	46
SD of actigraphy-assessed time spent asleep ≥1.5 hours/day		112	34		285	22		124	27
Apnea-hypopnea index score[e]	2.4 (0.4–6.9)			1.5 (0.4–5.1)			1.8 (0.4–6.3)		
Epworth Sleepiness Scale score	6.9 (5.0)			5.4 (4.3)			5.0 (4.0)		
Self-reported sleep duration, minutes/day[f]	368 (41)			478 (36)			587 (33)		
Actigraphy-assessed time spent asleep, minutes/day[g]	366 (58)			408 (54)			442 (62)		
Actigraphy-assessed time spent in bed, minutes/day[h]	425 (65)			474 (58)			521 (65)		
Difference between self-reported and actigraphy-assessed time spent asleep, minutes/day	2 (62)			70 (59)			145 (65)		
Difference between self-reported and actigraphy-assessed time spent in bed, minutes/day	−57 (70)			4 (60)			66 (66)		
Difference between actigraphy-assessed time in bed and actigraphy-assessed time asleep, minutes/day	59 (29)			66 (30)			79 (30)		

Abbreviations: CES-D-10, 10-item Center for Epidemiologic Studies Depression Scale; GED, General Educational Development; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SD, standard deviation; US, United States.

[a] All characteristics were measured at the Sueño visit of the HCHS/SOL unless otherwise indicated.

[b] Weight (kg)/height $(m)^2$.

[c] Measured at the HCHS/SOL baseline visit.

[d] Caffeinated beverages included coffee, tea, soda, and energy drinks.

[e] Values are presented as median (interquartile range).

[f] Sleep duration was the weighted average of weekend and weekday self-reported habitual bed time minus wake time measured at the Sueño visit.

[g] Actigraph-measured time spent asleep was the weighted average amount of time spent asleep during the main rest period, excluding periods of wakefulness, over weekends and weekdays.

[h] Actigraph-measured time spent in bed was the weighted average duration of the main rest period, including periods of wakefulness, over weekends and weekdays.

characteristics, including Hispanic/Latino background, and which characteristics contributed to the difference between self-reported and objective sleep measures. This research contributes to the interpretation of associations with self-reported sleep duration in epidemiologic studies in general, and it may have particular relevance to Hispanic/Latino health disparities. Differences in self-reported sleep habits between Hispanic subgroups have been identified (12), and associations of self-reported sleep with chronic diseases may vary by Hispanic/Latino subgroup (6, 13–16). Understanding whether the validity of self-reported sleep duration varies by Hispanic/Latino background or other characteristics is critical to interpreting these results.

METHODS

Study population

The Hispanic Community Health Study/Study of Latinos (HCHS/SOL) enrolled 16,415 self-identified Hispanics/Latinos aged 18–74 years (March 2008–June 2011). Participants were

recruited from randomly selected households in 4 US communities (the Bronx, a borough of New York, New York; Chicago, Illinois; Miami, Florida; and San Diego, California). The study was approved by review boards at each participating institution, and written informed consent was obtained from participants. Details of the study design and procedures have been published elsewhere (17, 18).

HCHS/SOL Sueño, an ancillary sleep study, enrolled 2,252 HCHS/SOL participants (October 2010–December 2013) aged <65 years without severe sleep disorders (narcolepsy, apnea-hypopnea index (AHI) ≥50 events/hour, or use of positive airway pressure). The present analysis included 2,086 eligible individuals with actigraphy and self-reported sleep measurements.

Self-reported sleep duration

Self-reported sleep duration was assessed at the Sueño visit of HCHS/SOL through participant report of habitual bed/wake times on weekends/weekdays, from which we calculated a weighted average of sleep duration (2/7 × weekends + 5/7 × weekdays), as done in other sleep studies (19). Self-reported sleep duration was examined both continuously and categorized into tertiles and a priori groupings (<7, 7–<9, or ≥9 hours/day) based on published literature.

Actigraphy measurements

At the Sueño visit, participants were instructed to wear an Actiwatch Spectrum actigraph (Philips Respironics, Murrysville, Pennsylvania) on the nondominant wrist for 7 days and to complete sleep diaries upon awakening each day. Sleep/wake status was determine in 30-second epochs based on a standardized method (20) using the Actiware 5.59 algorithm, which has been validated against polysomnography on an epoch-by-epoch basis (21, 22).

The mean number of valid nights of actigraphy was 7 (standard deviation (SD), 1; range, 5–17 days). We calculated a weighted average (2/7 × weekends + 5/7 × weekdays) of amount of time spent in bed (time between getting into and out of bed) and amount of time spent asleep (time within the in-bed interval scored as sleep). Time spent asleep was treated continuously, in tertiles, and in a priori groupings: <7 hours, 7–<9 hours, and ≥9 hours. In secondary analyses, time spent in bed was considered as the actigraphic variable of interest. Sleep efficiency was computed on each night as the proportion of time spent asleep between the first and last epochs of sleep and then averaged across all nights, dichotomized at 85% (<85%/≥85%). Variability in nightly sleep was defined as the standard deviation of time spent asleep across all recorded days. Participants in the top quartile (SD >1.5 hours) were considered to have "high" variability in time asleep.

Covariate assessment

As part of the HCHS/SOL baseline examination, participants underwent home sleep apnea monitoring using the ARES Unicorder 5.2 (B-Alert; Advanced Brain Monitoring, Inc., Carlsbad, California) for computation of the AHI, as has been previously described (16). Severity of sleep apnea was classified as none (AHI <5 events/hour), mild (AHI 5–15 events/hour), or moderate (AHI 15–50 events/hour). The HCHS/SOL baseline examination included interviewer-administered questionnaires in the participant's preferred language (Spanish or English) and other measurements described previously (17, 18). Information was obtained on demographic factors (Hispanic ethnic background (Cuban, Dominican, Mexican, Puerto Rican, Central American, or South American), nativity (mainland United States or elsewhere), education (less than high school, high school diploma, or more than high school), annual household income (<$30,000, ≥$30,000, or not reported), cigarette and alcohol use (current or noncurrent), and physical activity (Global Physical Activity Questionnaire: self-reported days/week of recreational, transportation, or work activity; corresponding metabolic equivalent units were categorized as high, moderate, or low (23)).

As part of the Sueño visit, interviewers administered questionnaires about sociodemographic factors, health, and sleep behaviors. Sleep-related symptoms were assessed using the Sleep Heart Health Study Sleep Habits Questionnaire (24), the Epworth Sleepiness Scale (25), and the Insomnia Severity Index (ISI) (26). Daytime sleepiness score on the Epworth Sleepiness Scale was dichotomized as <10 versus ≥10, and insomnia was divided into 4 categories: none (ISI score 0–7), subthreshold (ISI score 8–14), moderate (ISI score 15–21), and severe (ISI score 22–28). Depressive symptoms were evaluated using the 10-item Center for Epidemiological Studies Depression Scale, with scores dichotomized as <10 versus ≥10 (27, 28). Use of sleep medication was categorized as less than once/week versus once/week or more. Participants were asked about employment and work schedules. Nighttime, irregular, on-call, or rotating shifts that included late nights or early mornings were considered shift work. Intake of caffeinated beverages (including coffee, tea, soda, and energy drinks) was categorized as <3 cups/day versus ≥3 cups/day. Age was categorized into 18–44 years and 45–64 years. BMI was calculated as measured weight (in kilograms) divided by measured height (in meters) squared and was categorized into underweight (<18.5)/normal weight (18.5–<25), overweight (25–<30), and obese (class I: 30–<35; class II: 35–<40; or class III: 40).

Statistical analysis

We computed descriptive statistics for the HCHS/SOL cohort and the Sueño subsample by category of self-reported sleep duration. Next, we calculated Pearson correlation coefficients for the correlation of self-reported sleep duration with actigraphy-assessed time spent in bed and time spent asleep, overall and in subgroups defined by participant characteristics. We estimated unadjusted β coefficients and 95% confidence intervals for self-reported sleep duration as a predictor of actigraphy-assessed time in bed and time asleep using linear regression. Regression intercepts represented bias, the disparity between subjects' reported sleep duration and their actigraphy-measured values. If subjective and objective reports of sleep matched perfectly, there would be no bias and the intercept would be 0 minutes. We report the intercept at the average of 480 minutes (or 8 hours) of self-reported sleep.

To examine predictors of actigraphy-assessed time asleep and time in bed, we used multivariable linear regression with

Table 2. Prediction of Sleep-Related Actigraphy Measurements by Self-Reports, HCHS/SOL Sueño ($n = 2,086$), 2010–2013

Sleep Variable	Mean Time (SD), minutes/day			Correlation		480-Minute Intercept,[a] minutes	Self-Reporting[b] as a Predictor of Actigraphy Time Spent in Bed or Asleep	
	Self-Reports	Actigraphy	Difference	ρ	95% CI		β	95% CI
Time spent in bed								
Overall[c]	472 (77)	471 (67)	1 (74)	0.48	0.45, 0.52	475	0.42	0.39, 0.46
Weekdays	459 (85)	466 (73)	−8 (80)	0.49	0.46, 0.53	475	0.42	0.39, 0.45
Weekends	503 (99)	482 (92)	21 (114)	0.29	0.25, 0.33	476	0.27	0.23, 0.31
Time spent asleep								
Overall[d]	472 (77)	404 (61)	67 (75)	0.43	0.39, 0.46	407	0.34	0.31, 0.37
Weekdays	459 (85)	400 (65)	59 (81)	0.44	0.40, 0.47	407	0.34	0.31, 0.37
Weekends	503 (99)	415 (84)	88 (111)	0.27	0.23, 0.31	410	0.23	0.19, 0.26

Abbreviations: CI, confidence interval; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SD, standard deviation.

[a] The regression intercept represents bias, the disparity between subjects' reported sleep duration and their actigraphy-measured values. If subjective and objective reports of sleep matched perfectly, there would be no bias and the intercept would be 0 minutes. We report the intercept at the average of 480 minutes (or 8 hours) of self-reported sleep.

[b] Overall self-reported sleep duration was the weighted average of weekend and weekday self-reported habitual time in bed minus wake time measured at the Sueño visit of the HCHS/SOL.

[c] Overall actigraph-measured time spent in bed was the weighted average duration of the main rest period, including periods of wakefulness, over weekends and weekdays.

[d] Overall actigraph-measured time spent asleep was the weighted average amount of time spent asleep during the main rest period, excluding periods of wakefulness, over weekends and weekdays.

actigraphy outcomes predicted by self-reported sleep duration and participant characteristics: age, sex, BMI, insomnia, sleep apnea, sleepiness, efficiency, variability, sleep medication use, employment, education, Hispanic ethnicity, nativity, language, depression, caffeine intake, smoking, alcohol drinking, and physical activity. We also considered interaction terms for the interaction of each characteristic with self-reported sleep duration. To identify predictors of actigraphy measurements using self-reports and participant characteristics, we used stepwise regression with 10-fold cross-validation. Candidate variables introduced into this procedure included the above characteristics and their interactions with self-reported sleep duration. Interaction terms were entered into the model only with the corresponding main association.

Self-reported sleep duration is often treated categorically because of a U-shaped relationship with many disease outcomes (1). Thus, we assessed the accuracy of ranking by calculating κ scores and confidence intervals based on tertiles of self-reported and actigraphy-measured sleep duration. We also report the area under the receiver operating characteristic curve for logistic models using tertiles of self-reported sleep duration to predict measured actigraphy-assessed short sleep duration (excluding "long sleep," i.e., persons in the top tertile of sleep time) and actigraphy-assessed long sleep duration (excluding "short sleep," i.e., persons in the bottom tertile of sleep time).

In sensitivity analyses, we excluded participants in the top quartile of variability to assess the influence of variation in night-to-night sleep duration on the correlation between self-reported and actigraphy-assessed sleep duration. Further, we repeated all analyses using weekday data only. We also compared the fits of models with and without nonlinear relationships, adding quadratic and cubic terms for self-reported sleep to models, and testing linear and cubic splines. A 2-sided P value less than 0.05 was used to indicate statistical significance.

RESULTS

Table 1 shows characteristics of the Sueño sample by category of self-reported sleep duration. Overall, Sueño sample characteristics were similar to those of the HCHS/SOL parent cohort with respect to key demographic/health variables such as BMI, education, income, and employment (see Web Table 1, available at http://aje.oxfordjournals.org/). Mean age was 47.1 (SD, 11.5) years, and mean time between the HCHS/SOL baseline and Sueño examinations was 24 (SD, 5) months (range, 4–30 months). Mean self-reported sleep duration was 7.86 (SD, 1.28) hours; actigraphy-assessed time spent asleep was more than 1 hour shorter (6.74 (SD, 1.02) hours). Participants reporting short sleep were slightly older, had slightly higher scores for depression, sleepiness, insomnia, sleep apnea, and adiposity, and were more likely to consume 3 or more caffeinated beverages per day. Those reporting long sleep were younger and more likely to have incomes under $30,000 per year, to be unemployed, and to engage in no or low physical activity.

Table 2 shows descriptive statistics for self-reported sleep duration, actigraphy-assessed time spent asleep, and their difference, correlation, and bivariate associations. Overall, the correlation of self-reported sleep duration with time spent

Table 3. Actigraphy-Assessed Amount of Time Spent Asleep Each Day as Predicted by Self-Reported Sleep Duration, According to Participant Characteristics, HCHS/SOL Sueño ($n = 2,086$), 2010–2013

Participant Characteristic	No. of Persons	Mean Time Spent Asleep (SD), minutes/day			Correlation		Self-Reporting[a] as a Predictor of Actigraphy Time Spent Asleep			Interaction *P* Value (*F* Test)[b]
		Self-Reports	Actigraphy[c]	Difference	ρ	95% CI	480-Minute Intercept,[d] minutes	β	95% CI	
Sex										
Male	735	468 (77)	391 (64)	77 (81)	0.35	0.28, 0.41	395	0.29	0.23, 0.34	0.02
Female	1,351	473 (76)	412 (59)	62 (71)	0.47	0.43, 0.51	414	0.36	0.33, 0.40	
Age, years										
18–44	724	481 (75)	403 (59)	78 (76)	0.38	0.31, 0.44	403	0.30	0.25, 0.35	0.04
45–64	1,362	467 (73)	405 (62)	61 (74)	0.45	0.41, 0.49	410	0.37	0.33, 0.40	
Body mass index[e] category										
Normal (18.5–<25) or underweight (<18.5)	405	477 (76)	408 (66)	69 (78)	0.40	0.31, 0.48	409	0.35	0.27, 0.42	0.63
Overweight (25–<30)	791	477 (72)	409 (60)	68 (72)	0.42	0.36, 0.48	410	0.36	0.30, 0.41	
Obese (≥30)										
Obese I (30–<35)	506	462 (80)	401 (58)	61 (77)	0.42	0.34, 0.49	408	0.30	0.24, 0.36	
Obese II (35–<40)	249	470 (78)	398 (61)	72 (71)	0.49	0.39, 0.58	402	0.38	0.30, 0.47	
Obese III (≥40)	135	465 (89)	394 (63)	71 (84)	0.43	0.28, 0.56	399	0.30	0.20, 0.41	
Insomnia Severity Index category										
Severe	89	460 (100)	418 (77)	42 (87)	0.54	0.38, 0.67	426	0.42	0.28, 0.55	0.16
Moderate	265	456 (87)	403 (68)	55 (88)	0.37	0.26, 0.47	409	0.29	0.21, 0.38	
Subthreshold	471	474 (76)	410 (62)	64 (72)	0.48	0.40, 0.54	412	0.39	0.32, 0.45	
None	1,258	474 (72)	402 (58)	72 (71)	0.41	0.37, 0.46	404	0.33	0.29, 0.37	
Apnea-hypopnea index score										
≤5 (no sleep apnea)	1,516	474 (75)	407 (61)	66 (75)	0.40	0.36, 0.44	409	0.32	0.29, 0.36	0.30
>5–<15 (mild sleep apnea)	388	462 (79)	395 (60)	66 (73)	0.48	0.40, 0.55	402	0.36	0.30, 0.43	
≥15 (moderate/severe sleep apnea)	182	474 (84)	400 (68)	75 (78)	0.49	0.37, 0.59	402	0.39	0.29, 0.50	
Epworth Sleepiness Scale score										
≥10	386	453 (78)	383 (65)	70 (82)	0.35	0.26, 0.44	391	0.29	0.22, 0.37	0.27
<10	1,700	476 (76)	409 (59)	66 (73)	0.43	0.39, 0.47	411	0.34	0.30, 0.37	
Day-to-day variability, hours/day										
<1.5	1,565	470 (73)	408 (59)	62 (68)	0.48	0.44, 0.52	412	0.39	0.35, 0.42	<0.0001
≥1.5	521	476 (86)	395 (67)	81 (91)	0.32	0.24, 0.39	396	0.25	0.18, 0.31	
Sleep efficiency										
<85%	731	478 (85)	383 (64)	95 (84)	0.39	0.33, 0.45	383	0.29	0.24, 0.34	0.0002
≥85%	1,355	468 (71)	416 (57)	52 (65)	0.51	0.47, 0.55	421	0.40	0.37, 0.44	
Employment status										
Employed, non–shift worker	943	463 (67)	401 (54)	62 (65)	0.44	0.38, 0.49	407	0.36	0.31, 0.40	0.25
Shift worker	280	456 (83)	387 (66)	72 (86)	0.35	0.24, 0.44	393	0.28	0.19, 0.37	
Unemployed or retired	863	485 (83)	414 (65)	71 (81)	0.42	0.36, 0.47	412	0.33	0.28, 0.38	

Table continues

asleep was 0.43 (95% confidence interval (CI): 0.39, 0.46), with higher correlations for weekdays (Pearson's $\rho = 0.44$) versus weekends (Pearson's $\rho = 0.27$).

Before multivariable adjustment, actigraphy-assessed time spent asleep increased by 20 minutes (95% CI: 19, 22) for each additional hour of self-reported sleep duration. When

Table 3. Continued

Participant Characteristic	No. of Persons	Mean Time Spent Asleep (SD), minutes/day			Correlation		Self-Reporting[a] as a Predictor of Actigraphy Time Spent Asleep			Interaction *P* Value (*F* Test)[b]
		Self-Reports	Actigraphy[c]	Difference	ρ	95% CI	480-Minute Intercept,[d] minutes	β	95% CI	
Educational attainment										
Less than high school/GED	664	478 (82)	410 (65)	68 (75)	0.50	0.44, 0.56	410	0.40	0.35, 0.45	0.01
High school/GED	539	471 (76)	404 (58)	67 (75)	0.40	0.32, 0.47	407	0.31	0.25, 0.37	
More than high school/GED	880	467 (73)	401 (60)	67 (75)	0.37	0.31, 0.43	404	0.30	0.25, 0.35	
Hispanic ethnic background										
Cuban	376	468 (78)	403 (64)	65 (76)	0.44	0.35, 0.51	407	0.36	0.28, 0.43	0.25
Dominican	261	464 (78)	405 (58)	59 (78)	0.37	0.26, 0.47	409	0.27	0.19, 0.36	
Mexican	561	480 (69)	414 (57)	66 (66)	0.46	0.39, 0.52	414	0.38	0.32, 0.44	
Puerto Rican	428	476 (87)	401 (71)	75 (85)	0.44	0.36, 0.51	402	0.36	0.29, 0.43	
Central American	284	469 (74)	400 (52)	69 (72)	0.38	0.28, 0.48	403	0.27	0.19, 0.35	
South American	176	459 (67)	393 (60)	65 (72)	0.36	0.23, 0.49	400	0.32	0.20, 0.45	
Nativity										
Mainland US	343	476 (83)	398 (67)	79 (87)	0.34	0.25, 0.43	399	0.28	0.20, 0.36	0.12
Outside mainland US										
Had lived in US for ≥10 years	539	473 (76)	408 (61)	65 (73)	0.44	0.37, 0.51	406	0.35	0.29, 0.41	
Had lived in US for <10 years	1,197	466 (73)	401 (58)	65 (70)	0.45	0.40, 0.49	410	0.36	0.32, 0.40	
Language preference										
English	424	475 (85)	399 (68)	76 (87)	0.37	0.28, 0.45	400	0.3	0.23, 0.37	0.12
Spanish	1,662	471 (74)	406 (59)	65 (72)	0.45	0.41, 0.48	409	0.36	0.32, 0.39	
Depressive symptoms										
CES-D-10 score ≥10	643	473 (75)	403 (58)	70 (72)	0.42	0.36, 0.48	411	0.35	0.29, 0.41	0.56
CES-D-10 score <10	1,443	468 (81)	407 (68)	61 (81)	0.43	0.39, 0.47	406	0.33	0.30, 0.37	
Use of sleep medication, times/week										
≥1	293	471 (75)	402 (60)	69 (73)	0.38	0.28, 0.47	419	0.29	0.21, 0.38	0.19
<1	1,793	473 (85)	417 (66)	55 (86)	0.44	0.40, 0.47	405	0.35	0.32, 0.38	
Current smoker										
Yes	402	467 (84)	394 (72)	74 (88)	0.36	0.27, 0.44	398	0.31	0.23, 0.39	0.34
No	1,683	473 (75)	407 (58)	66 (71)	0.45	0.41, 0.48	410	0.35	0.31, 0.38	

Abbreviations: CES-D-10, 10-item Center for Epidemiologic Studies Depression Scale; CI, confidence interval; GED, General Educational Development; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SD, standard deviation; US, United States.

[a] Actigraph-measured time spent asleep was the weighted average over weekends and weekdays of the time spent asleep during the main rest period, excluding periods of wakefulness.

[b] Interaction *P* value for the product of the participant characteristic and self-reported habitual sleep duration.

[c] Self-reported sleep duration was the weighted average of weekend and weekday self-reported habitual amount of time spent in bed minus wake time measured at the Sueño visit of the HCHS/SOL.

[d] The regression intercept represents bias, the disparity between subjects' reported sleep duration and their actigraphy-measured values. If subjective and objective reports of sleep matched perfectly, there would be no bias and the intercept would be 0 minutes. We report the intercept at the average of 480 minutes (or 8 hours) of self-reported sleep.

[e] Weight (kg)/height $(m)^2$.

results were stratified by sociodemographic, sleep, and health characteristics (Table 3), the association of self-reported sleep duration with measured time asleep differed significantly by sex ($P = 0.02$), age ($P = 0.04$), sleep efficiency ($P = 0.0003$), nightly sleep variability ($P < 0.0001$), and education ($P = 0.01$), with weaker associations among males, younger participants, those with sleep efficiency <85%, and those with nightly variability ≥1.5 hours or greater education. We found no evidence that the association varied by Hispanic/Latino background (P for interaction > 0.05).

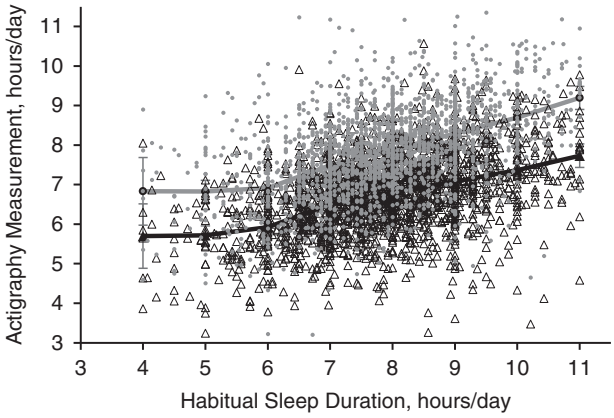

Figure 1. Actigraphy-assessed amounts of time spent asleep and time spent in bed per day, by self-reported sleep duration, in the Hispanic Community Health Study/Study of Latinos (HCHS/SOL) Sueño ancillary study ($n = 2,086$), 2010–2013. Self-reported sleep duration is plotted on the *x*-axis. White triangles represent individual data points for the observed values of actigraphy-assessed time spent asleep, while gray dots represent individual data points for the observed values of actigraphy-assessed time spent in bed (*y*-axis). The black line represents mean values for actigraphy-assessed time spent asleep within 1-hour segments of self-reported habitual sleep duration, while the gray line represents mean values for actigraphy-assessed time spent in bed within 1-hour segments of self-reported habitual sleep duration. Bars, 95% confidence intervals.

Self-report measurements did not uniformly overestimate actigraphy-assessed time spent asleep; self-reports underestimated actigraphy-assessed time asleep for 17% of participants. On average, self-reports of ≤6 hours were underestimates of actigraphy-assessed time spent asleep, while self-reports of >6 hours were overestimates (Figure 1). However, sensitivity analyses provided no evidence of nonlinear associations of self-reported sleep duration with actigraphy measurements (likelihood ratio test: $P > 0.05$).

As shown in Web Table 2, we then tested multivariable-adjusted regression models for actigraphy-assessed time asleep and time in bed. Self-reported sleep duration made the largest contribution to the overall model R^2 (partial $R^2 = 0.18$), with minimal additional variance being explained by sociodemographic, health, or sleep characteristics (R^2 rising to 0.32). Bias (the intercept) at a self-reported sleep duration of 8 hours was almost 1 hour. Holding self-reported sleep duration and other characteristics constant, males, participants with daytime sleepiness, persons with sleep efficiency <85%, persons with BMI ≥35, shift workers, and current smokers and drinkers spent 6–36 fewer minutes asleep per day. Persons who had insomnia, used sleep medication at least once per week, or were unemployed spent 7–22 more minutes asleep per day.

Table 4 shows results of a stepwise selection procedure using internal cross-validation to identify predictors of actigraphy-assessed time spent asleep given self-reported habitual sleep duration. From the list of candidate variables shown in Table 3 and Web Table 2, sex, daytime sleepiness, sleep efficiency, insomnia severity, and employment were selected as predictors of time asleep. The interaction of sex and sleep efficiency with self-reported sleep duration were also entered into the model. Results indicated that little information was added to the models by sociodemographic, health, and sleep characteristics, precluding the development of calibration models.

Table 5 shows κ scores indicating the level of agreement among subjects ranked in the low, medium, or high tertile of actigraphy-assessed time asleep given the participant's tertile of self-reported sleep duration, overall and by subgroup. Agreement between actigraphy and self-reported sleep duration was poor (κ values ranged from 0.17 to 0.33).

Web Figure 1 shows the receiver operating characteristic curves predicting tertile of actigraphy-assessed sleep duration from tertile of self-reported sleep duration, with and without adjustment for covariates. The probability that a randomly selected individual would be correctly classified as having an actigraphy-assessed sleep time in the lowest tertile (short sleep) based on tertile of self-reported sleep duration was 0.62. The corresponding probability for actigraphy-assessed sleep time in the highest tertile (long sleep) was 0.64. Both probabilities increased slightly, to 0.68, with addition of the covariates shown in Table 3.

In Sueño, sleep duration was reported as bed time minus wake time. However, not all time in bed is spent asleep; to assess the influence of this on our results, we repeated all analyses using actigraphy-measured time in bed in place of time asleep. As anticipated, mean actigraphy-assessed time in bed was longer than time asleep and was similar to self-reported sleep duration at 7.85 (SD, 1.12) hours/day (Table 1). However, the correlation with self-reported sleep duration was only slightly higher than that for time asleep, at $r = 0.48$ (95% CI: 0.45, 0.52), and for each additional hour of self-reported sleep duration, time in bed increased by 25 minutes (95% CI: 24, 27) (Table 2). The addition of covariates to self-reported sleep duration improved the overall model R^2 only slightly, from 0.23 to 0.30 (Web Table 2). In the stepwise selection procedure, at the same level of self-reported sleep duration, shift workers and participants with daytime sleepiness spent less time in bed, while those who had insomnia or were unemployed spent more time in bed (Table 4).

DISCUSSION

Study findings

In this diverse cohort of US Hispanics/Latinos, we found moderate correlations between self-reported habitual sleep duration and actigraphy-assessed time spent asleep ($r = 0.43$). To our knowledge, this is the largest study of sleep duration in Hispanics/Latinos to date and the only study we know of to identify predictors of actigraphy measurements from self-reported sleep duration in Hispanics/Latinos. Other studies have also observed moderate correlations between reported and actigraphy-assessed sleep, ranging from 0.31 to 0.47, but with few exceptions (7, 29), those studies have recruited older (8) and non-Hispanic white (9, 30, 31) populations.

One of the few studies examining racial/ethnic differences in the correlation between self-reported and actigraphy-measured sleep duration is CARDIA, which found higher correlations among white participants ($r = 0.56$, 95% CI: 0.44, 0.68) than among black participants ($r = 0.29$, 95% CI:

Table 4. Beta Coefficients and R^2 Values for Predictors of Actigraphy-Assessed Daily Amounts of Time Spent Asleep and in Bed, HCHS/SOL Sueño ($n = 2,086$), 2010–2013[a,b,c]

Participant Characteristic	Partial R^2	Time Spent Asleep, minutes/day		Partial R^2	Time Spent in Bed, minutes/day	
		β	SE		β	SE
Intercept		436.93	3.93		468.01	3.09
Self-reported sleep duration, centered at 480 minutes/day	0.18	0.40	0.04	0.23	0.35	0.03
Sex						
Male	0.02	−11.21	3.48			
Male × self-reported sleep duration	0	−0.12	0.04			
Insomnia Severity Index						
Subthreshold	0	−13.99	3.15	0	17.85	4.79
Moderate	0	1.21	3.74	0	17.61	5.86
Severe	0	−2.96	4.24	0.01	46.65	9.90
Epworth Sleepiness Scale score ≥10	0.02	−22.00	4.37	0.01	−24.83	4.90
Sleep efficiency						
<85%	0.08	−40.40	3.61			
<85% × self-reported sleep duration	0	−0.12	0.05			
Employment status						
Shift worker	0	−11.11	4.98	0.01	−12.13	5.58
Unemployed	0	8.38	3.82	0.01	11.34	4.26
Full-model R^2	0.31			0.28		
Root mean squared error	50.69			57.01		

Abbreviations: HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SE, standard error.

[a] Each column (time asleep and time in bed) represents a separate statistical model with adjustment for all of the variables in the column. The β coefficients were estimated through stepwise selection with the full list of candidate variables plus the interaction of each variable with self-reported sleep duration.

[b] Reference categories for selected variables were: female sex; Epworth Sleepiness Scale score <10; no clinical insomnia; and employed non–shift worker.

[c] All terms were statistically significant at the $P < 0.05$ level.

0.10, 0.48), suggesting the presence of important racial differences. In our study, the correlation between self-reports and actigraphy in a Hispanic/Latino population was intermediate to correlations reported for whites and blacks. Furthermore, the correlations did not differ significantly among Hispanic/Latino subgroups. This is important in interpreting the reported differences in the relationship between self-reported sleep duration and chronic disease outcomes. For example, in the National Health and Nutrition Examination Survey, the relationship between hypertension and self-reported short sleep duration was seen only among *non*-Mexican Hispanics/Latinos (32), while in the Hispanic Health and Nutrition Examination Survey, short sleep duration was associated with larger body size only among Mexican Americans (14).

In interpreting our findings, it is important to note that while some studies (e.g., CARDIA) based sleep self-assessments on a single question about the actual number of hours of sleep obtained on a typical night, habitual bed and wake times are commonly used to measure sleep duration in epidemiologic studies because participants may more easily report these habits than their hours of actual sleep (33, 34). However, not all time in bed is spent asleep. Consistent with this, the unadjusted difference between measured time asleep and self-reported sleep duration in our study exceeded 1 hour, while the difference between objectively measured time in bed and self-reported sleep duration was only 1 minute (though with substantial variation). Yet, correlations of actigraphy-assessed time asleep and time in bed with self-reported sleep duration were close (Pearson's ρ: $\rho = 0.43$ and $\rho = 0.48$), indicating that the measurement approach for self-reported sleep duration did not fully explain discrepancies between self-report and actigraphy assessments.

We observed higher correlations for weekdays than for weekends, perhaps due to consistent weekday routines enabling more accurate reporting. However, fewer nights of actigraphy recording were collected on weekends (median of 5 weekday nights of actigraphy vs. 2 weekend nights), which weakened the correlation with self-reported sleep duration.

Self-reported sleep duration made the largest contribution to the overall variance in actigraphy-assessed time spent asleep among all the variables we considered but only accounted for 18% of this variance; the model R^2 rose to 32% with the addition of sociodemographic, sleep, and health characteristics. Thus, the addition of covariates to self-reported habitual sleep duration did not result in a model that explained sufficient variation in actigraphy, making it challenging to develop calibration equations.

Table 5. Scores for Agreement Between Tertiles[a] of Actigraphy-Assessed Time Spent Asleep and Self-Reported Sleep Duration, According to Selected Participant Characteristics, HCHS/SOL Sueño ($n = 2,086$), 2010–2013[b]

Participant Characteristic	Total No. of Persons	Time Spent Asleep				Time Spent in Bed			
		Observed Agreement		κ	95% CI	Observed Agreement		κ	95% CI
		No. of Persons	%			No. of Persons	%		
Overall	2,086			0.23	0.20, 0.27			0.27	0.24, 0.31
Sex									
Male	735	129	54	0.19	0.14, 0.24	381	52	0.28	0.22, 0.33
Female	1,351	682	50	0.26	0.22, 0.30	694	51	0.27	0.23, 0.31
Age, years									
18–44	724	337	47	0.2	0.15, 0.25	347	48	0.22	0.16, 0.27
45–64	1,362	685	50	0.25	0.21, 0.29	728	53	0.3	0.26, 0.34
Body mass index[c] category									
Obese (≥30)	890	454	51	0.26	0.21, 0.31	462	52	0.28	0.23, 0.33
Nonobese (<30)	1,196	568	47	0.21	0.17, 0.25	613	51	0.27	0.23, 0.31
Insomnia severity									
Severe	89	49	55	0.33	0.18, 0.47	51	57	0.36	0.22, 0.51
Nonsevere	1,997	973	49	0.23	0.20, 0.26	1,024	51	0.27	0.24, 0.30
Day-to-day variability, hours									
≥1.5	521	232	45	0.17	0.11, 0.23	234	45	0.18	0.11, 0.24
<1.5	1,565	790	50	0.26	0.22, 0.29	841	54	0.31	0.30, 0.34
Sleep efficiency									
<85%	731	328	45	0.18	0.13, 0.23	368	50	0.25	0.20, 0.30
≥85%	1,355	694	51	0.27	0.23, 0.31	707	52	0.28	0.24, 0.32
Educational attainment									
Less than high school diploma/GED	664	348	52	0.28	0.23, 0.34	355	53	0.3	0.24, 0.36
High school diploma/GED or more	1,422	674	47	0.21	0.17, 0.25	720	51	0.26	0.22, 0.30

Abbreviations: CI, confidence interval; GED, General Educational Development; HCHS/SOL, Hispanic Community Health Study/Study of Latinos; SD, standard deviation.

[a] Mean values for low, intermediate, and high tertiles were as follows: for self-reported habitual sleep duration, 6.47 (SD, 0.73), 7.86 (SD, 0.29), and 9.24 (SD, 0.66) hours/day; for actigraph-assessed amount of time spent asleep, 5.64 (SD, 0.64), 6.78 (SD, 0.23), and 7.81 (SD, 0.55) hours/day; and for actigraph-assessed amount of time spent in bed, 6.65 (SD, 0.65), 7.85 (SD, 0.25), and 9.05 (SD, 0.64) hours/day.

[b] Self-reported sleep duration was calculated as the weighted average of weekday and weekend habitual amounts of time spent in bed minus wake time; actigraphy-measured amounts of time spent in bed and in sleep were also weighted averages of weekend and weekday measurements.

[c] Weight (kg)/height $(m)^2$.

When investigators conducting prior research in nutrition attempted to improve the accuracy of self-report measures of diet (compared with an objective measure such as a biomarker), often the addition of participant characteristics to the model substantially increased R^2 (35, 36). For example, in the Women's Health Initiative, the addition of characteristics such as BMI and age increased the model R^2 value for total energy intake from 4% for the food frequency questionnaire alone to 42% (36). One possibility is that the skills needed to report diet (e.g., portion estimation) are more complex than those needed to report habitual bed/wake times, leading to a less dramatic increase in R^2 with the addition of participant characteristics to the model for actigraphy-assessed time spent asleep. Difficulty in estimating habitual sleep duration may arise, in part, from night-to-night variability. In keeping with this hypothesis, the correlation between self-reported and actigraphy-assessed sleep duration was lower among persons in the highest quartile of night-to-night variability (Pearson's $\rho = 0.32$), while participants in the lowest variability quartile (<0.8 hours) had the highest correlation ($\rho = 0.54$). However, when high-variability participants were excluded from sensitivity analyses, self-reporting was still only able to explain 31% of the variation in time spent

asleep. Restricting the data to weekdays (when night-to-night sleep may be more consistent) yielded correlations ($\rho = 0.44$ vs. $\rho = 0.43$) and κ values ($\kappa = 0.26$ vs. $\kappa = 0.23$) similar to those of the weighted average results.

The association of self-reported sleep duration with actigraphy-assessed time spent asleep varied by sociodemographic, health, and sleep characteristics. Other studies have also observed overreporting of sleep duration relative to actigraphy, with greater discrepancies among men and persons with poor sleep quality (7, 29, 30). In our study, the difference between measured time asleep and self-reported sleep duration did not vary by sleep apnea severity or BMI. In contrast, there were differences identified by age, sex, nightly variability, sleep efficiency, sleep medication use, and smoking.

Other studies have noted that persons with higher BMI, sleep apnea, sleepiness, and depression report shorter sleep durations, which reduces the discrepancy between self-reported and actigraphy-assessed sleep duration (7, 31). In keeping with this, we found that after controlling for self-reported sleep duration, males, shift workers, persons with BMI $\geq$35, low sleep efficiency, and excessive daytime sleepiness, current smokers, and current drinkers slept for fewer minutes each night, while those who were unemployed, had insomnia, or used sleep medication weekly or more often slept a greater number of minutes per night.

Strengths and limitations

To our knowledge, no prior study has validated self-reported sleep duration in such a large sample or among a diverse group of US Hispanics/Latinos. Compared with other validation studies, the active exclusion of participants with severe sleep apnea and the use of a state-of-the-science actigraphy device with a light sensor and off-wrist detection for increased accuracy represent important strengths (7). Additionally, we included more than 5 days of actigraphy and measured key sleep characteristics, including insomnia, sleep apnea severity, and sleep medication use. The fact that our study population was comprised entirely of Hispanics/Latinos addresses an important gap in sleep research, but it could limit generalizability to other ethnic groups if cultural attitudes or home/neighborhood environments modify reporting of sleep duration relative to actigraphy. Notably, while total sleep time measured by actigraphy and polysomnography have good agreement ($r = 0.90$) (37, 38), actigraphy is not itself a gold standard measure and may misinterpret inactivity during wake time as sleep, or vice versa. However, polysomnography over the course of multiple nights is impractical in large studies because of the participant burden and expense (39). Additionally, we used an average of 7 nights of actigraphy to estimate habitual sleep duration. Though 7 nights is considered to have reasonable reliability, nightly variation in sleep or episodic variation in sleep duration (e.g., "good weeks" and "bad weeks") undoubtedly weakens the correlation with self-reported sleep duration, which is based on questions asking explicitly about habitual or "usual" sleep patterns (40). Finally, we asked participants to report bed/wake times but not sleep-onset latency, which may limit comparability with studies in which participants estimated the actual hours of sleep.

Conclusions

In this cohort of US Hispanics/Latinos, the correlation between self-reported sleep duration and actigraphy-assessed sleep duration was moderate. We confirmed the presence of systematic bias in self-reported sleep duration and showed that participant characteristics (including sex, age, sleep efficiency, and night-to-night variability) influence the association of self-reported sleep duration with actigraphy-measured time spent asleep. However, adding these and other characteristics to models provided little additional information to explain the variation in actigraphy-assessed sleep. Future research comparing associations of subjectively and objectively measured sleep duration with health outcomes and/or using actigraphy measurements in a subset of participants to correct measurement error would be informative as to the degree to which reporting bias influences the observed relationship between sleep duration and health.

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