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Sleep-duration extension and midpoint displacement in United States adults: joint classification and survey measurement constraints

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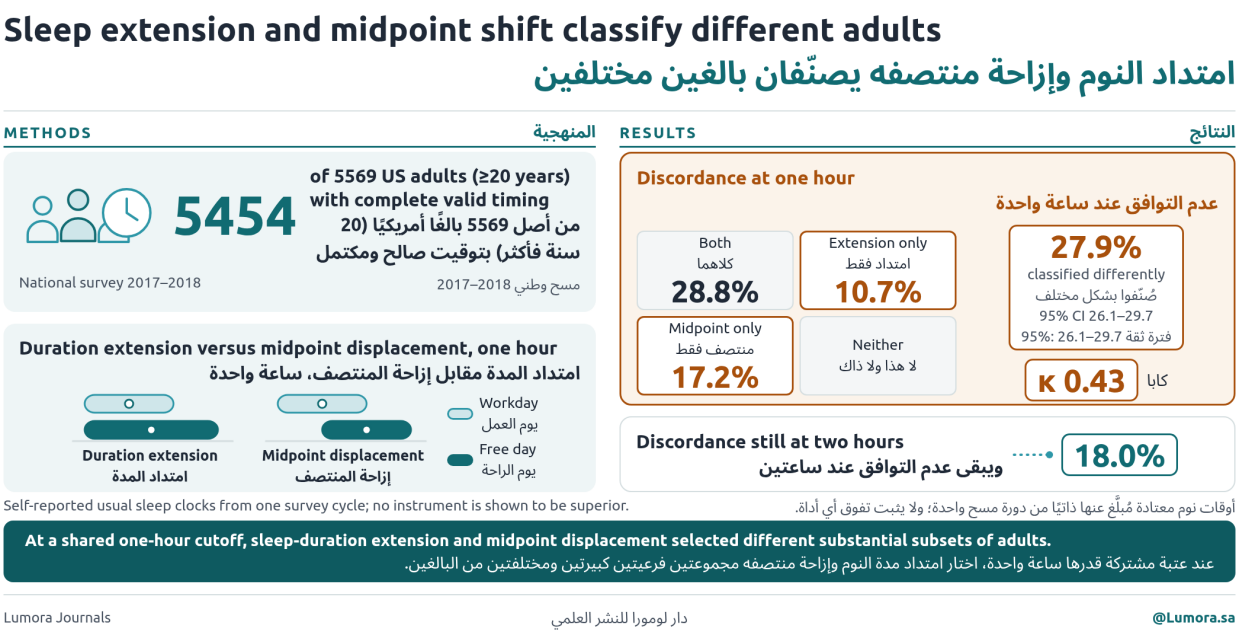
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Graphical abstract



Graphical abstract: At a shared one-hour cutoff, sleep-duration extension and midpoint displacement selected different substantial subsets of adults. Designed by the Lumora Journals production team using hand-coded HTML/SVG rendered in Google Chrome.

Abstract

Background: Duration extension and sleep-midpoint displacement are both expressed in hours but can select different respondents at a shared cutoff. We quantified their joint classification and the constraints of the released timing and summary data.

Methods: In an exploratory cross-sectional analysis of National Health and Nutrition Examination Survey (NHANES) 2017–2018 adults aged at least 20 years, using interview weights, strata and primary sampling units, signed free-day minus workday main-period duration (extension) was cross-classified against absolute circular midpoint displacement. The primary inclusive cutoff was one hour, with declared secondary thresholds. Rounded-duration comparisons excluded grouped extremes; 95% confidence intervals (CIs) are pointwise.

Results: Of 5569 adult interviews, 5454 had complete valid timing (weighted availability 98.6%, 95% CI 98.1–98.9). At one hour, extension only, midpoint only and both comprised 10.7%, 17.2% and 28.8%. Discordance was 27.9% (95% CI 26.1–29.7) and Cohen's κ was 0.43 (95% CI 0.40–0.47). The paired marginal difference was −6.5 (95% CI −8.5 to −4.6) percentage points. Discordance remained 18.0% at two hours despite close marginal proportions. Within 5442 ordinary-summary records, six and five classifications changed after summary rounding at one and two hours, respectively; these rare estimates require reliability review.

Conclusions: Joint tables reveal construct-dependent selection obscured by marginal prevalences. Clock availability, grouped summaries and circular interval conventions constrain interpretation. These shared-source operational quantities do not establish true sleep debt, instrument superiority, biological circadian misalignment or clinical thresholds.

Keywords: Sleep Duration; Circadian Rhythm; Nutrition Surveys; Cross-Sectional Studies; Surveys and Questionnaires

Introduction

Workday and free-day sleep are often described with two different quantities: how much the main sleep period lengthens and how far its midpoint moves. Their names can imply a common underlying problem even when their arithmetic and interpretation differ. A published National Health and Nutrition Examination Survey (NHANES) 2017–2020 analysis already described adult sleep duration, sleep debt and social jet lag [1]. The present study does not claim first measurement of weekend compensation or social jet lag. It asks a narrower question: when two operational quantities are calculated from the same released clocks, how often do they select different adults at the same numerical threshold, and which features of the public release constrain that comparison?

The distinction has a substantial conceptual history. The original Munich Chronotype Questionnaire separated work and free days, and social jet lag was subsequently framed through differences in sleep timing [2,3]. Jankowski argued that the conventional midpoint formulation can incorporate consequences of workday sleep restriction, proposing a sleep-corrected formulation [4]. The midpoint–duration distinction is therefore not a new biological insight, but it cautions against treating a duration contrast and a midpoint contrast as interchangeable because both are expressed in hours. We use descriptive names that state the calculation.

The 2017–2018 NHANES sleep questionnaire makes this question observable because it contains reported onset and wake clocks for weekday/workday and weekend/non-workday main sleep, together with derived duration summaries [5]. Its demographic file supplies age, recorded sex and the sampling design [6]. The source periods describe usual schedules, not a diary of the preceding seven days. We therefore retain the questionnaire's two period types and do not assume a conventional Monday-to-Friday schedule; "free" is a short period label, not evidence that a respondent was free of alarms or other obligations.

Validation studies of questionnaire-derived chronotype and comparisons of reported with actigraphic sleep concern relationships between different instruments [7,8]. Our comparison is different: both quantities share the same self-reported, edited clocks and inherit their errors. What the comparison can establish is the extent to which a common threshold description conceals different selections in one public-data domain.

Other studies reinforce the need for precise construct labels. UK Biobank work investigated weekday–weekend sleep-offset differences, whereas NHANES accelerometer studies examined day-to-day sleep variation and national duration, timing and continuity distributions [9–11]; offset, midpoint, duration extension and night-to-night irregularity are not the same variable. Applied studies also turn these questionnaire fields into exposures: Zhu and colleagues defined weekend catch-up sleep in NHANES 2017–2018 adults as sleeping 1 hour longer on weekends than on weekdays and related it to cardiovascular disease [12]. Which adults such a definition selects therefore determines the exposed and unexposed groups being compared.

Our primary analysis cross-classifies duration extension and absolute circular midpoint displacement at one hour, with secondary thresholds, agreement statistics, age, sex and work-status summaries, and an audit of clock availability, clock heaping and summary rounding. The contribution of this study is to quantify, in a national survey already used for such exposures, how many adults are selected by one definition but not the other at the same cutoff; to show that similar marginal prevalences can conceal substantial discordance; and to identify the release features (missing and grouped durations, heaped clocks and

rounded summaries) that analysts need to specify when they use these fields. Together these results give analysts a reproducible basis for naming, defining and reporting sleep-timing exposures.

Methods

Study design and reporting

We conducted a cross-sectional secondary analysis of the publicly released 2017–2018 NHANES demographic, sleep-questionnaire and occupation files [5,6,13], reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [14,15]. The clock formulas, the one-hour primary threshold, the secondary thresholds, eligibility and the variance treatment are described below. The analysis plan was not registered or deposited, and the descriptive analysis is not a confirmatory test. Other manuscripts drawing on the same public NHANES 2017–2018 cycle and addressing different questions have been submitted separately to this journal; they are listed in the cover letter.

The target population was adults aged at least 20 years represented by the household interview, with a positive two-year interview weight. The complete-timing estimand was conditional on a usable four-clock record; the rounding comparison additionally required both ordinary duration summaries. Age is top coded at 80 years in the release, and sex is the recorded male/female source variable. Current work status came from the occupation question on the type of work done in the previous week (OCD150) and was grouped as working (working at, or with, a job or business) or not working (looking for work or not working) [13].

Public files were joined one-to-one on the released respondent identifier, with uniqueness checked in each input. The sampling design was constructed from every positive-interview-weight demographic record before age or clock restrictions, using the two-year interview weight, masked stratum and masked primary sampling unit, following NHANES weighting and variance guidance [16,17]. Domain estimates therefore retain the zero contributions of excluded respondents in the represented sampling units.

Clock variables and missingness

Each released clock was parsed as hour and minute on a 24-hour scale. Midnight was a valid time, whereas blanks and refusal or unknown codes were missing; an unexpected format would stop the preparation. We used the edited public values and did not attribute missing timing to a single mechanism [5].

The ordinary summary values are half-hour duration categories from 3 through 13.5 hours. The special values 2 and 14 denote grouped short and long durations in the codebook, not exact observations, and were excluded from numerical comparisons of summary-derived extension. Some clock-derived intervals are exactly 14 hours and carry a long-duration code; these usable clocks were retained rather than imposing a new exclusion rule.

Clock completeness, valid derived timing and summary availability were audited separately. The released summaries were partitioned into ordinary pairs, paired summaries containing a tail code and records with at least one missing summary; a separate any-tail count overlaps with missing summaries and is not part of that partition. No censored duration, missing clock or schedule was imputed.

Duration and circular midpoint definitions

Let onset and wake be minutes after midnight in a period. The main-period duration is the wake–onset difference wrapped into a 24-hour day, so that a late-evening onset and next-morning wake form an overnight interval; it does not identify naps, interrupted sleep or time in bed. Duration extension is the free-day minus the workday interval, in hours. It is signed: shorter free-day sleep is not turned into a positive extension.

When onset and wake are the same reported clock, the interval cannot distinguish zero from 24 hours; such periods were classified as indeterminate and the record was excluded from the complete-timing domain, with its frequency reported. Otherwise, the midpoint is onset plus half the interval, wrapped to the 24-hour clock, so that midpoints shortly before and after midnight are close.

The signed midpoint difference is the free-day minus workday midpoint on the interval from −12 to less than +12 hours, and its absolute value is midpoint displacement. The antipodal tie is assigned −12 hours by convention, which does not affect the absolute value. We did not subtract extension from displacement, apply a sleep-corrected chronotype formula or infer sleep debt relative to an unobserved need [4].

Classifications can differ without contradiction. If neither interval crosses the circular branch, midpoint change combines the onset shift with half the duration change: lengthening sleep with a fixed onset changes both quantities by different amounts, whereas moving onset and wake together shifts the midpoint without changing duration.

Operational thresholds and estimands

At threshold t hours, extension-positive means signed extension of at least t, and displacement-positive means absolute circular displacement of at least t. The four categories are neither, extension only, midpoint only and both, and discordance is the sum of the two single-positive cells. We also estimated the difference between the extension-positive and displacement-positive proportions, retaining their within-person covariance; a small marginal difference does not imply small discordance because the two discordant cells can offset. The one-hour threshold was an operational primary choice, not an empirically optimised or clinical cutoff.

The 0.5-, 1.5-, 2- and 3-hour secondary thresholds use the same domain and describe how the joint selection changes; they are not independent replications or a search for favourable cutoffs. All categories use inclusive comparisons (≥). The age, sex and work-status analyses describe availability and one-hour discordance; they are unadjusted and test no interaction.

Extension is deliberately signed and displacement absolute. An adult whose free-day sleep is shorter is not extension-positive, even if the reduction is large, but can be displacement-positive if the midpoint moves earlier or later. We kept the stated definitions rather than choosing whichever gave closer agreement.

Additional analyses were: Cohen's κ for agreement between the two classifications at each threshold, computed with the survey weights [18]; the proportion of reported clocks on the hour, half-hour and quarter-hour, the proportion of extension and displacement values lying exactly on each cutoff and discordance recomputed with strict inequalities (>), to show the effect of the inclusive boundaries; bounds for the 115 adults without valid timing, obtained by recomputing discordance among all 5569 adults with these adults assumed all concordant or all discordant; one-hour classification by current work status, overall and among adults aged 20–59 years; and weighted characteristics of the complete-timing domain.

For quantization, clock-derived extension was compared at one and two hours with the difference between released ordinary summaries in the same domain, reporting the number and weighted proportion of respondents changing category and the direction of change. A within-period check compared each ordinary summary with its clock-derived duration against the nearest-half-hour bound. Neither value is treated as a gold standard for actual sleep.

Survey uncertainty and reliability

Weighted means and proportions were estimated with Taylor linearisation over the full positive-weight design, which contained 15 strata and 30 primary sampling units (15 design degrees of freedom) [19]. Proportion intervals used a logit transformation with the t critical value on 15 degrees of freedom; means and the paired marginal difference used linearised t intervals, and κ intervals used a delete-one-PSU jackknife. Intervals are pointwise, not simultaneous across thresholds or subgroups. No hypothesis tests were performed.

The sample size was fixed by the released survey cycle. Unweighted counts describe observed records and weighted percentages describe the represented population, so percentages cannot be obtained by dividing displayed counts. The denominators are all eligible adult interviews for timing availability, the complete-timing adult domain for joint classification and the ordinary-summary timing domain for rounding.

Observed all-zero or all-one categories are reported without a logit interval. Small event counts are flagged with relative standard errors; these flags are diagnostic and do not certify National Center for Health Statistics (NCHS) presentation standards [20–22]. Rare rounding changes and tail-category estimates are exploratory.

An independent calculation reconstructed all clock intervals, midpoint differences, eligibility domains and weighted aggregates from the unchanged public files and compared estimates, standard errors and intervals. The complete analysis was also re-run from newly downloaded public files with the code supplied as Supplementary Code S1, which reproduced every published count and estimate. Agreement checks address computation only; they cannot validate the source reports.

Ethics and source use

NHANES 2017–2018 was approved by the NCHS Ethics Review Board (continuation of protocol 2011-17 through October 26, 2017 and protocol 2018-01 from that date) [23]; that approval covers the source survey, not this secondary analysis. Public files were used under the NCHS data-user agreement, without reidentification, linkage or attempts to reconstruct restricted information [24].

Results

Availability and analysis domains

The demographic file contained 9254 positive-weight records, of which 5569 were adults aged at least 20. Paired duration summaries were present for 5500 adults and four clocks for 5458; 4 records had an indeterminate same-clock interval, leaving 5454 adults with complete valid timing. Weighted timing availability was 98.6% (95% CI 98.1–98.9), compared with 99.1% (95% CI 98.6–99.4) for paired summaries (Table 1). The 115 adults outside the complete-timing domain are addressed by the bounds below.

Table 1. Adult eligibility, summary availability and complete-timing domains

Domain or restriction	Respondents, n	Weighted share, % (95% CI)
All positive interview-weight demographic records	9254	Not an adult-domain percentage
Adults aged at least 20	5569	Adult availability denominator
Adults with paired duration summaries	5500	99.1 (98.6–99.4)
Adults with four complete clocks	5458	Parsing completeness; not a valid-interval denominator
Complete clocks with indeterminate same-clock interval	4	Excluded; zero versus 24 hours unresolved
Adults with complete valid timing	5454	98.6 (98.1–98.9)
Ordinary-summary timing comparison	5442	Conditional rounding domain

Notes for all tables and figures: n, unweighted respondents; CI, confidence interval; pp, percentage points; ≥, greater than or equal to. Percentages are weighted with the two-year household interview weight and the full stratum/primary sampling unit (PSU) design (15 degrees of freedom); intervals are pointwise logit 95% CIs (linearised t intervals for means and differences). Extension is signed free-day minus workday main-period duration; displacement is the absolute shortest circular midpoint difference; both come from the same reported clocks, and thresholds are inclusive. Unweighted counts do not reproduce weighted percentages.

Table 1: timing and summary percentages use all 5569 adult interviews as denominator; counts for summaries and clocks overlap and are not successive exclusions. Ordinary summaries are 3–13.5-hour half-hour categories; grouped short/long codes are not exact durations; a same-onset/wake clock cannot resolve a zero versus 24-hour interval.

The ordinary-summary-pair domain contained 5442 adults, all of whom had valid derived timing. The mutually exclusive summary-release categories were 5442 ordinary pairs, 58 pairs containing a grouped tail code, and 69 records with at least one missing summary. Only 12 of the 58 paired-tail records contributed complete valid timing; their weighted availability was 17.7% (95% CI 7.3–37.0) and was flagged for sparse counts. The separate any-tail count was 60. Some clocks remained available in 49 any-tail records, so the release cannot accurately be summarized as blanket removal of every clock whenever a tail code appears.

Table 2. Weighted characteristics of the complete-timing adult domain

Characteristic	Respondents, n	Weighted % or mean (95% CI)
Age, years, mean	5454	48.3 (47.1–49.4)
Age 20–39 years	1658	36.2 (33.5–39.1)
Age 40–59 years	1698	34.7 (31.7–37.8)
Age 60–79 years	1682	24.5 (21.5–27.7)
Age 80+ years	416	4.6 (3.9–5.6)
Male	2640	48.1 (46.1–50.1)
Female	2814	51.9 (49.9–53.9)
Working in the previous week	3000	63.5 (61.1–65.8)

Characteristic	Respondents, n	Weighted % or mean (95% CI)
Not working in the previous week	2452	36.5 (34.2–38.9)
Work status missing	2	<0.1
Workday main-period duration, hours, mean	5454	7.58 (7.51–7.65)
Free-day main-period duration, hours, mean	5454	8.26 (8.15–8.37)

Table 2: 5454 adults with complete valid timing. Work status is the type of work done in the previous week (OCD150): working, working at or with a job or business; not working, looking for work or not working. Age 80+ is released top coding.

Primary joint classification

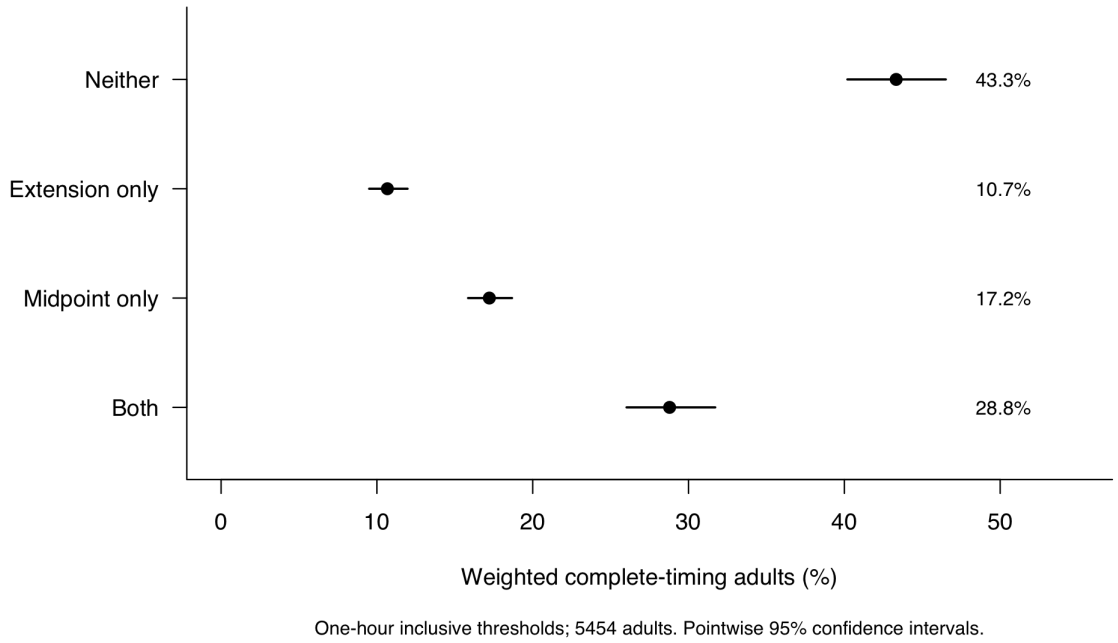
At one hour, the weighted joint distribution was 43.3% (95% CI 40.2–46.5) in neither category, 10.7% (9.5–12.0) extension only, 17.2% (15.9–18.7) midpoint only and 28.8% (26.0–31.7) in both (Table 3; Figure 1). The two discordant categories contained 1418 respondents and together represented 27.9% (95% CI 26.1–29.7); Cohen's κ was 0.43 (95% CI 0.40–0.47) [18]. Extension-positive and displacement-positive marginal proportions were 39.5% (36.5–42.5) and 46.0% (42.9–49.1), a paired difference of −6.5 (95% CI −8.5 to −4.6) percentage points. The excess of midpoint-only over extension-only classifications describes different selected respondents, not a mistaken measure.

Table 3. Joint one-hour classification of duration extension and midpoint displacement

Extension ≥ 1 hour	Displacement ≥ 1 hour	Sample, n	Weighted share, % (95% CI)
No	No	2553	43.3 (40.2–46.5)
Yes	No	548	10.7 (9.5–12.0)
No	Yes	870	17.2 (15.9–18.7)
Yes	Yes	1483	28.8 (26.0–31.7)
Discordant (one positive)	One of the two quantities	1418	27.9 (26.1–29.7)

Table 3: the denominator is the same 5454 complete-timing adults in all four mutually exclusive cells; the discordant row is the sum of the extension-only and midpoint-only cells, not a fifth category.

Figure 1. Joint one-hour classifications in the complete-timing adult domain



Points and error bars are weighted percentages and pointwise 95% CIs in four mutually exclusive cells (denominator 5454 adults).

Mean workday main-period duration was 7.58 (7.51–7.65) hours and free-day duration was 8.26 (8.15–8.37) hours. Mean signed extension was 0.68 (0.60–0.77) hours. Mean absolute midpoint displacement was 1.11 (1.03–1.20) hours, whereas the signed circular midpoint difference averaged 0.71 (0.57–0.84) hours. These averages are not substitute measures of required sleep or biological phase. The 6 antipodal midpoint records follow the declared negative-branch convention for signed summaries; their absolute displacement is unaffected.

Threshold and subgroup descriptions

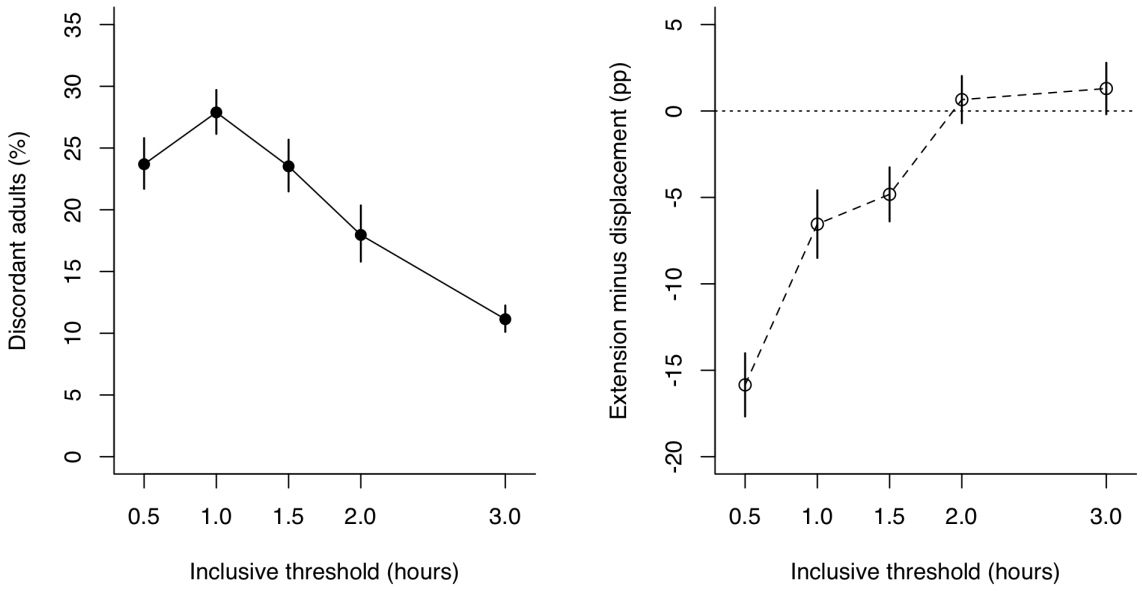
Discordance at 0.5, 1, 1.5, 2 and 3 hours was 23.7, 27.9, 23.5, 18.0 and 11.1%, respectively, and κ fell from 0.53 at 0.5 hours to 0.30 at 3 hours (Table 4; Figure 2); discordance was therefore not a monotone function of the cutoff. At two hours, the marginal proportions were close (difference 0.7 percentage points, 95% CI −0.7 to 2.0), while 18.0% (95% CI 15.8–20.4) of adults fell into different single-positive cells. Matched marginal percentages therefore did not mean matched respondents.

Table 4. Joint-classification sensitivity to declared operational thresholds

Cutoff, hours	Extension only, % (95% CI)	Midpoint only, % (95% CI)	Discordant, % (95% CI)	κ (95% CI)	Marginal difference, pp (95% CI)
0.5	3.9 (3.2–4.8)	19.8 (18.0–21.6)	23.7 (21.7–25.8)	0.53 (0.50–0.57)	−15.8 (−17.7 to −14.0)
1	10.7 (9.5–12.0)	17.2 (15.9–18.7)	27.9 (26.1–29.7)	0.43 (0.40–0.47)	−6.5 (−8.5 to −4.6)
1.5	9.3 (8.2–10.7)	14.2 (12.8–15.6)	23.5 (21.5–25.7)	0.42 (0.38–0.47)	−4.8 (−6.4 to −3.3)
2	9.3 (8.1–10.7)	8.7 (7.4–10.1)	18.0 (15.8–20.4)	0.43 (0.39–0.48)	0.7 (−0.7 to 2.0)
3	6.2 (5.3–7.3)	4.9 (4.1–5.8)	11.1 (10.1–12.3)	0.30 (0.24–0.36)	1.3 (−0.2 to 2.8)

Table 4: all rows use the same 5454 adults; the one-hour cutoff is primary and the others are descriptive. Marginal difference is the extension-positive minus the displacement-positive proportion, retaining within-person covariance. κ, survey-weighted Cohen's kappa (delete-one-PSU jackknife interval).

Figure 2. Discordance and paired marginal difference across declared thresholds



Same 5454 complete-timing adults; pointwise 95% confidence intervals. pp, percentage points.

Left panel: discordance (sum of single-positive cells); right panel: extension-positive minus displacement-positive percentage. The same 5454 adults contribute at every cutoff; connecting lines guide reading only.

Timing availability was high in every age, sex and work-status category, but one-hour discordance differed descriptively (Table 5; Figure 3). The weighted discordance estimates were 36.8, 29.0, 17.1 and 7.4% across ages 20–39, 40–59, 60–79 and 80 or older, and 28.1% and 27.7% in male and female adults, respectively. Discordance was 32.4% (95% CI 30.0–34.8) among adults working in the previous week and 20.1% (18.0–22.3) among those not working; among adults aged 20–59 years the corresponding estimates were 33.6% (30.8–36.5) and 30.7% (26.5–35.3), so much of the overall work-status contrast coincided with age. These unadjusted summaries were not tested.

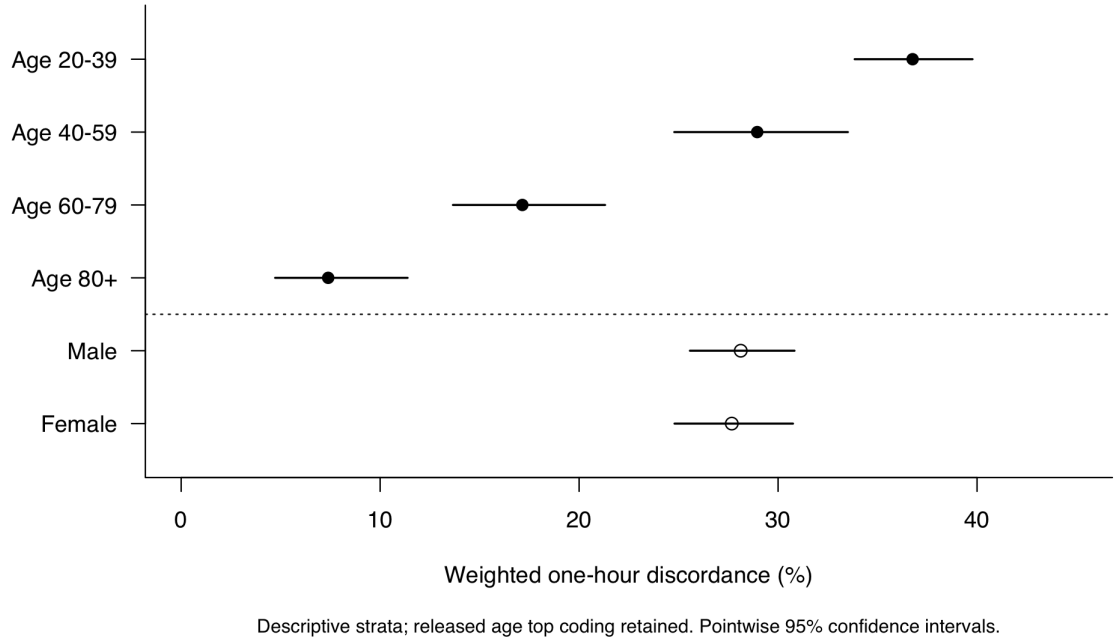
Table 5. Descriptive timing availability and one-hour discordance by age, recorded sex and work status

Source category	Adult sample, n	Timing sample, n	Timing available, % (95% CI)	Discordant, % (95% CI)
Age 20–39	1687	1658	98.8 (98.2–99.2)	36.8 (33.9–39.8)
Age 40–59	1732	1698	98.5 (97.8–99.0)	29.0 (24.8–33.5)
Age 60–79	1723	1682	98.5 (97.7–99.1)	17.1 (13.7–21.3)
Age 80+	427	416	97.9 (96.0–98.9)	7.4 (4.7–11.4)
Male	2702	2640	98.5 (98.0–98.9)	28.1 (25.6–30.8)
Female	2867	2814	98.6 (98.0–99.0)	27.7 (24.8–30.7)

Source category	Adult sample, n	Timing sample, n	Timing available, % (95% CI)	Discordant, % (95% CI)
Working in the previous week	3054	3000	98.8 (98.3–99.2)	32.4 (30.0–34.8)
Not working in the previous week	2513	2452	98.1 (97.3–98.7)	20.1 (18.0–22.3)

Table 5: availability uses each adult category and discordance its complete-timing subset. Age 80+ is released top coding. Age, sex and work-status rows are separate partitions and must not be summed; two adults with missing work status are not shown.

Figure 3. Descriptive one-hour discordance by age and recorded sex



Filled circles, age strata; open circles, recorded sex strata (separate partitions). Age 80+ retains top coding.

Release rounding and boundary audit

Reported clocks were heavily heaped. Of 22,022 clock values reported by adults, 79.1% fell on the hour and 98.3% on the hour or half-hour, and all four clocks fell on the hour or half-hour for 93.6% (95% CI 91.6–95.1) of the complete-timing domain. As a result, 95.0% of extension values were multiples of half an hour and many values lay exactly on a cutoff: at one hour, 12.7% (11.6–14.0) of adults had an extension of exactly one hour and 9.1% (7.7–10.6) a displacement of exactly one hour. With strict inequalities (>) instead of the inclusive rule, discordance was 28.2% (26.3–30.1) at 0.5 hours, 24.8% (22.8–27.0) at one hour, 20.0% (17.6–22.6) at 1.5 hours, 15.2% (13.4–17.1) at two hours and 7.7% (6.5–9.1) at three hours. The threshold profile therefore depends partly on the boundary convention, particularly at 0.5 and one hour, although discordance remained substantial under both conventions.

Within the 5442 ordinary-summary timing records, the largest absolute difference between a clock-derived period duration and its released summary was 0.25 hours, within the half-hour rounding bound. At the one-hour extension threshold, 6 respondents changed category (0.13%, 95% CI 0.04–0.44); at two hours, 5 changed (0.06%, 95% CI 0.02–0.17). Every observed change was summary-positive and clock-derived-

negative. Both are rare-event estimates with substantial uncertainty and are flagged for reliability assessment.

The clock audit found 12 complete-timing records with a grouped long-duration summary and an exactly 14-hour derived period (4 workday, 8 free-day). These records account for the complete-timing paired-tail subset and remain included under the declared clock rule (Table 6).

Table 6. Release-category timing availability and rounded-summary threshold changes

Release comparison	Domain, n	Events, n	Weighted share, % (95% CI)
Ordinary summaries: valid timing	5442	5442	100.00 (interval unavailable)
Paired summaries with tail code: valid timing	58	12	17.73 (7.33–36.98)
At least one missing summary: valid timing	69	0	0.00 (interval unavailable)
Rounded versus clock extension: ≥ 1 hour	5442	6	0.13 (0.04–0.44)
Rounded versus clock extension: ≥ 2 hours	5442	5	0.06 (0.02–0.17)

Table 6: the first three rows partition the 5569 adults (5442 ordinary pairs, 58 paired-tail records, 69 with a missing summary); tail codes 2 (<3 hours) and 14 (grouped long duration) are not exact hours, and the separate any-tail count (60) overlaps with missing summaries. Rounding rows use the 5442 ordinary-summary timing records; events are changed inclusive extension classifications, all summary-positive/clock-derived-negative. No interval is reported for observed all-zero/all-one categories; sparse estimates are exploratory.

Discussion

Principal interpretation

In this national interview cycle, roughly one quarter of adults with complete timing received different one-hour classifications from duration extension and circular midpoint displacement, and agreement beyond chance was moderate (κ 0.43). The joint distribution answers a question that separate prevalences cannot: whether the same respondents satisfy two similarly worded definitions. A midpoint-only classification means that the midpoint moves enough while signed extension does not reach the cutoff; an extension-only classification means the converse. The result is construct-dependent selection.

The two-hour analysis shows why the marginal difference needs the joint table: comparable percentages above a cutoff were obtained from different adults, with the extension-only and midpoint-only cells balancing. Reporting only marginal percentages could make two definitions appear interchangeable, which matters for how analysts label questionnaire-derived exposures and select participants.

Reports of exposures based on these fields should therefore state the source period labels, the clock interval convention, whether the contrast is signed or absolute, the threshold and its boundary rule, and the domain denominator, and should separate grouped summary values from exact intervals and rounded summaries from clock calculations. The heaping results add that, because most clocks are reported to the hour or half-hour, the boundary rule itself (≥ or >) moves several percentage points of adults between categories. These are reporting implications of this comparison, not an endorsed new standard.

The threshold variation is a descriptive mapping, not optimisation. Discordance rose between the lowest two cutoffs and then fell as both single-positive categories changed; fewer disagreements at three hours do not make that criterion more valid. Studies comparing health associations should carry the definition into the estimand, because it alters both exposed and unexposed groups.

Relation to prior work

Di and colleagues' national 2017–2020 sleep description is the closest direct source analogue [1]. Its period, eligibility and sleep-debt formulation differ from the present single-cycle extension contrast, so differing percentages are not a contradiction or a secular change. Applied analyses show the practical stakes. The weekend catch-up sleep definition of Zhu and colleagues in the same cycle (sleeping 1 hour longer on weekends than on weekdays) has the same form as the one-hour extension classification used here [12]. In the present data, 17.2% of adults were displaced by at least one hour without such an extension and 10.7% had the extension without the displacement, so a midpoint-based definition at the same cutoff would compare a different exposed group.

The chronotype and social-jet-lag literature, together with the sleep-corrected-formula critique, already recognises that duration and timing interact [2–4]. Our arithmetic makes that interaction explicit without proposing a new correction, and the questionnaire comparison and reported-versus-actigraphic studies show why instrument validity requires a different design [7,8].

The UK Biobank offset study and the NHANES actigraphy analyses concern related but distinct measures and designs [9–11]. Repeated-night accelerometry can address within-person variability that usual-period questionnaire clocks cannot observe, whereas questionnaire period labels reflect reported habits. The present work neither compares devices nor reproduces those health models; it supports source-specific description and a clear separation between habitual period contrasts and night-to-night variability.

Source availability and quantization

Complete timing covered 98.6% of weighted adult interviews. If all 115 adults without valid timing were concordant, one-hour discordance among all 5569 adults would be 27.5%; if all were discordant, it would be 28.9%. Missing timing could therefore move the primary estimate by at most about 1.4 percentage points (bounds 23.3–24.8% at 0.5 hours and 17.7–19.1% at two hours). The paired-tail availability estimate is sparse and is not used to quantify a general editing effect.

The boundary audit also prevents an overstatement about suppression. Any-tail records sometimes retained individual clocks, and exactly 14-hour derived intervals could coexist with a grouped long summary. Treating every long code as exactly 14 hours would misuse the grouped variable, and deleting every retained 14-hour clock would introduce a new restriction; we did neither.

Rounding changed very few classifications at the two specified extension thresholds in the ordinary-summary domain. This answers a concrete implementation choice but is not a general assurance that rounding is harmless: the domain excludes grouped extremes and missing clocks, and the difference of two rounded values can move a respondent across a threshold even when each rounded duration is compatible with its own interval. The small counts are reported with their reliability limits [20–22].

Strengths and limitations

The analysis links explicit operational definitions to a joint distribution, preserves the full survey design before domain restrictions, separates timing availability from summary availability and is fully reproducible from public files with the supplied code.

Several limitations qualify every result above. Both quantities are derived from the same reported, edited usual clocks, which are subject to recall, interpretation, editing and heaping; shared errors can strengthen or weaken their correspondence, so agreement does not validate sleep and discordance does not identify a misclassified person or a superior instrument. Neither quantity measures true sleep debt or sleep need, melatonin or other biological circadian phase, or a clinical threshold, and the main-period interval is not measured sleep. Workday/free-day labels may not match employment, shift patterns or alarm use; the work-status stratification describes only the previous week's activity and does not identify shift work. Age is top coded, and recorded sex is a limited source classification.

Inference is restricted to the 2017–2018 civilian noninstitutionalised interview population; this is not a trend, current prevalence or longitudinal study, and the age, sex and work-status contrasts are unadjusted descriptions that do not demonstrate causal, ageing or biological effects. The complete-timing estimand may differ from an all-adult estimand, although the simple bounds limit that difference to about 1.4 percentage points at one hour; no imputation was performed. Pointwise intervals are not adjusted for the family of thresholds and subgroups, and the analyses added during review are identified as such.

Sparse estimates require careful dissemination: an observed zero count is not proof that an event is impossible, and the reliability flags used here do not replace formal NCHS presentation criteria [21,22]. A substantive follow-on study should prespecify its biological or policy estimand, use an independent measure where validation is claimed and assess missingness.

Conclusion

Duration extension and circular midpoint displacement selected different substantial subsets of adults at a shared one-hour cutoff in NHANES 2017–2018. Joint classification revealed information that similar marginal prevalences could conceal, while the source audit separated complete timing, grouped duration summaries, indeterminate intervals and rare rounding-related changes. These findings support explicit construct names, domain denominators and local measurement definitions. They do not establish instrument superiority, true sleep debt, biological phase, a clinical threshold, causal demographic effects or independently verified novelty. Responsible use requires source-aware interpretation.

Declarations

Data and Code Availability: No new data were generated. The analysis used the publicly released NHANES 2017–2018 sleep disorders questionnaire (SLQ_J), demographic variables and sample weights (DEMO_J) and occupation questionnaire (OCQ_J) files from the National Center for Health Statistics, available with their documentation at https://wwwn.cdc.gov/Nchs/Data/Nhanes/Public/2017/DataFiles/SLQ_J.htm, https://wwwn.cdc.gov/Nchs/Data/Nhanes/Public/2017/DataFiles/DEMO_J.htm and https://wwwn.cdc.gov/Nchs/Data/Nhanes/Public/2017/DataFiles/OCQ_J.htm [5,6,13]. The complete analysis code, which downloads these files and reproduces every estimate in this article, is provided as Supplementary Code S1.

Ethics: The NHANES 2017–2018 protocols were approved by the NCHS Ethics Review Board (continuation of protocol 2011-17 and protocol 2018-01) [23]; that approval applies to the source survey. This secondary analysis used public-use, de-

identified files without re-identification or linkage. This study was exempt from ethics review because the data are public (secondary analysis of public, de-identified data).

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