

## SCIENTIFIC INVESTIGATIONS

# Self-Reported Sleep Duration and Pattern in Old Order Amish and Non-Amish Adults

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**Study Objectives:** We hypothesized that sleep duration in the Amish would be longer than in non-Amish.

**Methods:** Sleep duration was obtained by questionnaire administered to Amish individuals (n = 3,418) and from the 2015–2016 National Health and Nutrition Examination Survey (NHANES; n = 1,912). Self-reported sleep duration was calculated as the difference in usual times that the participants went to bed at night and woke up in the morning.

**Results:** In Amish (43.7 ± 16.7 years) and NHANES (50.0 ± 20.6 years), women had a longer sleep duration than men ( $P < .0001$  in both groups) and sleep was significantly longer in those aged 18–29 years and ≥ 70 years, compared to those aged 30–69 years. Seasonal-adjusted sleep duration was shorter in Amish than that in NHANES (7.8 minutes shorter, age- and sex-adjusted  $P < .0001$ ). However, Amish were less likely to report sleeping fewer than 7 hours per night (15.4% in Amish versus 20.5% in NHANES,  $P < .0001$ ). Amish went to bed 80.4 minutes earlier than NHANES and arose 87.6 minutes earlier (age-, sex-, and season-adjusted  $P < .0001$  for both). In the Amish, sleep duration was longer in clerks than in farmers ( $P < .0001$ ) and was significantly correlated among household members ( $.15 < r < .62$ ,  $P < .001$ ), although there was no evidence that this trait was heritable ( $h^2$  approximately 0) after adjustment for household.

**Conclusions:** The lower frequency of short sleepers in the Amish may contribute to the relatively lower risks of cardiometabolic diseases observed in this population.

**Keywords:** Sleep, Sleep Frequency, Amish, NHANES, heritability, family

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### BRIEF SUMMARY

**Current Knowledge/Study Rationale:** Sleep duration has been decreasing for many years in the U.S., and these changes have been attributed in part to technology and the modern American lifestyle that impinge upon sleep time. These trends motivated us to compare sleep duration between the overall United States population and the Old Order Amish, a culturally isolated population characterized by a very traditional culture that is much less affected by changes in the mainstream culture and artificial lighting.

**Study Impact:** The extent to which the modern lifestyle contributes to the increased prevalence of sleep deprivation has been difficult to discern. The comparison between Amish and the National Health and Nutrition Examination Survey could help to identify at least some of factors in modern culture that may impact sleep duration and inform strategies to improve the sleep duration and quality.

## INTRODUCTION

Sleep duration in the United States has been declining for many years. Between 1977 and 2009, the mean sleep duration decreased from 7.4 to 7.1 hours, and the percent of people reporting 6 or fewer hours of sleep per night during this time period increased from 21.4 to 29.1%.<sup>1</sup> In the baseline phase of the Sleep Health Study (1995–1998), 29.6% of individuals reported their usual sleep duration to be less than 7 hours.<sup>2</sup> These numbers are alarming given that short sleep duration has been associated with increased risk of numerous adverse health outcomes, including hypertension, diabetes, cardiovascular disease, and depression,<sup>3–8</sup> as well as substantial economic costs.<sup>9</sup> Over the past several years, major

sleep societies have issued consensus recommendations for the amount of sleep needed to promote optimal health in adults as 7–9 hours per night.<sup>10,11</sup>

The proximal causes of short sleep duration are varied, but many relate to the modern lifestyle, such as exposure to artificial bright lighting technology, exposure to short-wavelength emitting devices (eg, TVs, computers, tablets, mobile phones), stresses of daily life, the intrusion of work into nighttime hours, and ready availability of alternative activities that compete with sleep time.<sup>12,13</sup> To date, the extent to which the modern lifestyle has contributed to the increased prevalence of sleep deprivation has been difficult to discern because of the lack of sleep data from populations with more traditional, less modern lifestyles. The

Lancaster County, Pennsylvania, Old Order Amish (OOA) represents one such community that lacks at least some of the factors associated with modern culture that may impact sleep duration. For example, OOA culture prohibits network electricity into the home and therefore Amish households do not have access to bright electric lighting, electronic devices, and electronic forms of entertainment at home. In addition, Lancaster County is highly rural, and there is limited exposure to nighttime noise and light pollution outside the home. Finally, there is very strong family and community support within the OOA community that may ameliorate daily stress. We thus hypothesized that average sleep duration would be shorter in the general United States population than in the Amish, who are less exposed to many of the factors associated with more modern lifestyles that potentially contribute to shorter sleep duration. We tested this hypothesis by comparing sleep duration between the OOA and European American participants of the National Health and Nutrition Examination Survey (NHANES).

## METHODS

### Study Population

#### Amish

The OOA community of Lancaster County, Pennsylvania comprises approximately 38,000 individuals.<sup>14</sup> The Lancaster settlement was founded by the Amish in the early 1700s from Amish settlers immigrating to America from Central Europe, primarily present-day Switzerland. The present report is based on data collected from our long-standing studies in this community focusing primarily on cardiometabolic health.<sup>15–17</sup> This report uses sleep duration data collected from the Amish Wellness Study, an ongoing community-wide survey carried out to assess cardiovascular and metabolic health that was initiated in 2010. The protocol was approved by the Institutional Review Board of the University of Maryland, Baltimore.

Recruitment was carried out in person by teams comprising a study nurse and Amish liaison, who visited each household in selected church districts and invited the household heads and any other household members aged 18 and over to participate. Study examinations were conducted in the Amish Research Clinic or the Amish Wellness Mobile, a refurbished van modified to include space for participant interviews, anthropometry and blood pressure measurements, a blood drawing station, and a centrifuge for blood processing.

#### Non-Amish Caucasians

We compared sleep duration to European American participants from the 2015–2016 NHANES. NHANES is a national survey conducted by the Centers for Disease Control and Prevention to estimate risk factors of selected diseases and study the relationship between diet, nutrition and health in the United States population. We downloaded data from the NHANES 2015–2016 Survey (<https://www.cdc.gov/nchs/nhanes/search/datapage.aspx?Component=Questionnaire&CycleBeginYear=2015>) and used

only the European American subsample from NHANES ( $n = 1,912$ ) to match the ethnic background of the Amish.

### Sleep Measurements

Sleep duration was obtained by questionnaire from the Amish Wellness Study and NHANES. The Amish sleep questions were derived from Pittsburgh Sleep Questionnaire Index. In the Amish, participants reported their sleep schedules as the usual time they went to bed and the usual time that they got up in the morning. Sleep duration was calculated as the difference between these two times. In NHANES, participants reported their sleep schedules as the usual time on weekdays they got to sleep and the usual time they woke up, and sleep duration was calculated as the difference between these two times.

The Amish Study sleep questionnaire was modified in April 2013 to align it with other surveys; thus, this updated questionnaire was administered only to Amish participants enrolled between April 2013 and February 2018 ( $n = 3,418$ ). None of the Amish participants had night shift schedules. The sleep questionnaire was administered to 1,912 NHANES participants. We removed 28 NHANES participants who reported most of their sleep time to be during the daytime (5:00 AM–6:00 PM) to avoid the interference of night shift schedules.

### Statistical Analysis

To allow for seasonal differences in sleep duration (ie, shorter sleep duration in summer than winter), we accounted for the season during which the questionnaire was administered (summer versus winter). Summer was defined as May–October and winter as November–April, respectively, to be consistent with pre-existing data available from NHANES, as this is how they defined summer and winter. After calculating the mean difference in sleep duration between the summer and winter months in males and females, we standardized sleep duration to the summer season by subtracting the mean sleep duration difference between winter and summer from winter sleep duration. Throughout this manuscript, sleep duration has been preadjusted for season for all comparisons between groups unless otherwise indicated.

To compare differences in sleep duration between Amish and NHANES, we estimated preadjusted sleep duration and other characteristics using linear models that adjusted for sex and age groups. In a parallel analysis we also categorized sleep duration into short (<7 hours) and long (>9 hours) duration and compared frequencies by the Pearson chi-square test and logistic regression to account for age and sex. All analyses are performed using R studio version 1.1.447 (The R Foundation, Vienna, Austria). Boxplots and forest plots were produced by the package ggplot2 in R studio (The R Foundation).

We estimated the heritability of sleep duration in the Amish using a linear mixed model that included the relationship matrix as a random effect. Heritability was defined as the proportion of the variance accounted for by the relationship matrix, after accounting for the effects of age group and sex. We also estimated the familial correlations in seasonally adjusted sleep duration among spouse pairs, siblings, and parent-child pairs. We used MMAP software (Jeff O'Connell, <https://mmap.github.io/>) to estimate heritability<sup>18</sup> and Pearson correlations to estimate correlations among family members.

**Table 1**—Demographic characteristics of Amish (2013–2018, n = 3,400) and NHANES European American cohorts (2015–2016, n = 1,909).

Demographic Variables	Male			Female		
	Amish (n = 1,456)	Non-Amish (n = 955)	P	Amish (n = 1,962)	Non-Amish (n = 957)	P
Age (years)	45.4 ± 16.4	51.0 ± 20.5	< .001	42.5 ± 16.9	49.0 ± 20.7	< .001
BMI (kg/m <sup>2</sup> )	26.4 ± 4.3	28.8 ± 6.2	< .001	27.2 ± 5.6	29.1 ± 7.5	< .001
Married, yes	1,308 (89.9)	502 (56.6)	< .001	1,600 (81.7)	439 (50.1)	< .001
Smoker, yes	266 (18.3)	198 (20.7)	> .05	1 (0.1)	176 (18.4)	< .001

Data presented as mean standard deviation or n (%). *P* values from *t* test for numeric variables and Pearson chi square test for categorical variables. BMI = body mass index, NHANES = National Health and Nutrition Examination Survey.

## RESULTS

Basic characteristics of the Amish and NHANES comparison groups are provided in **Table 1**. Compared to NHANES, Amish were 6.5 years younger ( $P < .001$ ), had a lower body mass index (26.4 versus 28.8 kg/m<sup>2</sup> in men and 27.2 versus 29.1 kg/m<sup>2</sup> in women;  $P < .001$ ), were more likely to be married (89.9 versus 56.6% of men and 81.7 versus 50.1% of women;  $P < .001$ ), and less likely to self-report as a current smoker (18.3 versus 20.7% of men and 0.05 versus 18.4% of women;  $P < .001$ ).

Sleep questionnaires were administered in summer months to 57% of Amish and to 61% of NHANES participants ( $P < .01$ ). On average mean sleep duration was 14.4 minutes longer in winter than in summer in Amish (age- and sex-adjusted  $P < .0001$ ) and 10.8 minutes longer in winter than in summer in NHANES (age- and sex-adjusted  $P < .05$ ).

### Sleep Duration Stratified According to Sex and Age

Sleep duration was 7.8 minutes shorter in Amish compared to NHANES (7.52 versus 7.65 hours,  $P < .001$ ). In both NHANES and Amish, seasonally adjusted sleep duration was longer in women than in men (18.6 minutes longer in Amish (age-adjusted  $P < .0001$ ), and 16.8 minutes longer in NHANES (age-adjusted  $P < .0001$ ), **Figure 1A**). Amish women and men had 8.4 and 7.2 minutes shorter sleep duration than NHANES women and men, respectively (8.10 versus 8.24 hours for women, age-adjusted  $P < .001$ ; 7.73 versus 7.84 hours for men, age-adjusted  $P < .01$ ) (**Figure 1B**).

In **Figure 2A**, similar trends were observed in both seasonally adjusted sleep duration stratified by age groups in Amish and NHANES. It is shown that Amish and NHANES had seasonally adjusted sleep duration higher at ages 18–29 and at 70 years and older compared to ages 30–69. Because of the nonlinear relationship of age with sleep duration, we coded age as a categorical variable (age 18–29, 30–49, 50–69, and 70+) for subsequent analyses.

### Comparison of Bedtime and Wake Times Between Amish and NHANES

Similar to sleep duration, we standardized bedtime and wake time to the summer season by adding the difference in bedtime and wake time between summer and winter to those administered the questionnaire in the winter. **Figure 3** shows the

seasonally adjusted bedtime and wake time in Amish and NHANES, respectively. Following adjustment for sex, age group, and season, Amish reported going to bed 80.4 minutes earlier and waking up 87.6 minutes earlier than NHANES participants (age- and sex-adjusted  $P < .0001$ ).

### Frequency of Short and Long Duration Sleepers in the Amish and NHANES

We compared the frequency of short and long sleep duration between the Amish and NHANES (**Table 2**). The frequency of both short and long sleepers was higher in NHANES than in the Amish (short sleepers: 15.4% and 20.5% in Amish and NHANES, respectively, and long sleepers: 4.6% and 13.3% in Amish and NHANES, respectively;  $P < .0001$  for both).

### Sleep Duration in the Amish According to Occupation

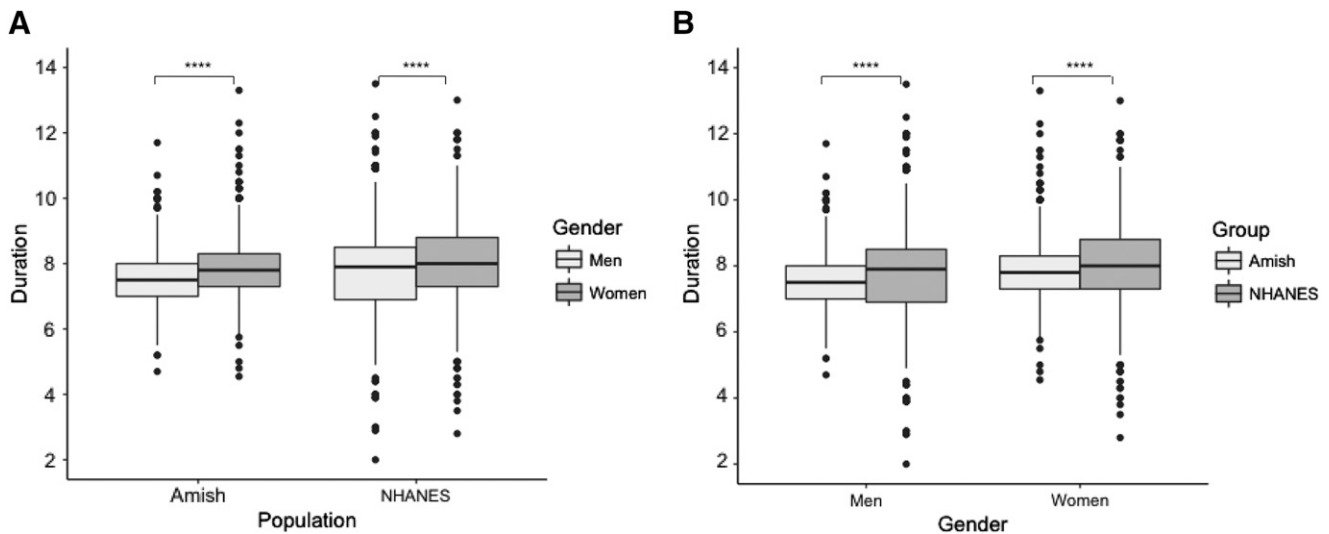
**Figure 4** shows seasonally adjusted sleep duration by occupation in the Amish. Sleep duration was significantly longer in clerk work and marketing (7.64 hours for clerk work, 7.70 hours for marketing) than farmers and contractors (7.15 hours for farming, 7.32 hours for contracting) after adjusting by sex, age and season ( $P < .0001$ ).

### Familial Aggregation of Sleep Duration in the Amish

In the Amish, seasonally adjusted sleep duration was significantly correlated among household members ( $P < .0001$ ) (**Table 3**). Correlations were strongest among spouse pairs ( $r = .62$ ). Same sex sibling pairs had a stronger correlation than opposite sex pairs (brother/brother:  $r = .24$ , sister/sister:  $r = .28$ , brother/sister:  $r = .20$ ). Sibling pairs in the same house had substantially stronger correlations in sleep duration than sibling pairs living in different houses across all sibling pair types (eg, same house:  $r = .34$ – $.63$ ; different house:  $r = .15$ – $.22$ ). Correlations in sleep duration between parent/offspring pairs were very small ( $-.10 < r < .07$ ) for each type of parent-offspring pair; data not shown).

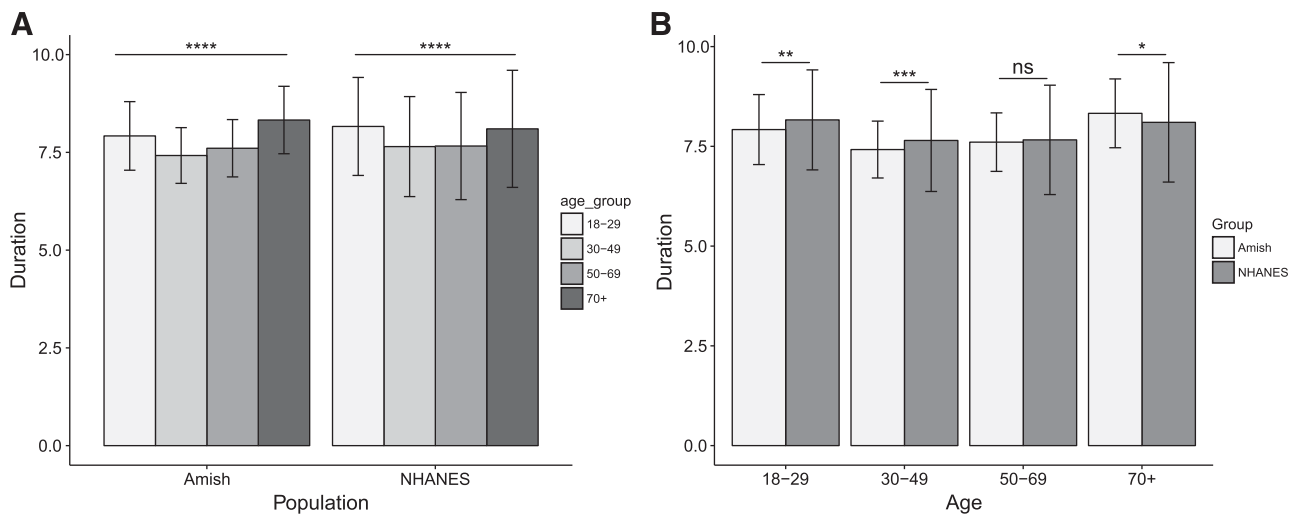
Using the linear mixed model, we estimated the heritability ( $h^2$ ) of sleep duration to be very modest ( $h^2 = 0.08$ ,  $P < .0001$ , adjusting for age and sex), although  $h^2$  was approximately 0 with adjustment for household included as an additional random effect. Household with or without  $h^2$  in the model accounted for approximately 20% of the variation in sleep duration after accounting for age and sex.

**Figure 1—Sleep duration, sex and population.**



Association of sleep duration with sex in Amish and NHANES (A) and with population in men and women (B). \*\*\*\*  $P < .0001$  for all differences. NHANES = National Health and Nutrition Examination Survey.

**Figure 2—Sleep duration, age groups and population.**



Association of sleep duration with age group in Amish and NHANES (A) and with population according to age group (B).  $P$  values from one-way analysis of variance: \*\*\*\*  $P < .0001$ , \*\*\*  $P < .001$ , \*\*  $P < .01$ , \*  $P < .05$ . NHANES = National Health and Nutrition Examination Survey, ns = not significant.

**DISCUSSION**

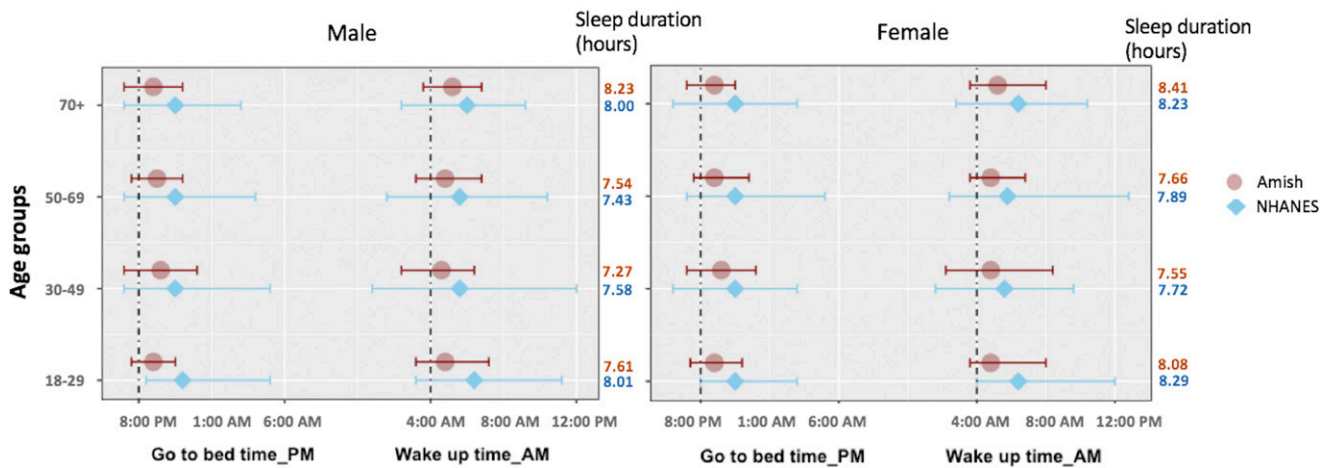
The duration and timing of biological night reflects the duration of recent exposure to day length. Sleep duration is regulated endogenously by circadian factors that regulate the thresholds of sleep and wake (ie, our internal circadian rhythms).<sup>19</sup> Additionally, superimposed on these internal regulatory factors are other sociocultural influences. The influence of external sociocultural factors on sleep duration is apparent from the decrease in sleep duration that has been well documented in this country in recent years.<sup>20-22</sup> It is widely speculated that changes associated with the modern lifestyle are associated with the trend toward decreasing sleep duration,<sup>23,24</sup> leading

to the speculation that a longer sleep duration in a more traditional community would more closely resemble that from 30–40 years ago compared to present day, and our main hypothesis of the study.

Contrary to our hypothesis, we observed a statistically significant shorter, but very similar seasonally adjusted duration of sleep duration in the traditional Amish community than in NHANES despite very different bedtime and wake time cycles between the two populations. We also observed a consistency in sex and age effects on sleep duration between the two populations, with sleep duration slightly longer in women than in men, and in younger and older adults compared to middle age. The similar seasonally adjusted

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**Figure 3**—Sleep duration, bedtime and wake times.



Variation in sleep duration, bedtime, and wake time according to age group in the Amish and NHANES. The red circles illustrate the midsleep time in all age groups of Amish. The blue diamonds represent the midsleep time in all age groups of NHANES. The left and right end whiskers represent the earliest and latest bedtime and wake time, respectively. NHANES = National Health and Nutrition Examination Survey.

**Table 2**—Frequency of short and long sleep duration between Amish 2013–2018 (n = 3,400) and NHANES European Americans in 2015–2016 (n = 1,909).

Sleep Duration	Amish	NHANES	P
Short	524 (15.4)	392 (20.5)	< .0001
Normal	2,720 (80.0)	1,264 (66.2)	Reference
Long	156 (4.6)	253 (13.3)	< .0001

Data presented as n (%). Sleep duration was defined as short (< 7 hours), normal (7–9 hours), and long (> 9 hours). P value from logistic regression adjusted by sex and age group. NHANES = National Health and Nutrition Examination Survey.

sleep duration in the Amish compared to NHANES is an important observation given the substantial lifestyle differences between the two populations. For example, some of the factors that could be construed as logical contributors to shorter sleep duration (ie, intense light and noise from the outside, daytime shift works, 24-hr access to cell phones and internet, decreased physical activity levels, flight travels, alcohol and smoking) are absent or present in a much less degree in the Amish.<sup>13,25,26</sup> In addition, the Amish may have other attributes that protect against shorter sleep duration, such as strong family and social connections that might serve as a buffer against daily stress.

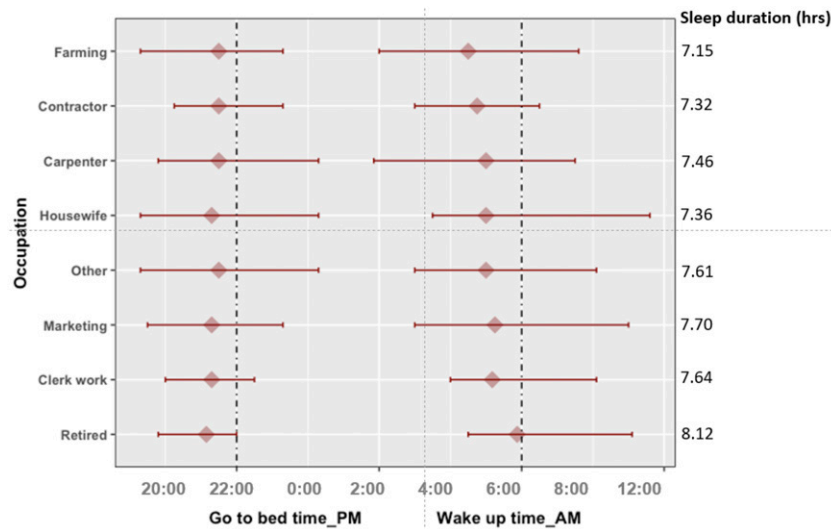
Despite a slightly shorter mean sleep duration, the Amish are significantly less likely than NHANES to be classified as a short (duration < 7 hours) or a long (duration > 9 hours) sleeper, both of which are associated with adverse health outcomes.<sup>2–8,27–30</sup> It is possible that the Amish lifestyle better insulates this population from straying outside the recommended 7–9 hours of sleep compared to NHANES despite a similar mean duration of sleep between the two populations. Moreover, while mean sleep duration is similar, there is a marked difference in the timing of sleep—with both bedtime

and wake time occurring at a much earlier time. Given that the Amish tend to be more physically active than non-Amish,<sup>25,31</sup> it is possible that physical activity differences may contribute to some of the differences we observe in sleeping behavior.<sup>32</sup>

The homogeneous lifestyle of the Amish is likely an important contributor to the lower variability in wake times and bed times of Amish relative to NHANES. The primary Amish occupations (eg, farming, carpentry, shop keeping) entail day work schedules and do not include rotation shifts. The Amish also do not own automobiles, providing fewer opportunities for nighttime social activities outside the home. In addition, the rural living environment leads to limited exposure to nighttime noise and light pollution outside the home. The prohibition of recreational electronic devices in the home also leads to reduced, and more homogeneous, levels of short wavelength light reaching the retina. Several factors likely contribute to the earlier bedtime and wake time in the Amish relative to NHANES. First, the farming lifestyle of many Amish requires an early wake-up time and a higher exposure to natural morning sunlight as a consequence of increased time spent outdoors. Second, NHANES participants generally experience higher evening exposure to artificial bright and low wavelength light from artificial network electric lighting and blue-green emitting electronic screens. The increased artificial light exposure after sunset cause circadian and sleep-wake cycle delay in modern humans relative to natural dark-light cycle conditions.<sup>33,34</sup> The higher natural light exposure in Amish could contribute to their earlier bedtime and wake time. It has been proposed that sleep phase advance could result in a more restorative sleep and be beneficial to metabolic and mental health,<sup>35–43</sup> although more mechanistic studies of this hypothesis are warranted.

The heritability of usual sleep duration has been estimated from twin studies to range from 0.31–0.44,<sup>44–46</sup> and two loci were recently associated with sleep duration in a large meta-analysis

**Figure 4**—Sleep duration, bedtime and wake times according to occupation in the Amish.



Variation in sleep duration, bedtime, and wake time according to occupation in the Amish. The red diamond illustrates the midsleep time across occupations in Amish. The left and right end of whiskers stands for the earliest and latest bedtime and wake time, respectively.

of genomewide association studies.<sup>47</sup> In contrast, our analyses revealed very little evidence for heritability of sleep duration in this Amish community, although we found very strong evidence for a shared household influence. Possibly, sleep duration is less heritable in the Amish because of social and community constraints that may require more uniformity of bedtime and wake time. That is, the strong demands of the Amish life may be a primary influence on sleep patterns. Supporting this strong environmental effect, there is a substantial correlation in sleep duration among family members, especially those residing in the same household (Table 3). Occupation is also strongly associated with sleep duration in the Amish. It is also possible that heritability of sleep duration may be overestimated in twin studies to the extent that non-genetic influences on sleeping patterns may be shared more strongly among monozygotic compared to dizygotic twins.

Our study has several limitations. Foremost, sleep duration was measured by questionnaire and not through objective measurements. However, we have previously published that sleep timing as assessed by physical activity monitoring (Actical accelerometers [versions 8.2 and 8.3; Mini Mitter Co, Inc, Bend, Oregon]) is highly correlated with sleep timing accessed through sleep diaries.<sup>32</sup> The Amish and NHANES sleep questions were both derived from the Pittsburgh Sleep Questionnaire Index, which has been shown to be reliable and valid for estimating total sleep time.<sup>48</sup> Secondly, our sleep assessment included only nocturnal sleep and did not account for possible naps during the day, which would increase estimates of sleep duration. Nonetheless, nocturnal sleep time is commonly used in the epidemiologic sleep literature as a proxy for total sleep.<sup>4,49</sup> Our data do not permit inferences about differences in actual sleep quantity and quality between Amish and NHANES. It is also important to acknowledge that our survey methodology did not permit assessment of sleep disorders such as insomnia or

**Table 3**—Correlation of seasonally adjusted sleep duration between family members in Amish, 2013–2018.

Familial Pairs	No. of Pairs	Sleep Duration Correlation
Spouse pair	1,030	.62
Siblings (mix)		
Brother/sister	3,182	.20
Brother/brother	817	.24
Sister/sister	978	.28
Siblings (same house)		
Brother/sister	200	.34
Brother/brother	31	.63
Sister/sister	79	.43
Siblings (different house)		
Brother/sister	2,976	.15
Brother/brother	785	.22
Sister/sister	896	.21

The household variable has missing values, which make the sample size of all sibling pairs bigger than the sum of sibling pairs from same and different houses. *P* value is from Pearson correlation test, *P* < .001 for all correlations.

obstructive sleep apnea. Thirdly, we do not have historical data on sleep duration in Amish, so it is not possible to evaluate temporal trends in sleep duration in the Amish as has been done in NHANES. It is also possible that sleep duration used to be longer in the Amish and has also decreased over time. Finally, our classification of seasonal light exposure does not fully align with the astronomical dates. We do note that many Amish are farmers and consequently experience an intense environmental exposure to light in September and October (months classified in our analysis as summer months).

## CONCLUSIONS

Although sleep duration has declined in the United States population over the past 30 years, our analyses indicate that sleep duration in the OOA is slightly but significantly shorter than in NHANES; however, the proportion of Amish classified as short and long sleepers is considerably lower in the Amish than in NHANES. Additionally, the Amish bedtime and wake time are much earlier than in NHANES, a pattern recently associated with a lower physical and mental health morbidity and general mortality. The lower frequency of short and long sleepers and the earlier sleep timing in the Amish might provide insights into the relatively lower risks of cardiometabolic diseases observed in this population.

## ABBREVIATIONS

NHANES, National Health and Nutrition Examination Survey  
OOA, Old Order Amish

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