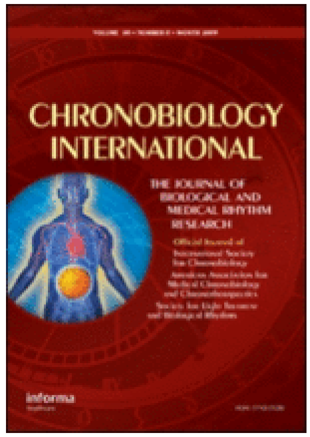

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Evening chronotype, late weekend sleep times and social jetlag as possible causes of sleep curtailment after maintaining perennial DST: ain't they as black as they are painted?

Arcady A. Putilov[1*], Michael G. Poluektov[2], Vladimir B. Dorokhov[1]

[1] Laboratory of Sleep/Wake Neurobiology, the Institute of Higher Nervous Activity and Neurophysiology of the Russian Academy of Sciences, Moscow, Russia

[2] Department of Normal Physiology, Pirogov Russian National Research Medical University, Moscow, Russia

[*] Dr. Arcady Putilov, 11, Nipkowstr., 12489 Berlin, Germany, phone/fax: 0049-30-53674643; e-mail address: putilov@ngs.ru; ORCID: 0000-0003-2779-9046

Short title: Estimation of sleep losses from bed- and risetimes

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Ethics

The study reported in papers from which samples with sleep times were collected have been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

Abstract

People sleep less in response to setting social clocks earlier relative to the sun clocks. We proposed here a model-based approach for estimating sleep loss as the difference between weekend and weekday risetimes divided on the difference between weekend risetime and weekday bedtime. We compared this approach with a traditional approach to estimating sleep curtailment as the difference in weekly average sleep duration in two conditions. Weekday and weekend sleep times reported for 320 samples provided possibility of testing whether evening types with later weekend sleep times and larger social jetlag differ from morning types with earlier weekend sleep times and smaller social jetlag on amount of sleep lost 1) throughout the week and 2) in response to an advance of weekday wakeups, for instance, after the expected installation of perennial Daylight Saving Time (DST). We found that 1) an amount of sleep lost due to advancing shift of weekday wakeups depends upon neither chronotype nor weekend sleep times nor social jetlag, 2) a very large amount of sleep is usually lost by evening types with later weekend sleep times and larger social jetlag, and 3) an essential sleep loss is caused by our usual work/school schedules, even in morning types with early weekend sleep times and small social jetlag. As compared to such permanent sleep losses experienced by any types, an additional loss due to switching from Standard Time (ST) to perennial DST are expected to be relatively small. We also found that the traditional way of calculation of sleep curtailment leads to paradoxical conclusions, such as 1) sleep loss is larger when social jetlag is smaller, not larger, 2) sleep loss is larger when weekend sleep times are earlier, not later, 3) despite 1-h difference between two student samples in weekday wakeups, their sleep losses can be identical.

Key words: evening type; morning type; sleep timing; sleep duration; sleep curtailment; sleep-wake regulation; two-process model; simulation

Introduction

People tend to sleep less when social clocks are set earlier relative to the sun clocks. Recently, Giuntella & Mazzonna (2019) demonstrated that employed people living on the late sunset side of a time zone border slept, on average, 19 fewer minutes than employed people living on the opposite side of the border (in neighboring US counties). Health index dropped by 0.3 standard deviations when people were living on the late sunset side of the border compared to the index of people living on the early sunset side (Giuntella & Mazzonna, 2019). Gu et al. (2017) reported that risk for total and many specific cancers increased from the east to the west in a time zone and VoPham et al. (2018) found that an increase in longitude moving east to west within a time zone significantly increased the risk of developing hepatocellular carcinoma. Moreover, the results presented online by Jagnani (2019) indicated that, in near equatorial countries, later sunset times are associated with fewer hours of sleep and poorer academic performance.

The occurring twice a year switches between Daylight Saving Time (DST, or 'summertime') and Standard Time (ST, or 'wintertime') are expected to be soon ended in the EU and several states of the USA. Would clocks be set in a way that does not make people sleep less year-round? Chronobiologists and sleep researchers are alarming about the negative effects on sleep and health of maintaining perennial DST as compared to the effects from installing perennial ST with noon occurring when the sun is overhead. Several international chronobiological and sleep societies insisted that, after ending the clock changes twice a year, the best choice for EU, California and any other places around the world would be to set social clocks to year round ST (EBRS, 2019; ESRS, 2019; Roenneberg et al., 2019b; Skeldon & Dijk, 2019; SRBR, 2019; Watson, 2019). However, only one third of several million respondents voted for setting year-round "winter time", whereas more than a half of the respondents voted for constant "summer time" in an EU public international consultation (European Commission, 2018).

One of possible explanations of such amazing choice of the majority of respondents (e.g., Roenneberg et al., 2019a) suggests simple misunderstanding around the terms “winter time” and “summer time”. They might be associated with a shorter natural daylight interval during “winter time” and a longer daylight interval during “summer time”, while, in fact, the switching between DST and ST has nothing to do with the seasonal variation in photoperiod. If this explanation is correct, then one way of challenging the dominated public opinion would be to estimate the amount of sleep that is expected to be lost due to setting social clocks earlier relative to the sun and biological clocks.

Wittmann et al. (2006) introduced the term “social jetlag” to determine a misalignment between social and biological clocks and proposed to quantify it by calculation of a difference between when a person wakes up and goes to sleep on free days and when he/she wakes up and goes to sleep for work/school days. They also suggested that this kind of misalignment would be most pronounced in “late chronotypes” (or, in other terms, E[vening]-types as opposed to M[orning]-types) “who substantially have to readjust their temporal habits to social demands, i.e., having to get up early without being able to advance their circadianly controlled sleep-onset” (Wittmann et al., 2006). In the mentioned above report of Giuntella & Mazzonna (2019), the effects of 1-h difference in sunset time were larger among individuals with early working schedules and children of school age. Therefore, individual chronobiological differences between people as well as the differences in the extent of misalignment between their biological clocks and social clocks would be taken into account in evaluations of sleep curtailment caused by setting social clocks earlier relative to the sun and biological clocks. Individual variation in vulnerability to sleep loss would, in particular, predict that such a setting will be favoring exclusively early chronotypes thus ignoring the negative consequences for sleep and health of late chronotypes.

Here, we suggested that it is necessary to replace a traditional approach to estimation of sleep curtailment from weekday and weekend sleep times in two conditions by a new approach and we illustrated such necessity by comparing the estimates of sleep curtailment in samples with distinct (M- and E-) chronotypes, earlier and later sleep timing on free days, smaller and larger social jetlag, and later and earlier weekday wakeups. When the results of applying the traditional and new approaches are compared, what would be the answers to such questions as: Does early chronotype or early weekend sleep times or small social jetlag let people 1) sleep more and 2) lose fewer minutes of sleep after a shift from later to earlier wakeups, in particular, due to the expected installation of perennial DST? The results of applying the two approaches were illustrated by the examination of the following two hypotheses:

E-types (with later sleep timing on free days and larger social jetlag) compared to M-types (with earlier sleep timing on free days and smaller social jetlag)

1) sleep less throughout a 7-day week consisting of 5 working/school days and two free days, and
2) will lose even more sleep when responding to earlier weekday wakeups, for example, after installation of perennial DST.

Methods

Samples

Bed- and Risetimes on weekdays and weekends (or, in general, free days) were collected form the journal papers. Sleep times for approximately a half of the analyzed here samples were previously used as an input to the model of sleep-wake regulating processes to simulate weekday and weekend time courses of Slow-Wave Activity (SWA), an electroencephalographic marker of these processes (Putilov, Verevkin, 2018; Putilov et al., 2019; Figure 1).

Since sleep times dramatically vary with age (i.e., early chronotypes are mostly children and people over 50, while late chronotypes are mostly adolescents and young adults), we enlarged this dataset to 320 samples by searching for the new samples mostly in most recent publications (years 2018 and 2019). Such increase in size of the whole collected dataset provided a possibility of further subdivision of each of 8 age subsets into, at least, two smaller subsets differed in either sleep timing or social jetlag or weekday wakeups. The sizes of such age subsets are reported in Supplementary 1 in the first two tables, Tables S1 and S2 (Supplementary Tables and Figures). Moreover, Supplementary 2 contains the list 320 samples with sleep times that were either added more recently for the present analysis or were previously used for simulation (see also this simulation in Supplementary 3).

We applied subdivision of the whole set of samples into two subsets in accord with social jetlag, sleep phase, and weekday wakeups. Additionally, we arbitrarily subdivided the whole set of 320 samples in accord with year of publication (earlier than year 2014 or later), even-odd number of a sample (after ranging samples on mean age in a sample), country (Germany or other countries) and availability of data on distinct chronotypes (27 paired samples). Comparison of subsets obtained by such artificial subdivisions allowed the examination of replicability of sleep times calculated by averaging over samples collected without applying such selection criteria as a limited range of mean ages of study participants, sex ratio, employment/student status, years of education, outdoors light exposure, season of data collection, geographic location of the sample relative to the borders of time zone, longitude, latitude, and so on.

Subdivision in accord with social jetlag and sleep phase

The major subdivisions of the whole set of samples into two subsets of approximately similar size were performed in accord with smaller or larger social jetlag and in accord with earlier or later sleep phase.

First, we calculated three measures of social jetlag proposed for its quantitative evaluation (Jankowski, 2017; Roenneberg et al., 2007; Wittmann et al., 2006). However, the way of this calculation slightly differed from the originally proposed way (see also the limitation paragraph in Discussion). The main difference was in using bed- and risetimes instead of sleep onsets and offsets. Moreover, we need not calculate an absolute difference between weekday and weekend times because, due to averaging within each sample and then over the samples included in a subset, the obtained mean times always indicated a delay rather than advance of sleep timing on weekends. Therefore, we termed such an estimate "time-lag" rather than "social jetlag" and calculated this lag as a weekend-weekday difference in either bedtime or risetime or midway from bedtime to risetime (either "bedtime-lag" or "risetime-lag" or "midway time-lag" abbreviated as either "BTL" or "RTL" or "MTL", respectively; Tables 1 and S3).

Second, we utilized three measures for subdividing samples into subsets in accord with sleep phase. Following publications of Roenneberg et al. (2004, 2007, 2019a) we used a measure named "sleep corrected weekend midway time" (MT_{sc}) that is a half of weekly average time in bed (see below) added to weekend bedtime. Again, it differed from the originally proposed "sleep corrected midpoint between sleep onset and offset" due to utilizing for calculations bedtime instead of sleep onset (Tables 1 and S1).

We also suggested another sleep phase measure that we need not calculate because this is risetime on weekends (RT_{we}; Table 1). The reason for considering it as a measure of sleep phase was that, in accord with the simulation prediction, clock hour for wakeups seems to remain stable throughout the week in the case of spontaneous sleep termination, i.e., irrespective of bedtime that was always earlier on weekdays and always later on weekends (Figure 1).

In 26 publications, the estimates of bed- and risetimes were reported separately for 27 samples of M- and E-types. These data (27 of 320 samples) were included in the whole dataset after their averaging over chronotype (Table S4) while the pairs of samples of M- and E-types provided the 3rd subdivision into samples with earlier and later sleep phase named "Type". However, only 27 paired samples were available for analysis of samples representing this third subdivision into earlier and late sleep phase (Tables 2 and S3).

In overall, the six subdivisions allowed the comparison of two subsets of samples differed on three indicators of sleep phase named "Type", "RT_{we}" and "MT_{sc}" and on three measures of social jetlag named "RTL", "MTL" and "BTL" (Table 1, left, 2, S5 and S6, left).

Subdivision in accord with earlier and later wakeups on weekdays

We also subdivided the whole sample into two subsets in accord with weekday wakeups. If mostly people' biology determines earlier sleep phase and smaller time-lag (six previous subdivisions), earlier weekday risetime (seventh subdivision) is expected to be mostly set by social clocks. Therefore, such a division into early and late risetime allowed the prediction of possible response to constant DST of people differed in sleep phase and social jetlag. We used this last subdivision, into earlier and later RT_{wd}, for testing whether samples with smaller time-lag and earlier chronotype differed from samples with larger time lag and later chronotype in responsiveness to earlier wakeups. In particular, such a response is expected after switching from ST to constant DST (the subsets with later and earlier RT_{wd}, respectively). Two subsets of samples with RT_{wd} being earlier and later than 7 a.m. were compared (Table 1, right).

Moreover, we further subdivided each of these two subsets into two smaller subsets with either earlier or later RT_{we}, either smaller or larger RTL, and so on (Tables S7-S11). Such 4-subset division was applied to all 8 ages for comparison of three measures of time-lag (RTL, MTL and BTL; Tables S7-S9). However, a similar comparison of two sleep phase measures (MT_{sc} and RT_{we}; Tables S10 and S11) was limited to three of 8 ages due to the absence of either samples with earlier phase (MT_{sc} <4 a.m.) or samples with later phase (MT_{sc} >4 a.m.) among samples of 5 other ages.

Comparison of paired samples

Additionally, several pairs of samples from separate studies allowed the examination of differences in sleep times in two conditions, either with different – earlier and later - weekday wakeups or during DST and ST (Tables S6 S12-S15). Therefore, we compared sleep times collected in such studies that can be considered "natural experiments" (see their list in Supplementary references of Supplementary 1).

A similar "natural experiment" was recognized in samples of two ages (16+ vs. 18+) in the collected dataset. Earlier age was mostly represented by high school students with early wakeups due to early school start time while older age was mostly represented by college/university students with much later weekday risetimes (Table S6, right).

Traditional approach to estimation of sleep reduction

A traditional approach to estimating sleep curtailment (e.g., caused by early wakeups) requires the calculation of a pair of weekly average sleep durations (e.g., for two conditions, with earlier and later weekday wakeups) and the following subtraction of one sleep duration from another. In other words, sleep curtailment can be, in particular, traditionally calculated as the difference between sleep durations after later weekday wakeups and sleep duration after earlier weekday wakeups.

To apply this traditional approach, we estimated the differences between rise- and bedtimes ("time in bed") on weekdays and the differences between rise- and bedtimes ("time in bed") on weekends. These times in bed were further used to calculate "weekly average time in bed" or, simply, "average" (in Tables 1-4 and S3-S20) that is 1/7th of the sum of time in bed for 5 weekdays and two weekends. This measure is an analog of weekly average sleep duration in social jetlag studies (e.g., Roenneberg et al., 2019a), but, again, we used for our calculations bed- and risetimes instead of self-reported times of sleep onset and offset.

Although such way of calculation of amount of sleep is very simple, its usefulness for estimation of sleep loss can be questioned by the results of simulation of weekday and weekend sleep times with a sleep-wake regulatory model (Putilov, Verevkin, 2018; Putilov et al., 2019; these simulations are described in more details in Supplementary). They, as we expected, confirmed the much earlier published results of simulation of experimental data on circadian variation in sleep duration (Åkerstedt & Gillberg, 1981) suggesting the sine-form 24-h modulation of sleep duration. The result explained the paradoxical observations of graduate decreasing rather than increasing in duration of sleep caused by delaying bedtimes due to prolongation of wakefulness into night and early morning hours (Daan et al., 1984; Putilov, 1995). Such experimental and modelling results imply that sleep curtailment can be simply calculated as the difference between sleep durations in two conditions only in one case: when in both conditions sleep was initiated at the same circadian phase, but it was not (e.g., in the cases of sleep initiation on either weekdays or weekends either after earlier or after later weekday wakeups).

Estimation of actual sleep loss

Therefore, to take into account the circadian modulation of sleep duration, we proposed another, model-based approach to calculation of sleep curtailment (e.g., sleep loses due to earlier weekday wakeups, including sleep losses cause by observing DST).

Weekend-weekday difference in time in bed was named “sleep shortening” or simply “shortening”. It equals to the difference between rise- and bedtime-lags as illustrated in Figure 1B. The simulation (Figures 1C and 2C) prompted a measure of sleep curtailment named “actual sleep loss” or, shortly, “sleep loss” that is calculated as the difference between rise- and bedtime-lags (shortening) expressed in percentage to the difference between weekend risetime (RT_{we}) and weekday bedtime (Tables 1 and S3). In other words, shortening (weekend-weekday difference in time in bed) is expressed in percentage to time in bed expected in the case of naturally occurring sleep on Friday-Saturday night, when bedtime is initiated after the last working/sleep day, earlier than on weekend, to be spontaneously terminated already in the beginning of first free day, later than on weekday (Figure 1C).

To provide direct comparison of difference in the results of using two measures for estimation of sleep curtailment, the difference between two subsets of samples in weekly average time in bed was expressed in percentage to mean value obtained by averaging over these two weekly average times in bed (Tables 3 and S16-20). The final results of such comparison are given in Table 4.

List of time measures

In overall, the bed- and risetimes for weekdays and weekends were used to calculate the following time measures (Tables 1-3, S3-S20 and Figure 1):

Time in Bed (TiB), hours, = Risetime (RT), clock hours, - Bedtime (BT), clock hours, + 24 hours;

Weekday Time in Bed (TiB_{wd}), hours, = Weekday Risetime (RT_{wd}), clock hours, - Weekday Bedtime (BT_{wd}), clock hours, + 24 hours;

Weekend Time in Bed (TiB_{we}), hours, = Weekend Risetime (RT_{we}), clock hours, - Weekend Bedtime (BT_{we}), clock hours, + 24 hours;

Averaged time in bed (Average), hours, = (5 $*$ Weekday Time in Bed (TiB_{wd}) + 2 $*$ Weekend Time in Bed (TiB_{we}))/7, hours;

Midway Time (MT), clock hours, = Bedtime (BT), clock hours, + (Time in Bed (TiB))/2, hours, - 24 hours;

Weekday Midway Time (MT_{wd}), clock hours, = Weekday Bedtime (BT_{wd}), clock hours, + (Weekday Time in Bed (TiB_{wd}))/2, hours, - 24 hours;

Weekend Midway Time (MT_{we}), clock hours, = Weekend Bedtime (BT_{we}), clock hours, + (Weekend Time in Bed (TiB_{we}))/2, hours, - 24 hours;

Bedtime-lag (BTL), hours, = Weekend Bedtime (BT_{we}), clock hours, – Weekday Bedtime (BT_{wd}), clock hours;

Risetime-lag (RTL), hours, = Weekend Risetime (RT_{we}), clock hours, – Weekday Risetime (RT_{wd}), clock hours;

Midway Time-lag (MTL), hours, = Weekend Midway Time (MT_{we}), clock hours, – Weekday Midway Time (MT_{wd}), clock hours;

Sleep shortening (Shortening), hours, = Weekend Time in Bed (TiB_{we}), hours, - Weekday Time in Bed (TiB_{wd}), hours = Risetime-lag (RTL), hours, - Bedtime-lag (BTL), hours;

Actual sleep loss (Sleep loss), %, = 100 $*$ Risetime-lag (RTL), hours, / (Weekend risetime (RT_{we}), clock hours, - Weekday bedtime (BT_{wd}), clock hours, + 24 hours);

Difference in Sleep loss, %, = Difference in Sleep loss in one of two conditions, %, - Difference in Sleep loss in another condition, %;

Difference in Averaged time in bed, %, = 100 $*$ (Average in one of two conditions, hours, - Average in another condition, hours)/ (Average in one of two conditions, hours, + Average in another condition, hours);

Sleep Corrected weekend Midway Time (MT_{sc}), clock hours, = Weekend Bedtime (BT_{we}), clock hours, + Average/2, hours.

Statistical analyses

All statistical analyses were performed with the Statistical Package for the Social Sciences ($SPSS_{23}$, IBM, Armonk, NY, USA). The estimates derived from the collected sleep times were related one to another using the Pearson's coefficients of correlation (Figure 2 and Supplementary Figure S1). We performed two-way MANOVAs of 12 (collected and derived) sleep times (Tables 1, 2 and S2-S6) to test, for each of these 12 sleep times, significance of main effect of factor "Subset" (Tables 1, 2 and S2-S6) and its interaction with the second independent factor "Age" (see Results and Figures 3, S2-S4). We also run three-way MANOVAs of these 12 sleep times when each of two subsets was further subdivided into two smaller subsets to test significance of main effects of two "Subset" factors (Tables S7-S11) and interaction between them (see Results and Figure 4). For paired samples (e.g., M- and E-types), two-way repeated measure ANOVAs (rANOVAs) were performed. The second factor was "Age" (Table 2). Paired t-test was employed for paired samples from "natural experiments" (Table S12, S13, S15) in statistical analysis of data from several such pairs of samples of separate "natural experiments" (Table S14).

Results

Replicability of the results of collection of sleep times

Comparison of subsets obtained by applying any of arbitrary ways of subdivision of the whole set of 320 samples into two subsets suggested high replicability of the results of such approach to sleep times collection (Supplementary Tables S3 and S4). For example, when we used the year of publication (before 2014 or later) for such an arbitrary subdivision of the whole set of samples into two halves, none of 12 analyzed sleep times significantly differed in two halves as indicated by non-significant main effects of factor "Subset" in two-way MANOVAs (Supplementary Table S3, left). The largest of these differences between these two halves was 7 min (weekend bedtime) and the smallest was one min (weekday risetime).

Figure 1 illustrates the simulated curves consisting of the points divided by the smallest intervals of 6 min length each. Therefore, we only way to show the pairs of subset-averaged sleep times (weekday and weekend bed- and risetimes) obtained from earlier and later publications was to assign any of them to the neighboring points divided by such a 6-min interval. Figure 1 also suggested that the fit between empirical sleep times and their model-based simulation remained excellent despite using the newly obtained results of averaging bed- and risetimes with doubled number of samples as compared to the number of previously simulated samples.

Relating sleep curtailment to later sleep phase and larger time-lag

Our proposed measure of sleep curtailment, actual sleep loss, was introduced here to account for a profound circadian modulation of sleep duration. Figure 1 illustrates that, due to such circadian modulation of the parameters of homeostatic sleep regulation, sleep duration was longer when sleep was initiated earlier in the evening to becoming shorter and shorter with sleep being initiated later and later. Because the simulation predicted that, in overall, the sleep-wake cycle remained to be entrained by the circadian clocks throughout the week, sleep, even when it was initiated at weekday bedtime (earlier), was expected to be spontaneously terminated at the same circadian clock time as sleep initiated at weekend bedtime (later). This mechanism of entrainment provided stability to the phase of sleep-wake cycle to allow it to remain in synch with the circadian clocks throughout the week despite the termination of sleep on weekdays prior to its expected spontaneous termination. Ideally, a long spontaneously terminated sleep might be observed only at one of 7 nights, between the last working/school day (Friday) and the first free day (Saturday) in the condition when bedtime and risetime are determined exclusively by internal sleep-wake regulating mechanism (e.g., when people do not delay voluntarily their bedtime in the Friday evening). Because sleep in the previous nights was terminated earlier (weekday wakeups), sleep curtailment equals to the difference between weekend and weekday wakeups, that is risetime-lag (Figure 1C), and when this lag is expressed as percentage to total time in bed predicted for Friday-Saturday night, that is the difference between weekday bedtime and weekend risetime, this estimate reveals the amount of actually lost sleep (Tables 1-4, S3-S20).

Figure 2 illustrates the strength of relationships between time-lags, sleep phase and such an actual sleep loss. In particular, the correlation analysis suggested that sleep shortening (reduction of time in bed on weekdays) was unrelated to bedtime-lag but, in contrast, it was very closely related to risetime-lag. This risetime-lag, in turn, demonstrated almost functional relationship with actual sleep loss in accord with the prediction of the model (Figure 2C). For example, when a risetime-lag was small, e.g., just one hour, this lag suggested a relatively small sleep curtailment, but, nevertheless, even such a 1-h risetime-lag corresponded to, at least, 10% weekday sleep loss. When risetime-lag was large, e.g., two hours, weekday sleep loss was doubled (i.e., as many as 20% of expected time in bed was lost on weekdays).

Moreover, significant but less strong relationship with sleep loss was shown by such sleep phase measure as risetime on weekends, RT_{we} (Figure 2F). When, on average, wakeup occurred at 9 a.m., the same 20% of expected time in bed was lost, and when risetime was set at 10:30, this resulted in almost 30% sleep loss. In overall, the estimates of actual sleep loss suggested dramatic increasing in sleep loss with delaying sleep phase on free days and, consequently, with increasing time-lag (social jetlag).

Table 3 summaries the differences between pairs of subsets representing earlier and later sleep phase as indicated by Type, RT_{we} and MT_{sc} and smaller and larger social jetlag as estimated with such measures as RTL, MTL and BTL. Additionally, Figure 3 and Supplementary Figures 1-4 illustrate the relationships of such division with age. The results fully confirmed the results of correlation analysis indicating 1) a profound loss of sleep even in people of M-type characterized by advanced weekend sleep timing and small social jetlag and 2) a dramatic increase in sleep loss in people of E-type with delayed sleep timing on weekend and large social jetlag. Depending upon measure, the difference between subsets in actual sleep loss varied from 6% to 11% ($p<0.001$ for any of 6 comparisons).

For example, M-type was associated with losing, on average, 16% of time in bed whereas E-type was associated with loosing 10% more time (Tables 1 and 3). This implies that more than a quarter, 26%, of sleep was lost by people of late types (Tables 1). The loss was even higher for some of ages, for instance, approximately a third of total sleep duration in late adolescence (Figure 3).

Time in bed in relation to later sleep phase and larger time-lag

However, a different and, to our mind, much less realistic picture was painted when sleep curtailment was measured in the traditional way, as the difference in time in bed between subsets with different Type, RT_{we}, MT_{sc}, RTL, MTL and BTL (Table 3 and Figures 3, S1-S4). The difference between subsets was mostly non-significant. When it was, sometimes, significant, it indicated a shorter sleep in subsets representing early chronotype (or weekend sleep times) and smaller time-lag, e.g., in the case of early RT_{we} and smaller BTL (Tables 1, 3 and S5, and Figures 3 and S2).

Even more, weekday time in bed was also found to be significantly shorter in the subset with smaller BTL despite earlier sleep phase (Table 3). Figures 3 and S1-S4 illustrate statistically significant interaction of weekday time in bed with age. This interaction suggested that, when the difference between subsets was non-significant, it can be explained by a linear relationship between age and weekday time in bed. Interaction term in the results of MANOVAs gave $F_{7/304} = 5.4$, $p < 0.001$, $F_{7/304} = 3.4$, $p < 0.001$, $F_{7/304} = 2.9$, $p < 0.01$, $F_{7/304} = 2.9$, $p < 0.01$ and $F_{7/304} = 4.3$, $p < 0.001$ for interaction of RT_{wd} with RT_{we}, MT_{sc}, RTL, MTL and BTL, respectively (e.g., Figures 3, S2 and S4), and interaction term in the results of rANOVA yielded $F_{7/19} = 3.2$, $p = 0.02$ for interaction of RT_{wd} with Type. For instance, Figure S1 shows that weekday time in bed in M-types (with later weekend sleep times and larger social jetlag) was longer only in younger ages to become shorter in older ages.

Thus, these results suggested that, compared to people with earlier sleep phase and smaller time-lag, people with later sleep phase and larger time-lag did not spend in bed, in overall, less time than the opposing types, even on weekdays (Tables 3). As for weekly average time in bed (Tables 3 and 4), they tended to stay in bed even longer, namely, longer on 13, 10 and 20 min as indicated by the estimates of RT_{we}, MTL and BTL, respectively ($p < 0.001$ for all).

Time in bed and actual sleep loss in relation to early wakeups

The estimates of actual sleep loss and weekly average time in bed were in a better agreement in the results of comparison of two subsets with earlier and later RT_{wd}. They indicated that earlier weekday wakeups significantly increased sleep loss and significantly decreased time in bed (Tables 1, 3 and 4).

However, such an increase in sleep loss due to earlier rather than later weekday wakeups was found to be relatively small (2%) in comparison with the described above sleep losses caused by early weekday wakeups per se that reached 15%-16% in samples with earlier sleep phase and 23%-24% in samples with later sleep phase (Type, RT_{we} and MT_{sc}). Similarly, in samples with smaller and larger time-lag such a sleep loss reached 14%-17% and 23%-25%, respectively (RTL, MTL and BTL). Moreover, an increase in sleep loss due to earlier rather than later weekday wakeups was rather small when compared to the difference between the subsets of these samples obtained by the division in accord with their earlier-later sleep phase and smaller-larger time-lag (6%-10% and 6%-11%, respectively).

In contrast, weekly average time in bed demonstrated a relatively large significant reduction (23 min or 5%) compared to the described above difference between either earlier and later sleep phase or between smaller and larger time-lag. They were mostly non-significant and, when significant, suggested the opposite direction compared to the direction of reduction of weekly average time in bed with up to 13 min shorter time in bed in samples with earlier phase and up to 20 min smaller time-lag in samples with smaller time-lag (Tables 3 and 4).

None of three-way MANOVAs revealed significant interaction between two factors “Subset” when further division of two subsets of RT_{wd} (before and after 7 a.m.) into two smaller subsets was performed to differential samples on sleep phase and time-lag, (RT_{wd} vs. RT_{we}, MT_{sc} and vs. RTL, MTL, BTL, respectively). Figure 4 illustrates these results indicating that earlier wakeups produced identical effects on samples characterized by either earlier and later sleep phase or by smaller and large time-lag (Tables S4, S7-S11, S16 and S17). Such results, in particular, suggested that none of two chronotypes benefited more from later wakeups and any chronotype suffered from sleep curtailment caused by shifting wakeups on an earlier clock hour. The results were similar when the difference between types was measured either as actual sleep loss or as reduction of weekly average time in bed (Tables S4, S10, S11 and S17).

Time in bed and actual sleep loss in “natural experiments”

Sleep times in samples of school age students provided possibility to compare the effects of earlier wakeups, either by comparing with sleep times of later ages when weekday risetimes significantly delayed (Lund et al., 2010; Urner et al., 2009) or by comparing with holidays (Warner et al., 2008) and delayed school start times (Arrona-Palacios & Díaz-Morales, 2018; Arrona-Palacios et al., 2015; Boergers et al., 2014; Brandalize et al., 2011; Carissimi et al., 2016; Lima et al. (2002); Peixoto et al., 2009; Perkinson-Gloor et al., 2013). In overall, they confirmed the results of comparison of the impact of early and late RT_{wd} on actual sleep loss and weekly average time in bed (Table 4). However, the attending school in early hours was associated with larger and significant sleep loss whereas the reduction of time in bed was much smaller (Table 4, S6, right, S12, S14, S15, S17, right, S18 and S20). Moreover, it was not noted in any of pairs of samples/subsets and, most importantly, it was always found to be non-significant (Table 4, S6, right, S14, S17, right, S18 and S20).

Thus, the results of these "natural experiments" revealed significant actual loss of sleep but did not provide evidence for significant decrease in weekly average time in bed in students of school age as compared to the students of older age and students of the same age attending school in later hours.

Six studies provided possibility of comparison of seasonally of sleep times under observing DST and ST (Friborg et al., 2012; Johnsen et al., 2013; Lo et al., 2014; Lowden et al., 2019; Miller et al., 2010; Shochat et al., 2019). In overall, this dataset does not support the expectation of a significant sleep loss and a significant reduction of weekly average time in bed due to the observing DST (Tables S13, S14, S19 and S20). It only allows the conclusion that the effects of DST seemed to be weaker than the effects of early school start times (Table 4).

The only "natural experiment" allowing the direct comparison of samples collected during perennial DST and perennial ST was provided in a study of school students in northern regions of Russia (Borisenkov et al., 2016). Our estimates suggested that weekly average time in bed was non-significantly reduced under DST (only by 1%). Actual sleep loss was larger, 5%, but not as large as the permanent sleep curtailment caused, presumably, by early school times, either 36% and 31% during perennial DST and perennial ST, respectively (Tables 4, S15, S19 and S20).

Discussion

We tested here the hypotheses that, throughout a 7-day week consisting of 5 working/school days and two free days, E-types (with later sleep timing on free days and larger social jetlag) 1) sleep less than M-types (with earlier sleep timing on free days and smaller social jetlag) and 2) are expected to additionally lose more sleep in response to earlier weekday wakeups, in particular, when observing perennial DST. The answers mostly disagreed one with another when provided by applying the traditional and presented here approaches to estimation of sleep curtailment (by calculating the difference in weekly average time in bed and as the difference between weekend and weekday risetimes divided on the difference between weekend risetime and weekday bedtime).

First, no evidence for significant positive association of the amount of sleep loss with E-type, late sleep timing on free days and larger social jetlag was provided by the results of applying the traditional approach to measurement of sleep curtailment. Instead, a significant positive association with M-type and larger social jetlag was shown for some of six sleep phase and time-lag measures. Do these results of answering to the question of whether E-types sleep less than M-types allow the conclusion that any concerns about vulnerability of E-type (or late sleep timing or large social jetlag) to sleep curtailment and health problems would be ill-advised? The answer seems to be no after applying the proposed here approach to quantification of actual sleep losses. These estimates suggested that, irrespective of whether we are M- or E-types, our usual work/school schedules might be harming our sleep and health. Besides, E-types seem to be more than M-types vulnerable to such effects. They have a higher percentage of lost sleep due to a larger weekend-weekday difference in sleep times. For example, empirical results supported the model prediction that actual sleep loss doubles, from 10% to 20%, due to an increase of the weekend-weekday risetime difference (risetime-lag) from one to two hours (Figure 2C).

Second, the answer to the question of whether M-types compared to E-types expected to lose fewer minutes of sleep when responding to earlier weekday wakeups appeared to be less dependent upon the applied approach to measurement of sleep curtailment. However, this answer was no when it was provided by implication of any approach. The results of our analysis suggested that such responses were fully identical in samples of either M- or E-chronotypes, with either earlier or later weekend sleep times, and with either smaller or larger time-lag. Therefore, neither chronotype nor sleep timing on free days nor social jetlag would influence the amount of sleep lost due to a shift from later to earlier wakeups, in particular, when ST would be ended for establishing year round DST.

The comparison of two conditions of "natural experiments" provided further evidence for the difference between two approaches to calculation of sleep curtailment. Some of these results based on traditional approach were again found to be rather paradoxical.

For instance, at school age a time-lag was found to be very large due to early school start times but it became significantly smaller either after shifting school start time on later hours or after leaving school in a later age. Despite this, evidence for significant sleep curtailment was not provided by comparing weekly average time in bed reported by students of school age with weekly average time in bed reported by university/college students or by comparing time in bed before and after a shift of school start time on later hours. Similar results were provided by the comparison of samples from two neighboring ages, 16+ and 18+. Such lack of evidence for sleep curtailment contradicted to the general concern about the epidemic of sleep deprivation among adolescents (i.e., when schedules maintained during the school year are resulted in insufficient and ill-timed sleep). For instance, this epidemic was recognized in many postindustrial societies with different cultural traditions (see Carskadon, 2011; Gradisar et al., 2011; Hagenauer et al., 2009). However, when actual sleep loss was estimated in accord with the proposed here approach, the general results of such "natural experiments" pointed at an extremely large sleep curtailment. It is important to emphasize that only the model-based simulation allowed the introduction of this estimate capable to uncover the dramatic permanent sleep curtailment caused by early school times (e.g., it might exceed one third of the total weekday night sleep duration expected in the case of its spontaneous rather than forced termination).

Results on the estimates obtained in "natural experiments" under seasonal switching between DST and ST did not yield a significant curtailment of sleep. Such results were obtained irrespective of the method of calculation of sleep curtailment and it was not a surprise. Such studies cannot separate two opposing effects observed under DST. The first is an increase in actual sleep loss due to earlier wakeups in summer and the second is a seasonal reduction of sleep duration in this season. Such reduction was, for instance, demonstrated in a current study of population in Japan that does not observe DST (Hashizaki et al., 2018). It is important to note that, even when researchers are sampling sleep times under exactly the same photoperiods (e.g. only in certain days of spring and fall), these sleep times remains to be incomparable due to the difference in aftereffects of exposure to short and long photoperiods in the previous winter and summer months, respectively.

Only two samples that were collected in northern regions of Russia allowed the direct comparison of perennial DST with the following perennial ST. The comparison did not reveal an essential reduction of weekly average time in bed. Although it yielded 5% sleep loss, such a loss was relatively small compared to loss caused by early school start times in both conditions. In general, the changes in social clocks in Russia during the last 10 years can be considered a "natural experiment". However, its results seem to be also inconclusive. Perennial DST was introduced by a Russian president (Medvedev) in March 2011 to be observed until October 2014 when another president from this tandem (Putin) introduced perennial ST. Therefore, if someone would suggest that there was any misunderstanding around the terms "winter time' and "summer time" in Russian population, there was enough time to feel the difference, both before and after

October 2014. Meanwhile, as soon as in summer 2015, several regional parliaments adopted the lows suggesting the return of their regions back to perennial DST (i.e., by adding one to the current number of their time zones). In the last four years (2015-2018), 11 regional parliaments, including the parliament of Novosibirsk region, voted for such a return, and it seems that this process will be continued in the nearest future. Paradoxically, currently in Moscow and Novosibirsk that are the 1st and 3rd largest cities of Russia located at similar latitudes (55.7°N and 55.0°N), sunrise and sunset on March 15 occur at 6:45 and18:31 and at 7:44 and 19:30, respectively.

Let us imagine that the difference in weekly average time in bed was accurately estimated during winter months with ST and during summer months with DST by those millions of respondents from an EU public international consultation who voted for year-round "winter time" (European Commission, 2018). In overall, the result of such estimates would be misguided. They would fail to reveal 1) any consistent difference between DST and ST due to seasonal shortening of sleep duration in summer, 2) a large amount of sleep lost due to usual work/school schedules during both DST and ST, and 3) a large difference between M- and E-types in this permanent sleep loss. Further, the comparisons that traditionally relies on calculation of weekly average time in bed would lead them to the conclusion that sleep lost by E-types with later weekend risetimes and larger bedtime-lag during the week is larger than that lost by M-types with earlier weekend risetimes and smaller bedtime-lag. Finally, let us imagine that they carefully read the paper of Borisenkov et al., (2016) with the only published results of direct comparison of sleep times under year round DST and year round ST. They can see in this paper's table that the estimates of weekly average sleep duration were identical for samples collected under perennial DST and perennial ST.

If someone would ask a lay person about his/her personal experience, he/she would confirm that runs short of sleep during the week due to extended wakefulness after the scheduled early wakeups. When Saturday comes, that person feels he/she needs for extra hours of sleep at

Friday-Saturday and Saturday-Sunday nights to get back to optimal condition and, doing so, he/she successfully catches up on lost sleep throughout just two weekend nights to be able, finally, to go back to feeling normal. However, conventional wisdom would not always be right, even when supported by the accurate estimations of weekly average sleep duration and careful reading scientific reports. Our simulation (Figure 1) suggested that people do not sleep the extra time they lost during workdays. Instead, their sleep is mostly of normal and optimal duration during two weekend nights whereas their sleep curtailment during workday is even larger than that provided by calculating the difference between weekend and weekday sleep durations. Therefore, we proposed the estimates of sleep loss that accounted for predictions of a sleep-wake regulatory model and allowed the uncovering a profound negative influence of our usual work/school schedules on weekday sleep duration and, hence, on health.

There are several limitations of the applied method of estimation of sleep curtailment. Only a small fraction of the samples was collected from actigraphic studies of sleep times. We previously showed that one of four sleep times, namely weekend risetime, might be overestimated for some of the samples (Putilov, Verevkin, 2018; Putilov et al., 2019). Moreover, we modified the previously proposed measures of sleep phase and social jet lag by direct utilization of bed- and risetimes rather than sleep onsets and offsets for their calculation. The major reasons for this modification of the previously proposed estimates were the following. First, the authors of most of publications did not report sleep latencies. Second, since the authors of the vast majority of publications collected sleep times from either questionnaire self-reports or sleep diaries, it is hard to imagine that way by which these sleep latencies were self-measured by study participants. Third, in order to calculate most of the estimates, it was necessary to subtract one latency from another, at least, twice. For example, one latency was subtracted from another to obtain a weekend-weekday difference for each sample and then one of the obtained differences in sleep latency was subtracted from another difference in sleep latency to calculate a difference in this difference between two subsets of samples. Therefore, it is unlikely that our estimates might be significantly challenged even in the case of the existence of small (i.e., few minutes) difference between self-reported sleep latencies.

In conclusion, we proposed here a model-based approach for calculation of sleep curtailment caused by earlier weekday wakeups (e.g., due to observing perennial DST). Unlike the difference in time in bed, the suggested measure allows the estimation of actual sleep loss without comparison of samples in two conditions. Our estimates relying on this new methodology suggested that 1) neither chronotype nor weekend sleep times nor social jetlag can influence the change in sleep duration after an advancing shift of weekday wakeups, 2) E-type with later weekend sleep times and larger social jetlag is associated with a very large sleep loss, and 3) our usual work/school schedules are the causes of an essential sleep loss even in M-types with early weekend sleep times and small social jetlag. Compared to this loss, an additional loss due to switching from ST to perennial DST are expected to be relatively small. The traditional way of calculation of sleep loss leads to rather paradoxical conclusions, e.g., 1) that sleep loss is larger when social jetlag is smaller, not larger, 2) that sleep loss is larger when weekend sleep times are earlier, not later, 3) that sleep in school students attending school in early hours is not shorter than sleep in school students attending school in later hours or in college/university students practicing a 1-h later wakeups, etc.

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Tables

Table 1. Samples sorted into two subsets: weekend and weekday risetimes.

Subdivision		Weekend Risetime (RT_{we})					Weekday Risetime (RT_{wd})				
Two subsets		<9:00		>9:00		p for	<7:00		>7:00		p for
Sleep time		Mean	SEM	Mean	SEM	$F_{1/304}$	Mean	SEM	Mean	SEM	$F_{1/304}$
Bed-time	Weekday	22.71	0.07	23.04	0.06	<0.001	22.63	0.05	23.06	0.06	<0.001
	Weekend	23.43	0.06	24.31	0.06	<0.001	23.67	0.06	24.06	0.06	<0.001
	Time-lag	0.72	0.05	1.27	0.05	<0.001	1.03	0.04	0.99	0.05	0.562
Rise-time	Weekday	6.81	0.05	7.18	0.05	<0.001	6.56	0.02	7.42	0.03	<0.001
	Weekend	8.24	0.06	9.71	0.05	<0.001	8.65	0.06	9.31	0.07	<0.001
	Time-lag	1.43	0.06	2.53	0.05	<0.001	2.09	0.06	1.89	0.07	0.031
Time in Bed	Weekday	8.10	0.07	8.15	0.06	0.576	7.92	0.05	8.35	0.06	<0.001
	Weekend	8.80	0.06	9.41	0.05	<0.001	8.98	0.04	9.25	0.05	<0.001
	Shortening	0.71	0.06	1.26	0.05	<0.001	1.06	0.05	0.90	0.05	0.038
	Average	8.30	0.06	8.51	0.05	0.010	8.22	0.04	8.61	0.05	<0.001
	Sleep loss	15.05	0.50	23.57	0.45	<0.001	20.58	0.51	18.24	0.59	0.003
MT_{sc}		3.58	0.05	4.56	0.05	<0.001	3.78	0.05	4.36	0.05	<0.001

Notes. Bedtime and Risetime: Times to go to bed and to wake up, respectively, clock hours (decimals). Time-lag (TL): Weekend-weekday difference for Rise- and Bedtimes, hours (Figure 1A); Time in Bed: Difference between clock hours for Risetime and Bedtime, hours; Shortening: Reduction of Time in Bed calculated as the weekend-weekday difference in Time in Bed equaled to the difference between Rise- and Bedtime-lags, hours (Figure 1B); Average: Weekly Average Time in Bed calculated as 1/7th of the sum of Time in Bed for 5 weekdays and two weekends, hours; Sleep loss: Actual Sleep loss calculated by dividing Risetime-lag on difference between Weekend Risetime and Weekday Bedtime (Figure 1C), in %; SEM: Standard Error of Mean; Weekend and Weekday Risetime (RT_{wd} and RT_{wd}): Subdivisions of the whole set of 320 samples into a pair of subsets (either 155 or 176 samples with RT_{wd} or RT_{wd} earlier than either 9:00 or earlier than 7:00, respectively); p for $F_{1/304}$: p-value for main effect of factor "Subset" from two-way MANOVAs, the samples were subdivided into 8 ages (another factor "Age", see also sample sizes in Table S1 and Figures 3, S2-S4).

Table 2. Samples of distinct chronotypes and samples sorted in two subsets: sleep phase.

Subdivision		Type					Sleep Corrected Midway Time (MT_{sc})				
Two subsets		M-type		E-type		p for	<4:00		>4:00		p for
Sleep time		Mean	SEM	Mean	SEM	$F_{1/19}$	Mean	SEM	Mean	SEM	$F_{1/304}$
Bed-time	Weekday	22.33	0.11	23.34	0.15	<0.001	22.60	0.08	23.15	0.08	<0.001
	Weekend	23.28	0.19	24.97	0.14	<0.001	23.18	0.07	24.38	0.07	<0.001
	Time-lag	0.94	0.13	1.62	0.13	<0.001	0.57	0.06	1.22	0.05	<0.001
Rise-time	Weekday	6.62	0.13	7.42	0.20	0.002	6.67	0.06	7.19	0.05	<0.001
	Weekend	8.25	0.22	10.31	0.20	<0.001	8.27	0.08	9.61	0.08	<0.001
	Time-lag	1.62	0.11	2.89	0.19	<0.001	1.59	0.08	2.41	0.08	<0.001
Time in Bed	Weekday	8.28	0.14	8.07	0.15	0.050	8.06	0.08	8.03	0.08	0.803
	Weekend	8.97	0.16	9.34	0.11	0.016	9.08	0.07	9.22	0.07	0.210
	Shortening	0.68	0.13	1.26	0.16	0.002	1.02	0.07	1.18	0.07	0.122
	Average	8.48	0.13	8.43	0.12	0.586	8.36	0.07	8.37	0.07	0.866
	Sleep loss	16.15	1.08	25.85	1.60	<0.001	16.35	0.74	22.73	0.70	<0.001
MT_{sc}		3.52	0.19	5.19	0.17	<0.001	3.36	0.06	4.57	0.06	<0.001

Notes. Type: 27 pairs of samples were selected as representatives of distinct chronotypes (M[orning]- and E[vening]-types); MT (Midway Time): Midpoint of time in bed calculated by adding a half of Time in Bed to Bedtime, clock hours; MT_{sc} (Sleep Corrected Weekend MT): Weekend Bedtime plus a half of Average, clock hours; p for $F_{1/19}$: p-value from two-way rANOVAs for main effect of "Chronotype" (27 paired samples of M- and E-types), the samples were distributed into 8 ages (another factor "Age", see sample sizes in Table S1); p for $F_{1/304}$: p-value obtained in two-way MANOVAs for main effect of factor "Subset" (165 samples from the whole set of 320 samples with MT_{sc} >4:00), the samples were distributed into 8 age groups (another factor "Age"). See also notes to Table 1 and Figures 3, S3 and S4.

Table 3. Summary on comparisons of samples sorted into two subsets.

Sleep time	Subdivision Subset	Year <2014	Type M-type	RT_{we} <9:00	MT_{sc} <4:00	RTL <2h	MTL <1.5h	BTL <1h	RT_{wd} <7:00
Bed-time	Weekday	$5\downarrow^{\approx}$	$1\downarrow^{***}$	$4\downarrow^{***}$	$2\downarrow^{***}$	$6\downarrow^{\approx}$	$7=^{\approx}$	$8\uparrow^{*}$	$3\downarrow^{***}$
	Weekend	$8\downarrow^{\approx}$	$2\downarrow^{***}$	$3\downarrow^{***}$	$1\downarrow^{***}$	$6\downarrow^{***}$	$4\downarrow^{***}$	$5\downarrow^{***}$	$7\downarrow^{***}$
	Time-lag	$7\downarrow^{\approx}$	$6\downarrow^{***}$	$4\downarrow^{***}$	$3\downarrow^{***}$	$5\downarrow^{***}$	$2\downarrow^{***}$	$1\downarrow^{***}$	$8\uparrow^{\approx}$
	in minutes	-3	-41	-33	-39	-35	-51	-56	2
Rise-time	Weekday	$5\uparrow^{\approx}$	$2\downarrow^{**}$	$4\downarrow^{***}$	$3\downarrow^{***}$	$7\uparrow^{*}$	$6\downarrow^{\approx}$	$4\downarrow^{\approx}$	$1\downarrow^{***}$
	Weekend	$8\downarrow^{\approx}$	$2\downarrow^{***}$	$1\downarrow^{***}$	$3\downarrow^{***}$	$5\downarrow^{***}$	$4\downarrow^{***}$	$6\downarrow^{***}$	$7\downarrow^{***}$
	in minutes	-4	-124	-88	-80	-73	-77	-62	-40
	Time-lag	$7\downarrow^{\approx}$	$6\downarrow^{***}$	$3\downarrow^{***}$	$5\downarrow^{***}$	$1\downarrow^{***}$	$2\downarrow^{***}$	$4\downarrow^{***}$	$8\uparrow^{*}$
	in minutes	-5	-76	-66	-49	-82	-73	-55	12
Time in Bed	Weekday	$6\uparrow^{\approx}$	$8\uparrow^{+}$	$5\uparrow^{\approx}$	$3\uparrow^{\approx}$	$7\uparrow^{*}$	$4\downarrow^{\approx}$	$2\downarrow^{***}$	$1\downarrow^{***}$
	in minutes	5	13	-3	2	13	-4	-21	-26
	Weekend	$8\uparrow^{\approx}$	$4\downarrow^{***}$	$2\downarrow^{***}$	$7\downarrow^{\approx}$	$1\downarrow^{***}$	$3\downarrow^{***}$	$6\downarrow^{***}$	$5\downarrow^{***}$
	in minutes	3	-22	-37	-8	-35	-26	-19	-16
	Shortening	$5\downarrow^{\approx}$	$2\downarrow^{***}$	$3\downarrow^{***}$	$6\downarrow^{\approx}$	$1\downarrow^{***}$	$4\downarrow^{***}$	$7\uparrow^{\approx}$	$8\uparrow^{*}$
	in minutes	-2	-35	-33	-10	-47	-22	1	10
	Average	$7\uparrow^{\approx}$	$8\uparrow^{\approx}$	$3\downarrow^{*}$	$5\downarrow^{\approx}$	$6\downarrow^{\approx}$	$4\downarrow$+	$2\downarrow^{***}$	$1\downarrow^{***}$
	in minutes	4	3	-13	-1	-1	-10	-20	-23
	% to mean	1%	1%	-2%	0%	0%	-2%	-4%	-5%
	Sleep loss	$6\downarrow^{\approx}$	$4\downarrow^{***}$	$3\downarrow^{***}$	$5\downarrow^{***}$	$1\downarrow^{***}$	$2\downarrow^{***}$	$7\downarrow^{***}$	$8\uparrow^{**}$
	in %	-1%	-10%	-9%	-6%	-11%	-9%	-6%	2%
MT_{sc}		$8\downarrow^{\approx}$	$2\downarrow^{***}$	$3\downarrow^{***}$	$1\downarrow^{***}$	$6\downarrow^{***}$	$4\downarrow^{***}$	$5\downarrow^{***}$	$7\downarrow^{***}$

Notes. Subdivision: The way of subdividing a set of samples into two subsets; Year: Year (of publication), one of the arbitrary divisions into two subsets (see Table S3, left); Subset: One of two Subsets with earlier weekend sleep timing (see Tables 1, 2, S5 and S6); ↑ or ↓ or =: Value in this Subset was either higher or lower or the same as in another subset with later weekend sleep timing; in minutes: This difference between subsets was additionally shown in minutes, (-) indicates earlier Risetime on Weekends, smaller sleep curtailment due to a smaller Bed- and Risetime-lags and Shortening, and shorter sleep due to shorter Weekday, Weekend and Average Time in Bed; % to mean: The same difference expressed in percentage to mean Average for two subsets; in %: The difference in actual Sleep loss measured in percentage, (-) indicates smaller loss; statistical analyses (Tables 1, 2, S3, S5 and S6) yielded main effect of factor "Subset" with levels of significance $^{\approx}$(p > 0.1), $^{+}$(p < 0.1 or p = 0.05), *(p < 0.05 or p = 0.01), **(p < 0.01), and ***(p <0.001); a value in Subset was also ranked relative to values obtained by 7 other divisions, from the smallest (1) to the largest (8). See also notes to Tables 1, S3, and Figures 3 and S2-S4.

Table 4. Summary on comparisons of weekly average time in bed and actual sleep loss.

Sleep time	Subdivision One subset	Type M-type	RT_{we} <9:00	MT_{sc} <4:00	RTL <2h	MTL <1.5h	BTL <1h
Average	in minutes	3	-13	-1	-1	-10	-20
	% to mean	1%$^{\approx}$	-2%*	0%$^{\approx}$	0%$^{\approx}$	-2%+	-4%***
Sleep loss	in %	-10%***	-9%***	-6%***	-11%***	-9%***	-6%***
	One subset	RTwd <7:00		RTwd <7:00		RTwd <7:00	
	Further subdivision	RTL		MTL		BTL	
	Two subsets	<2h	>2h	<1.5h	>1.5h	<1h	>1h
Average	in minutes	-23	-25	-27	-23	-26	-26
	% to mean	-5%***	-5%***	-5%***	-5%***	-5%***	-5%***
Sleep loss	in %	2%**	3%**	2%*	1%*	4%***	2%***
	One subset	RTwd <7:00		RTwd <7:00		RT_{wd}	Age
	Further subdivision	RT_{we}		MT_{sc}		<7:00	16+ 18+
	Two subsets	<9:00$^{\wedge}$	>9:00$^{\wedge}$	<4:00$^{\wedge}$	>4:00$^{\wedge}$	One subset	16+
Average	in minutes	-31	-34	-20	-37	-23	3
	% to mean	-6%***	-7%***	-4%**	-8%**	-5%***	1%$^{\approx}$
Sleep loss	in %	9%***	7%***	7%**	5%**	2%**	8%***
	"Natural experiment"	DST vs. ST		School start times		In vs. after school in	
	Another sample(s)	Seasonal	Perennial	Later	Holydays	University	College
	Sample(s)	DST	DST	Early	Early	School	School
Average	in minutes	-10	-4	-31	-64	-9	1
	% to mean	-2%$^{+}$	-1%	-6%$^{\approx}$	-12%	-2%	0%
Sleep loss	in %	0%$^{\approx}$	5%	14%***	17%	5%	10%

Notes. Subdivision: Division of samples into two subsets; One subset: One of two subsets with earlier sleep timing (Tables 1, 2, S5 and S6); in minutes and % to mean: The difference between subsets in Average measured either in minutes or as percentage to mean Average for two subsets; in %: The difference in actual Sleep loss measured in percentage, (-) indicates shorter Average and smaller Sleep loss in One subset; Two subsets: Further subdivision into Two smaller subsets with RT_{wd}<7:00 and >7:00; $^{\wedge}$: For RT_{we} and MT_{sc}, only three of 8 ages were analyzed (see Table S2); Age (16+ 18+): Two of 8 ages, 16.5-18.0 years and 18.5-23.0 years (Tables S6, right, S17 and S20); DST vs. ST: Seasonal and Perennial DST vs. ST (Tables S13-S15, S19 and S20); School start times: Early vs. Later or vs. Holidays (Tables S11, S14, S15, S18 and S20); In vs. after school: Early wakeups when at School age compared to later wakeups in University/College age (Table S15 and S20); statistical analyses (Tables 1, 2, S4-S10 and S14) yielded main effect of factor "Subset" with levels of significance $^{\approx}$($p > 0.1$), $^{+}$($p < 0.1$ or $p = 0.05$), *($p < 0.05$ or $p = 0.01$), **($p < 0.01$), and ***($p < 0.001$). See also notes to Tables 1 and 3.

Figure Legends

Figure 1. Weekend-weekday difference in sleep timing and duration.

A. To illustrate the way of calculation of Bed- & Risetime-lags, Bed- and Risetimes for two halves of the whole dataset of 320 samples from earlier and later publications (see Table S3, left) are shown along with the time courses of relative value of slow-wave activity (SWA). Previously, these time courses were obtained by simulating three sleep-wake cycles of the week (Saturday-Sunday, Wednesday-Thursday, and Friday-Saturday) with a model postulating circadian modulation of SWA (Bed- & Risetimes obtained by averaging over app. a half of the samples were used as a input; see Putilov, Verevkin, 2018; Putilov et al., 2019, and Supplementary 3). The simulation also suggested that Weekend Risetime predicted the phase of sleep-wake cycle at which sleep was spontaneously terminated irrespective of the days of the week. B. To illustrate that Sleep shortening (weekend-weekday change in Time in Bed) equaled to the difference between Rise- and Bedtime-lags, the time course for Wednesday-Thursday and Weekday Bed- and Risetimes were shifted on the interval of Bedtime-lag. C. To illustrate that actual Sleep loss due to earlier weekday wakeups equaled to Risetime-lag, the time course for Wednesday-Thursday and Weekday Bed- and Risetimes were further shifted on the interval of Risetime-lag, i.e., Risetime-lag equaled to sleep duration on Friday-Saturday night minus sleep duration on Wednesday-Thursday; this means that the parameters of the homeostatic process are modulated by the circadian clocks in such a way that sleep duration increases with advancing circadian phase at which sleep was spontaneously initiated (see also Figure 2C with empirical data suggesting a very strong correlation between Risetime-lag and Sleep loss). SWA_b and SWA_b: To illustrate the impact of circadian modulation of sleep homeostasis, the sine-form time courses of the upper and lower limits of normal variation in SWA are shown, i.e., spontaneous initiation of sleep and wake states was predicted to occur at the upper and lower thresholds of the sleep homeostatic process, respectively. Only further prolongation of wake state above the upper threshold would lead to accumulation of sleep debt, but the simulation did not reveal it.

Figure 2. Predictors of risetime lag, sleep shortening and sleep loss.

Lines illustrate linear relationships. A and B. Bed- and Risetime-lags (weekend-weekday difference in Bed- and Risetime, respectively) vs. Sleep shortening (weekend-weekday difference in Time in bed) equaled to the difference between Rise- and Bedtime-lags (A and B, respectively). C and D. Risetime-lags and Sleep shortening vs. Actual sleep loss (Risetime-lag expressed as percentage to the difference between Weekend Risetime and Weekday Bedtime, C and D, respectively). E and F. Risetime-lags and Actual sleep loss vs. Weekend Risetime (E and F, respectively).

Figure 3. Sleep loss and time in bed in two-subset divisions in accord with sleep phase.

A. Shortening: Sleep Shortening calculated as the weekend-weekday difference in Time in Bed equaled to the difference between Rise- and Bedtime-lags (Figure 1B). B. Sleep loss: Actual Sleep loss (Figure 1C) calculated by dividing Risetime-lag*100 on the difference between Weekend Risetime and Weekday Bedtime, in %. C. Weekly Average Time in Bed calculated as $1/7^{th}$ of the sum of times in bed for 5 weekdays and two weekends. D. Time in Bed on Weekdays and Weekends (left and right, respectively). Two subdivisions of the whole set of 320 samples into two subsets, either with different RT_{we} (weekend Risetime) or with different MT_{sc} (Sleep Corrected weekend Midway Time), and 27 paired samples representing two distinct chronotypes (M- and E-types). See also notes in Table 1, sizes of subsets in Table S1 and see mean (averaged over 8 ages) sleep times in Tables 1, left, and 2.

Figure 4. Sleep loss and time in bed in 4-subset divisions in accord with time-lag.

A-D. Sleep Shortening, Actual Sleep loss, Weekly Average Time in Bed, and Weekday and Weekend Time in Bed (the same variables as in Figure 3) in samples sorted into four subsets, with the first division in accord with weekday risetime (<7:00>) and the second division in accord with Time Lags (either 1h<BTL>1h or 1.5h<MTL>1.5h or 2h<RTL>2h). See also sizes of subsets in Table S2 and sleep times in Tables S7-S9.

Figures

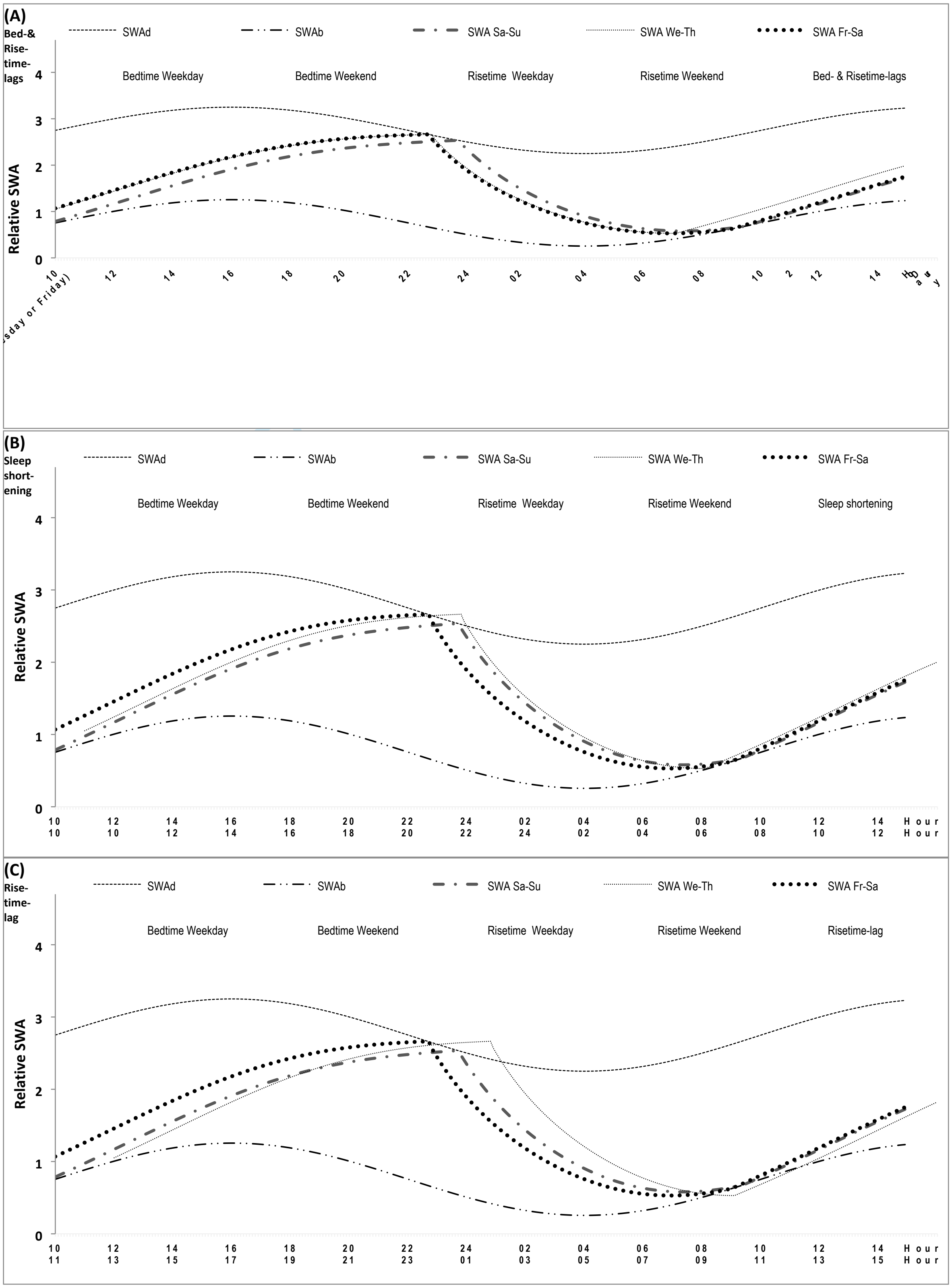

Figure 1

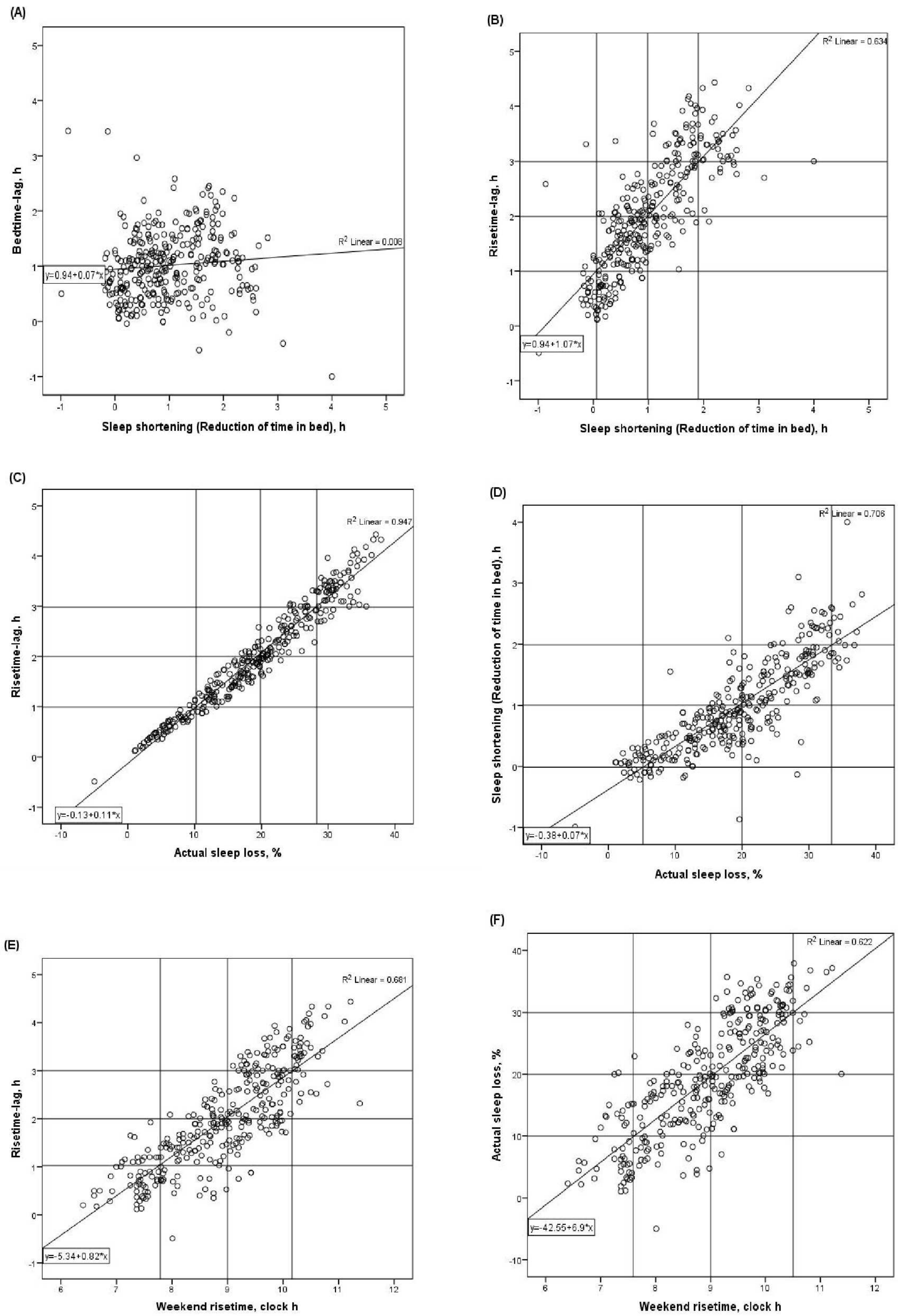
(A)
Bedtime-lag, h
Sleep shortening (Reduction of time in bed), h
R² Linear = 0.008
y=0.94+0.07*x
(B)
Risetime-lag, h
Sleep shortening (Reduction of time in bed), h
R² Linear = 0.634
y=0.94+1.07*x
(C)
Risetime-lag, h
Actual sleep loss, %
R² Linear = 0.947
y=-0.13+0.11*x
(D)
Sleep shortening (Reduction of time in bed), h
Actual sleep loss, %
R² Linear = 0.706
y=-0.38+0.07*x
(E)
Risetime-lag, h
Weekend risetime, clock h
R² Linear = 0.681
y=-5.34+0.82*x
(F)
Actual sleep loss, %
Weekend risetime, clock h
R² Linear = 0.622
y=-42.55+6.9*x

Figure 2

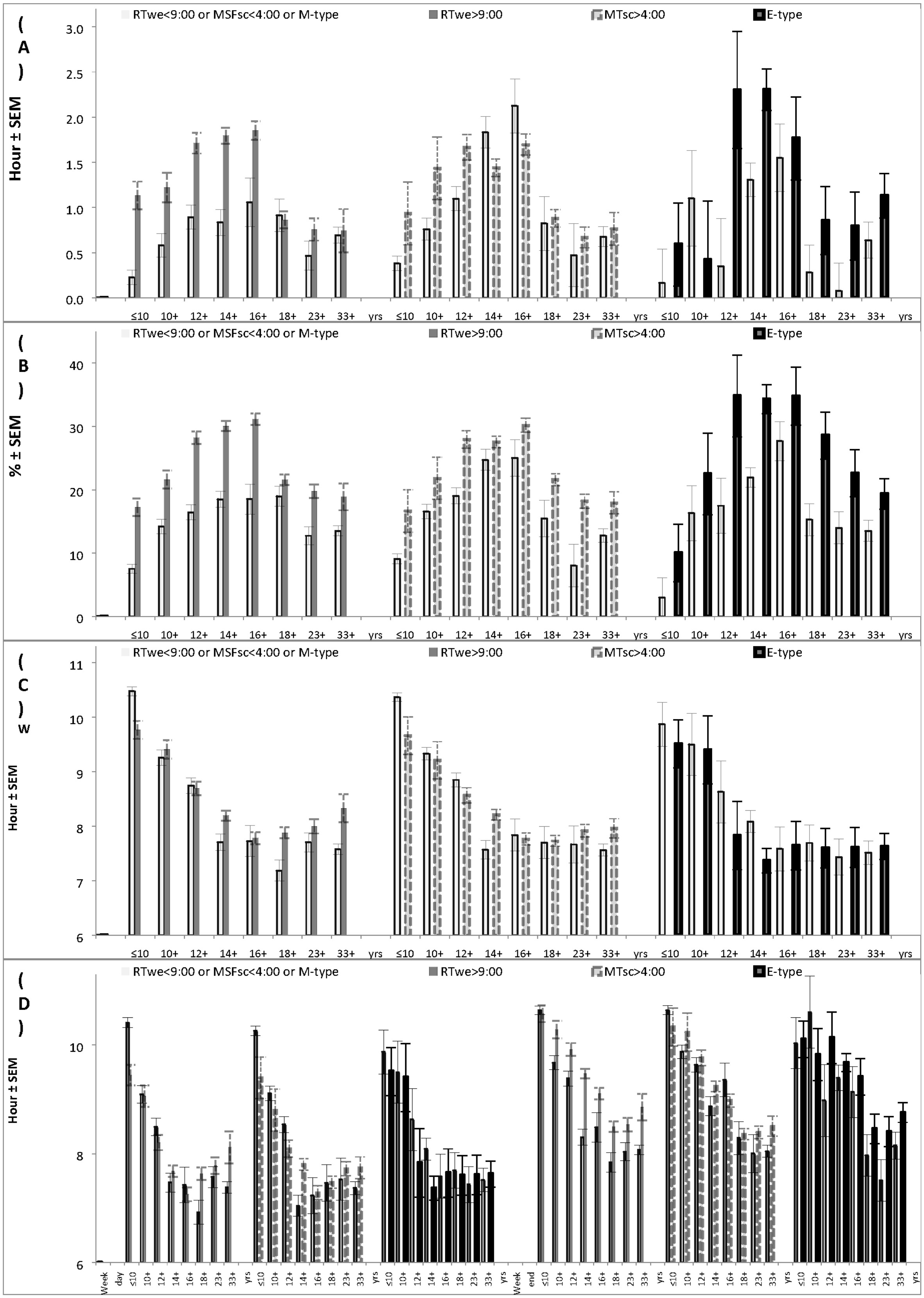
RTwe<9:00 or MSFsc<4:00 or M-type
RTwe>9:00
MTsc>4:00
E-type
(A)
Hour ± SEM
(B)
% ± SEM
(C)
Hour ± SEM
(D)
Hour ± SEM
≤10
10+
12+
14+
16+
18+
23+
33+
yrs
Week day
Week end

Figure 3

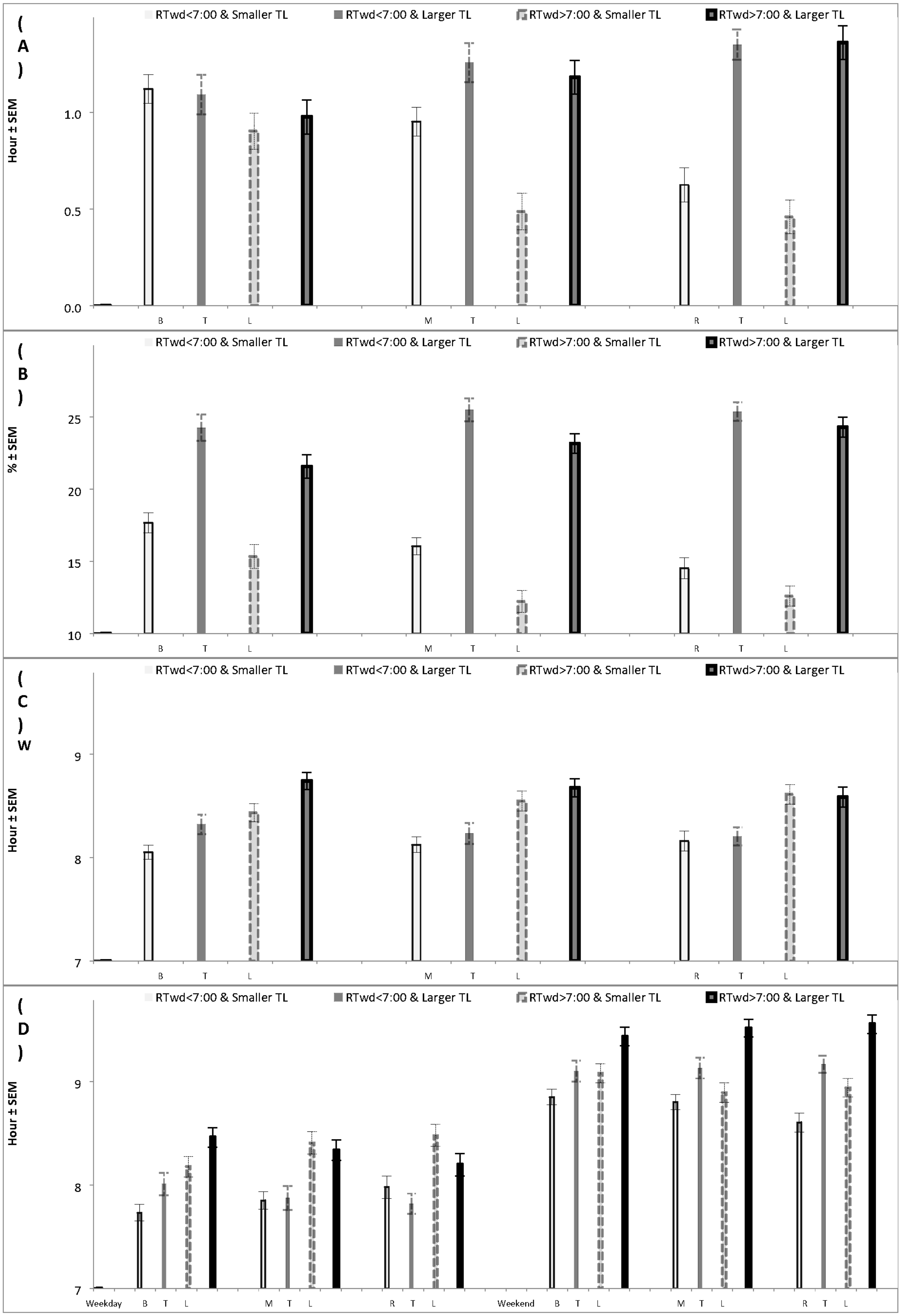
(A)
RTwd<7:00 & Smaller TL
RTwd<7:00 & Larger TL
RTwd>7:00 & Smaller TL
RTwd>7:00 & Larger TL
Hour ± SEM
1.0
0.5
0.0
B T L M T L R T L
(B)
% ± SEM
25
20
15
10
(C) W
Hour ± SEM
9
8
7
(D)
Hour ± SEM
Weekday
Weekend

Figure 4

Supplementary1_Tables and Figures

to

Evening chronotype, late weekend sleep times and social jetlag as possible causes of sleep curtailment after maintaining perennial DST: ain't they as black as they are painted?

Supplementary Tables

Table S1. Number of samples included in one of two subsets.

Subdivision One subset		RT_{we} >9:00		MT_{sc} >4:00		RTL >2h		MTL >1.5h		BTL >1h		RT_{wd} >7:00	
Age	Type	n	%	n	%	n	%	n	%	n	%	n	%
≤10	2	12	20.0	3	5.0	9	15.0	10	16.6	15	25.0	39	65.0
10+	1	11	39.2	3	10.7	12	42.8	15	53.5	17	60.7	8	28.5
12+	1	22	57.8	18	47.3	26	68.4	27	71.0	30	78.9	9	23.6
14+	8	37	72.5	39	76.4	40	78.4	39	76.4	34	66.6	14	27.4
16+	2	27	87.1	27	87.1	29	93.5	27	87.1	19	61.2	8	25.8
18+	3	32	78.0	37	90.2	22	53.6	23	56.1	29	70.7	30	73.1
23+	3	19	63.3	27	90.0	10	33.3	14	46.6	15	50.0	22	73.3
33+	7	5	12.2	11	26.8	4	9.7	3	7.3	3	7.3	14	34.1
Total	27	165	51.5	165	51.5	152	47.5	158	49.3	162	50.6	144	45.0

Notes. Age: 8 ages, 10+ refers to ages from 10.5 years to 12.0 years, etc. Total: Either 27 pairs of samples (Type) or the whole set of 320 samples in subdivisions into two subsets. One subset: One of two subsets. See sleep times for these subsets in Tables 1, 2, S5 and S6.

Table S2. Number of samples included in two quarters of subsets.

One subset		RT_{wd} <7:00				RT_{wd} <7:00				RT_{wd} <7:00			
Two subsets		RTL <2h		RTL >2h		MTL <1.5h		MTL >1.5h		BTL <1h		BTL >1h	
Age	Total n	n	%	n	%	n	%	n	%	n	%	n	%
≤10	60	18	35.3	3	33.3	18	36.0	3	30.0	17	37.8	4	26.7
10+	28	10	62.5	10	83.3	8	61.5	12	80.0	6	54.5	14	82.4
12+	38	7	58.3	22	84.6	7	63.6	22	81.5	6	75.0	23	76.7
14+	51	6	54.5	31	77.5	7	58.3	30	76.9	13	76.5	24	70.6
16+	31	1	50.0	22	75.9	3	75.0	20	74.1	9	75.0	14	73.7
18+	41	5	26.3	6	27.3	7	38.9	4	17.4	4	33.3	7	24.1
23+	30	5	25.0	3	30.0	5	31.3	3	21.4	5	33.3	3	20.0
33+	41	25	67.6	2	50.0	26	68.4	1	33.3	26	68.4	1	33.3
Total	320	77	45.8	99	65.1	81	50.0	95	60.1	86	54.4	90	55.6

One subset		RT_{wd}<7:00											
Two subsets		RT_{we} <9:00 or MT_{sc}<4:00						RT_{we} >9:00 or MT_{sc}>4:00					
Age		12+		18+		23+		12+		18+		23+	
	Total n	n	%	n	%	n	%	n	%	n	%	n	%
RT_{we}	48	11	28.95	8	19.51	7	23.33	18	47.37	3	7.32	1	3.33
MT_{sc}	48	16	42.11	3	7.32	2	6.67	13	34.21	8	19.51	6	20.00

Notes. Total: 176 samples of one of two subsets obtain in the previous subdivisions into two subsets (RT_{wd} <7:00; see Table S1). One subset: One of two subsets; Two subsets: Further subdivision of one of the subsets into Two subsets. Total: Either the whole set of 320 samples or a subset with smaller number of samples after the first division into Two subsets (see Table S1). See also sleep times for these subsets in Tables S7-S11.

Table S3. Samples sorted into two subsets: publication year and odd-even number.

Subdivision		Year (of publication)					Odd-even number				
Two subsets		<2014		≥2014		p for	Odd		Even		p for
Sleep time		Mean	SEM	Mean	SEM	$F_{1/304}$	Mean	SEM	Mean	SEM	$F_{1/304}$
Bed-time	Weekday	22.77	0.05	22.83	0.05	0.414	22.80	0.06	22.81	0.06	0.594
	Weekend	23.78	0.05	23.89	0.05	0.183	23.88	0.06	23.81	0.06	0.781
	Time-lag	1.01	0.04	1.06	0.04	0.468	1.08	0.05	1.00	0.05	0.789
Rise-time	Weekday	6.95	0.04	6.93	0.04	0.799	6.93	0.04	6.97	0.04	0.943
	Weekend	8.96	0.06	9.02	0.06	0.477	9.01	0.07	9.00	0.07	0.764
	Time-lag	2.00	0.06	2.09	0.06	0.332	2.07	0.06	2.03	0.06	0.733
Time in Bed	Weekday	8.17	0.05	8.09	0.05	0.300	8.13	0.06	8.16	0.06	0.662
	Weekend	9.17	0.04	9.12	0.04	0.521	9.13	0.05	9.19	0.05	0.125
	Shortening	0.99	0.05	1.03	0.05	0.617	1.00	0.05	1.03	0.05	0.848
	Average	8.46	0.04	8.39	0.04	0.304	8.41	0.05	8.46	0.05	0.410
	Sleep loss	19.43	0.50	20.20	0.50	0.278	19.99	0.51	19.67	0.51	0.655
MT_{sc}		4.01	0.05	4.09	0.05	0.316	4.09	0.06	4.03	0.05	0.950

Notes. Bedtime and Risetime: Sleep timing estimated as times to go to bed and to wake up, respectively, clock hours (decimals). Time-lag (TL): Weekend-weekday difference in sleep timing estimated for Rise- and Bedtimes, hours (Figure 1A); Time in Bed: Difference between clock hours for Risetime and Bedtime, hours; Shortening: Reduction of Time in Bed calculated as the weekend-weekday difference in Time in Bed equaled to the difference between Rise- and Bedtime-lags, hours (Figure 1B); Average: Weekly Average Time in Bed calculated as 1/7th of the sum of Time in Bed for 5 weekdays and two weekends, hours; MT (Midway Time): Midpoint of sleep calculated by adding a half of Time in Bed to Bedtime, clock hours; MT_{sc} (Sleep Corrected weekend MT): Weekend Bedtime plus a half of Average, clock hours; Sleep loss: Actual Sleep loss calculated by dividing Risetime-lag on the difference between Weekend Risetime and Weekday Bedtime (Figure 1C), in %; SEM: Standard Error of Mean; Year (of publication) and Odd-even number: Two arbitrary subdivisions of the whole set of 320 samples into a pair of subsets (either 161 or 160 samples with either later publication years, ≥2014, or odd number of sample assigned to these numbers after sorting mean ages of people included in samples from the youngest to oldest age, respectively); p for $F_{1/304}$: p-value for main effect of factor "Subset" from two-way MANOVAs, the samples were subdivided into 8 ages (another factor "Age"). See also Table 3.

Table S4. Samples sorted into two subsets: country and distinct chronotypes.

Subdivision		Country					Type-averaged				
	Two subsets	Germany		Other 36		p for	Averaged		Other		p for
Sleep time		Mean	SEM	Mean	SEM	$F_{1/304}$	Mean	SEM	Mean	SEM	$F_{1/304}$
Bed-time	Weekday	22.74	0.14	22.82	0.04	0.550	22.84	0.17	22.79	0.04	0.800
	Weekend	23.76	0.14	23.87	0.04	0.502	24.13	0.18	23.81	0.04	0.094
	Time-lag	1.02	0.11	1.04	0.03	0.900	1.28	0.13	1.02	0.03	0.061
Rise-time	Weekday	7.00	0.10	6.95	0.03	0.625	7.04	0.12	6.93	0.03	0.434
	Weekend	9.13	0.17	9.00	0.05	0.463	9.26	0.20	8.97	0.04	0.168
	Time-lag	2.12	0.15	2.05	0.04	0.636	2.22	0.18	2.03	0.04	0.330
Time in Bed	Weekday	8.26	0.14	8.12	0.04	0.328	8.19	0.17	8.13	0.04	0.738
	Weekend	9.36	0.12	9.13	0.03	0.079	9.13	0.15	9.15	0.03	0.881
	Shortening	1.09	0.12	1.00	0.03	0.504	0.93	0.15	1.01	0.03	0.603
	Average	8.57	0.12	8.40	0.03	0.191	8.46	0.15	8.42	0.03	0.820
	Sleep loss	20.46	1.27	19.81	0.38	0.628	21.04	1.54	19.72	0.37	0.406
MT_{sc}		4.01	0.05	4.09	0.05	0.316	3.78	0.05	4.36	0.05	<0.001

Notes. Country: Arbitrary subdivision of the whole set of samples into two subsets that include samples from Germany and other countries; Type-averaged: Averaged over separately reported sleep times for 27 pairs of samples of M- and E-types and included in the whole set of 320 samples after such an averaging; p for $F_{1/304}$: p-value from two-way MANOVAs for main effect of factor "Subset" (either 44 or 27 samples from the whole set of 320 samples, either collected in Germany or obtained by averaging over M- and E-types, respectively), the samples were assigned to 8 ages (another factor "Age"). See also notes to Table S3.

Table S5. Samples sorted into two subsets: bed- and risetime-lags.

Sleep time	Subdivision / Two subsets	Bedtime-lag (BTL) <1h Mean	<1h SEM	>1h Mean	>1h SEM	p for $F_{1/19}$	Risetime-lag (RTL) <2h Mean	<2h SEM	>2h Mean	>2h SEM	p for $F_{1/304}$
Bed-time	Weekday	23.00	0.06	22.76	0.06	0.012	22.83	0.08	22.88	0.07	0.663
	Weekend	23.53	0.06	24.23	0.06	<0.001	23.57	0.07	24.21	0.07	<0.001
	Time-lag	0.53	0.03	1.46	0.03	<0.001	0.73	0.06	1.32	0.05	<0.001
Rise-time	Weekday	6.94	0.04	7.06	0.05	0.116	7.09	0.06	6.93	0.05	0.049
	Weekend	8.53	0.06	9.56	0.07	<0.001	8.38	0.07	9.59	0.06	<0.001
	Time-lag	1.58	0.05	2.50	0.06	<0.001	1.29	0.05	2.66	0.05	<0.001
Time in Bed	Weekday	7.94	0.06	8.29	0.06	<0.001	8.25	0.07	8.04	0.06	0.049
	Weekend	9.00	0.05	9.32	0.06	<0.001	8.80	0.06	9.38	0.05	<0.001
	Shortening	1.05	0.05	1.03	0.06	0.808	0.55	0.06	1.33	0.05	<0.001
	Average	8.24	0.05	8.58	0.05	<0.001	8.41	0.07	8.43	0.06	0.838
	Sleep loss	16.72	0.50	23.09	0.56	<0.001	13.56	0.49	24.87	0.43	<0.001
MT_{sc}		3.65	0.05	4.52	0.05	<0.001	3.78	0.07	4.42	0.06	<0.001

Notes. BTL (Bedtime-lag) and RTL (Risetime-lag): Time-lag for Bed- and Risetime (Bed- and Risetime-lag, respectively), hours (Figure 1A and 1C); p for $F_{1/304}$: p-value from two-way MANOVAs for main effect of factor "Subset" (either 162 or 152 samples from the whole set of 320 samples either with BTL>1h or with RTL>2h, respectively), the samples were distributed into 8 ages (another factor "Age"). See also Tables 3 and S3, and Figures S2-S4.

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Table S6. Samples sorted into two subsets: midway time-lag and two of 8 ages.

	Subdivision	Midway Time-lag (MTL)					Two ages, 16+ and 18+				
	Two subsets	<1.5h		>1.5h		p for	16+		18+		p for
Sleep time		Mean	SEM	Mean	SEM	$F_{1/19}$	Mean	SEM	Mean	SEM	$F_{1/70}$
Bed-time	Weekday	22.87	0.07	22.87	0.07	0.985	23.45	0.12	23.99	0.10	0.001
	Weekend	23.45	0.06	24.30	0.06	<0.001	24.78	0.10	25.13	0.09	0.017
	Time-lag	0.57	0.04	1.42	0.04	<0.001	1.33	0.12	1.13	0.10	0.237
Rise-time	Weekday	6.98	0.05	7.04	0.05	0.390	6.72	0.10	7.46	0.08	<0.001
	Weekend	8.36	0.06	9.65	0.06	<0.001	9.80	0.12	9.48	0.10	0.050
	Time-lag	1.38	0.05	2.60	0.05	<0.001	3.08	0.12	2.01	0.10	<0.001
Time in Bed	Weekday	8.10	0.06	8.16	0.07	0.522	7.27	0.11	7.47	0.10	0.205
	Weekend	8.91	0.05	9.35	0.06	<0.001	9.02	0.09	8.35	0.08	<0.001
	Shortening	0.81	0.05	1.18	0.06	<0.001	1.75	0.11	0.87	0.10	<0.001
	Average	8.33	0.06	8.50	0.06	0.050	7.77	0.09	7.72	0.08	0.712
	Sleep loss	14.76	0.46	24.23	0.48	<0.001	29.50	1.07	21.00	0.93	<0.001
MT_{sc}		3.62	0.05	4.55	0.05	<0.001	4.67	0.11	4.99	0.09	0.035

Notes. MTL: Midway Time-lag calculated as weekend-weekday difference in MT (Midway Time), hours; p for $F_{1/304}$: p-value from two-way MANOVAs for main effect of factor "Subset" (158 samples from the whole set of 320 samples with MTL >1.5h), the samples were distributed into 8 ages (another factor "Age"). Two age subdivisions: Only two of 8 ages, ages 16+ (16.5-18.0 years) and 18+ (18.5-23.0 years), n = 31 and 41, respectively; p for $F_{1/70}$: p-value for main effect of factor "Age" from one-way MANOVA. See also notes to Table 1 and S3, and Tables S17 and S20.

Table S7. Samples sorted into 4 subsets: weekday risetime by bedtime-lag.

Sleep time	Two subsets / Four subsets	RT_{wd} <7:00				RT_{wd} >7:00				Main effect p for $F_{1/288}$	
		BTL<1h		BTL>1h		BTL<1h		BTL>1h			
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	RT_{wd}	BTL
Bed-time	Weekday	22.80	0.08	22.54	0.11	23.29	0.10	23.03	0.10	<0.001	0.010
	Weekend	23.33	0.08	24.02	0.11	23.87	0.10	24.39	0.10	<0.001	<0.001
	Time-lag	0.53	0.05	1.48	0.06	0.59	0.06	1.36	0.05	0.555	<0.001
Rise-time	Weekday	6.53	0.04	6.55	0.06	7.47	0.05	7.49	0.05	<0.001	0.680
	Weekend	8.18	0.08	9.12	0.11	8.96	0.10	9.82	0.10	<0.001	<0.001
	Time-lag	1.65	0.08	2.58	0.10	1.49	0.10	2.33	0.09	0.033	<0.001
Time in Bed	Weekday	7.73	0.08	8.01	0.11	8.18	0.10	8.46	0.09	<0.001	0.003
	Weekend	8.85	0.08	9.10	0.10	9.08	0.09	9.44	0.09	0.002	0.001
	Shortening	1.12	0.08	1.09	0.10	0.90	0.09	0.98	0.09	0.067	0.804
	Average	8.05	0.07	8.32	0.10	8.44	0.09	8.74	0.08	<0.001	0.001
	Sleep loss	17.66	0.68	24.26	0.92	15.33	0.84	21.57	0.80	0.002	<0.001
MT_{sc}		3.35	0.06	4.18	0.09	4.09	0.08	4.76	0.08	<0.001	<0.001

Notes. Two subsets: Division of the whole set of 320 samples into two subsets (either 144 or 176 samples with Weekday Risetime, RT_{wd}, either earlier or later than 7:00); Four subsets: Further subdivision of each subsets into two smaller subsets with BTL (Bedtime-lag) calculated as weekend-weekday difference in Bedtime, either smaller or larger than 1 hour; p for $F_{1/288}$: p-values from three-way MANOVAs for main effects of two factors "Subset", the samples were distributed into 8 ages (factor "Age", see sizes of subsets in Table S2, notes to Table S3, Table S16, and Figure 4).

Table S8. Samples sorted into 4 subsets: weekday risetime by risetime-lag.

Sleep time	Two subsets / Four subsets	RT_{wd} <7:00				RT_{wd} >7:00				Main effect p for $F_{1/288}$	
		RTL<2h		RTL>2h		RTL<2h		RTL>2h			
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	RT_{wd}	RTL
Bed-time	Weekday	22.59	0.11	22.72	0.10	23.05	0.11	23.24	0.11	<0.001	0.153
	Weekend	23.30	0.11	24.02	0.10	23.82	0.11	24.51	0.11	<0.001	<0.001
	Time-lag	0.71	0.09	1.30	0.08	0.77	0.09	1.27	0.09	0.857	<0.001
Rise-time	Weekday	6.57	0.06	6.54	0.05	7.53	0.05	7.44	0.06	<0.001	0.239
	Weekend	7.91	0.09	9.19	0.09	8.76	0.09	10.07	0.09	<0.001	<0.001
	Time-lag	1.34	0.08	2.65	0.08	1.23	0.08	2.63	0.08	0.441	<0.001
Time in Bed	Weekday	7.98	0.11	7.82	0.10	8.48	0.11	8.20	0.11	<0.001	0.036
	Weekend	8.61	0.09	9.17	0.08	8.94	0.09	9.56	0.09	<0.001	<0.001
	Shortening	0.63	0.09	1.35	0.08	0.46	0.09	1.36	0.09	0.363	<0.001
	Average	8.16	0.10	8.21	0.09	8.61	0.09	8.59	0.10	<0.001	0.915
	Sleep loss	14.52	0.71	25.38	0.65	12.58	0.70	24.30	0.71	0.030	<0.001
MT_{sc}		3.38	0.09	4.12	0.08	4.13	0.09	4.80	0.09	<0.001	<0.001

Notes. Two subsets: Division of the whole set of 320 samples into two subsets (either 144 or 176 samples with Weekday Risetime, RT_{wd}, either earlier or later than 7:00); Four subsets: Further subdivision of each subsets into two smaller subsets with RTL (Risetime-lag) calculated as weekend-weekday difference in Risetime, either smaller or larger than 2 hours; p for $F_{1/288}$: p-values from three-way MANOVAs for main effects of two factors "Subset", the samples were distributed into 8 ages (factor "Age", see sizes of subsets in Table S2, notes to Table S3, Table S16, and Figure 4).

Table S9. Samples sorted into 4 subsets: weekday risetime by midway time-lag.

Sleep time	Two subsets / Four subsets	RT_{wd} <7:00				RT_{wd} >7:00				Main effect p for $F_{1/288}$	
		MTL<1.5h		MTL>1.5h		MTL<1.5h		MTL>1.5h			
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	RT_{wd}	MTL
Bed-time	Weekday	22.69	0.09	22.66	0.12	23.12	0.12	23.15	0.10	<0.001	0.988
	Weekend	23.21	0.08	24.08	0.11	23.81	0.11	24.48	0.10	<0.001	<0.001
	Time-lag	0.53	0.06	1.42	0.08	0.69	0.08	1.33	0.07	0.601	<0.001
Rise-time	Weekday	6.54	0.04	6.53	0.06	7.53	0.06	7.49	0.05	<0.001	0.680
	Weekend	8.01	0.07	9.21	0.10	8.71	0.10	10.00	0.09	<0.001	<0.001
	Time-lag	1.48	0.07	2.68	0.09	1.18	0.09	2.51	0.08	0.004	<0.001
Time in Bed	Weekday	7.85	0.09	7.88	0.12	8.41	0.11	8.34	0.10	<0.001	0.821
	Weekend	8.80	0.07	9.13	0.10	8.90	0.10	9.52	0.09	0.008	<0.001
	Shortening	0.95	0.07	1.26	0.10	0.49	0.10	1.18	0.09	0.003	<0.001
	Average	8.12	0.08	8.24	0.10	8.55	0.10	8.68	0.09	<0.001	0.190
	Sleep loss	16.04	0.59	25.50	0.79	12.21	0.76	23.16	0.68	<0.001	<0.001
MT_{sc}		3.27	0.07	4.20	0.09	4.09	0.08	4.82	0.08	<0.001	<0.001

Notes. Two subsets: Division of the whole set of 320 samples into two subsets (either 144 or 176 samples with Weekday Risetime, RT_{wd}, either earlier or later than 7:00); Four subsets: Further subdivision of each subsets into two smaller subsets with MTL (Midway Time-lag) calculated as weekend-weekday difference in MT (Midway Time), either smaller or larger than 1.5 hour; p for $F_{1/288}$: p-values from three-way MANOVAs for main effects of two factors "Subset", the samples were distributed into 8 ages (factor "Age"; see sizes of subsets in Table S2, notes to Table S3, Table S16, and Figure 4).

Table S10. Samples sorted into 4 subsets: weekday risetime by weekend risetime.

Sleep time	Two subsets / Four subsets	RT_{wd} <7:00				RT_{wd} >7:00				Main effect p for $F_{1/97}$	
		RT_{we}<9:00		RT_{we} >9:00		RT_{we}<9:00		RT_{we} >9:00			
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	RT_{wd}	RT_{we}
Bed-time	Weekday	23.09	0.11	23.41	0.21	23.37	0.22	23.55	0.11	0.227	0.144
	Weekend	23.89	0.10	24.84	0.19	23.82	0.20	24.81	0.10	0.749	<0.001
	Time-lag	0.80	0.09	1.43	0.17	0.46	0.18	1.26	0.09	0.065	<0.001
Rise-time	Weekday	6.61	0.07	6.73	0.13	7.55	0.13	7.56	0.07	<0.001	0.545
	Weekend	8.28	0.08	9.64	0.16	8.40	0.17	9.84	0.08	0.229	<0.001
	Time-lag	1.66	0.10	2.91	0.19	0.85	0.20	2.28	0.10	<0.001	<0.001
Time in Bed	Weekday	7.52	0.10	7.32	0.19	8.18	0.20	8.01	0.10	<0.001	0.232
	Weekend	8.39	0.10	8.81	0.19	8.57	0.19	9.04	0.09	0.171	0.004
	Shortening	0.87	0.09	1.49	0.18	0.39	0.19	1.03	0.09	0.002	<0.001
	Average	7.77	0.09	7.74	0.18	8.29	0.18	8.30	0.09	<0.001	0.960
	Sleep loss	17.99	0.88	28.49	1.72	8.99	1.76	21.88	0.85	<0.001	<0.001
MT_{sc}		3.78	0.08	4.71	0.15	3.97	0.16	4.96	0.08	0.072	<0.001

Notes. Two subsets: Division of the whole set of 320 samples into two subsets (either 144 or 176 samples with Weekday Risetime, RT_{wd}, either earlier or later than 7:00); Four subsets: Further subdivision of each subsets into two subsets with RT_{we} (Weekend Risetime), either earlier or later than 9:00; p for $F_{1/97}$: p-values from three-way MANOVA for main effects of two factors “Subset”, the samples were distributed into 3 ages (factor “Age”, see sizes of subsets in lower part of Table S2, notes to Table S3, and Table S17).

Table S11. Samples sorted into 4 subsets: weekday risetime by sleep corrected midway time

	Two subsets	RT_{wd} <7:00				RT_{wd} >7:00				Main effect	
Sleep	Four	MT_{sc}<4:00		MT_{sc}>4:00		MT_{sc}<4:00		MT_{sc}>4:00		p for $F_{1/288}$	
time	subsets	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	RT_{wd}	MT_{sc}
Bed-time	Weekday	22.84	0.16	23.36	0.10	23.20	0.26	23.59	0.09	0.076	0.007
	Weekend	23.45	0.14	24.62	0.09	23.63	0.22	24.76	0.08	0.248	<0.001
	Time-lag	0.62	0.15	1.26	0.09	0.44	0.23	1.17	0.08	0.373	<0.001
Rise-time	Weekday	6.56	0.11	6.65	0.07	7.38	0.17	7.59	0.06	<0.001	0.171
	Weekend	8.08	0.17	9.14	0.11	8.25	0.27	9.70	0.09	0.037	<0.001
	Time-lag	1.52	0.19	2.49	0.12	0.87	0.30	2.11	0.11	0.010	<0.001
Time in Bed	Weekday	7.72	0.15	7.29	0.09	8.18	0.23	8.00	0.08	<0.001	0.046
	Weekend	8.63	0.16	8.53	0.10	8.62	0.26	8.94	0.09	0.232	0.538
	Shortening	0.91	0.16	1.23	0.10	0.44	0.25	0.93	0.09	0.021	0.014
	Average	7.98	0.13	7.65	0.09	8.31	0.21	8.27	0.08	0.001	0.172
	Sleep loss	15.80	1.63	24.97	1.05	9.18	2.58	20.41	0.92	0.001	<0.001
MT_{sc}		3.44	0.12	4.44	0.08	3.79	0.19	4.90	0.07	0.002	<0.001

Notes. Two subsets: Division of the whole set of 320 samples into two subsets (either 144 or 176 samples with Weekday Risetime, RT_{wd}, either earlier or later than 7:00); Four subsets: Further subdivision of each subsets into two smaller subsets with MT_{sc} (Sleep Corrected Midway Time), either earlier or later than 4:00; p for $F_{1/97}$: p-values from three-way MANOVA for main effects of two factors "Subset", the samples were distributed into 3 ages (factor "Age", see sizes of subsets in lower part of Table S2, notes to Table S3, and Table S17).

Table S12. Early and later school start times in "natural experiments" (be continued).

Reference School times	Perkinson-Gloor et al Early	Perkinson-Gloor et al Later	Arrona-Palacios et al Early	Arrona-Palacios et al Later	Arrona-Palacios & Díaz-Morales Early	Arrona-Palacios & Díaz-Morales Later	Carissimi et al Early	Carissimi et al Later	Boergers et al Early	Boergers et al Later
Weekday	22.47	22.65	23.00	24.10	22.82	24.33	22.17	22.86	23.80	23.73
Weekend	24.78	24.98	24.50	25.20	24.42	25.42	23.43	23.51	24.75	24.77
Time-lag	2.31	2.33	1.50	1.10	1.60	1.08	1.26	0.65	0.95	1.03
Weekday	6.43	6.88	6.18	9.48	6.08	9.57	6.23	8.21	7.03	7.43
Weekend	10.74	10.9	10.5	10.97	9.47	9.30	8.86	9.07	9.85	9.88
Time-lag	4.31	4.02	4.32	1.48	3.38	-0.27	2.63	0.87	2.82	2.45
Weekday	7.97	8.23	7.18	9.38	7.27	9.23	8.06	9.35	7.23	7.70
Weekend	9.97	9.92	10.00	9.77	10.00	9.77	9.43	9.56	9.10	9.12
Shortening	2.00	1.68	2.82	0.38	2.73	0.53	1.37	0.21	1.87	1.42
Average	8.54	8.71	7.99	9.49	8.05	9.39	8.45	9.41	7.77	8.10
Sleep loss	35.1	32.79	37.54	13.65	31.77	-2.97	24.57	8.47	28.03	24.14
	5.04	5.34	4.49	5.95	4.44	6.11	3.65	4.22	4.63	4.82

Notes. Perkinson-Gloor et al. (2013): School start time was either advanced or delayed on 20 min for 2373 and 343 15.5-yr Swiss students, RT_{wd} 6:26 or 6:53, respectively; Arrona-Palacios et al. (2015): 287 and 281 14-yr Mexican adolescents, RT_{wd} 06:11 and 09:29; Arrona-Palacios & Díaz-Morales (2018): 200 and 200 14-yr old Mexican adolescents, RT_{wd} 06:05 and 09:34 with school start times 07:30 and 13:20, respectively (the same in both publications); Carissimi et al. (2016): 538 and 101 school students in southern Brazil, ages 13 and 11 years, RT_{wd} 6.23 and 8.21 with school start times 07:30 and 13:20, respectively; Boergers et al. (2014): 197 14-yr US students studied in Time 1 and Time 2 (regular and experimental) with school start times 08:00 and 8:25, RT_{wd} 7.02 and 7.26, respectively. See also notes to Table S3, averaging in Table S14 and summary in Tables S18 and S20.

Table S12 (continued). Early and later school start times in "natural experiments".

Sleep time	Reference School times	Brandalize et al		Lima et al		Peixoto et al. Electricity at home: With		Without	
		Early	Later	Early	Later	Early	Later	Early	Later
Bed-time	Weekday	22.57	22.88	23.78	24.42	21.85	23.88	20.63	23.77
	Weekend	23.75	23.67	24.3	25.23	22.07	22.22	21.77	21.02
	Time-lag	1.18	0.78	0.52	0.82	0.22	-1.67	1.13	-2.75
Rise-time	Weekday	6.53	8.97	6.52	7.72	6.60	7.97	6.40	7.37
	Weekend	9.80	9.75	8.20	8.90	6.88	7.83	6.77	6.90
	Time-lag	3.27	0.78	1.68	1.18	0.28	-0.13	0.37	-0.47
Time in Bed	Weekday	7.97	10.08	6.73	7.30	8.75	8.08	9.77	7.60
	Weekend	10.05	10.08	7.90	7.67	8.82	9.62	9.00	9.88
	Shortening	2.08	0.00	1.17	0.37	0.07	1.53	-0.77	2.28
	Average	8.56	10.08	7.07	7.40	8.77	8.52	9.55	8.25
	Sleep loss	29.08	7.21	20.00	13.95	3.14	-1.68	3.62	-6.54
MT_{sc}		4.03	4.71	3.83	4.94	2.45	2.48	2.54	1.14

Notes. Brandalize et al. (2011): 379 12.5-yr students from southern Brazil before and after transition from 13:00 to 7:30 school start times, RT_{wd} 06:32 and 09:48, respectively; Lima et al. (2002): 27 20-yr medical students in northern Brazil with classes started either at 7:00/8:00 or at 10:00, RT_{wd} 06:31 and 07:43, respectively; Peixoto et al., (2009): 15 12.5-yr and 13 13-yr students in southern Brazil, With Electricity at home, attended school classes started at 07:30 and 19:00, respectively, vs. 5 12.5-yr and 6 14.5 yr students, respectively, Without Electricity at home, RT_{wd} 06:36 and 07:58 vs. 06:24 and 07:22, respectively. See also notes to Table S3, averaging in Table S14 and summary in Tables S18 and S20.

Table S13. Seasonal alternation between DST and ST in "natural experiments".

Reference	Miller et al		Shochat et al		Lo et al		Johnsen et al		Friborg et al		Lowden et al	
DST & ST	DST	ST	DST	ST	DST	ST	DST	ST	DST	ST	DST	ST
Age, years	18.5	19	19	18.5	25	25	52	54	23	22.5	45	45.5
Weekday	23.35#	24.38	23.53#	24.57	22.30#	23.42	22.53#	23.50	22.78#	23.98	22.50#	23.08
Weekend	23.88#	25.28	24.18#	25.07	23.30#	24.38	23.32#	24.35	24.05#	25.25	22.07#	24.10
Time-lag	0.53	0.90	0.65	0.50	1.00	0.97	0.78	0.85	1.27	1.27	-0.43	1.02
Weekday	5.22#	6.27	7.73#	8.88	6.68#	7.80#	5.60#	6.65	7.07#	8.60	4.53#	5.88
Weekend	7.27#	8.93	9.12#	9.63	7.82#	9.05#	7.15#	8.67	9.00#	10.10	5.98#	7.67
Time-lag	2.05	2.67	1.38	0.75	1.13	1.25	1.55	2.02	1.93	1.50	1.45	1.78
Weekday	5.87	5.88	8.20	8.32	8.38	8.38	7.07	7.15	8.28	8.62	6.03	6.80
Weekend	7.38	7.65	8.93	8.57	8.52	8.67	7.83	8.32	8.95	8.85	7.92	7.57
Shortening	1.52	1.77	0.73	0.25	0.13	0.28	0.77	1.17	0.67	0.23	1.88	0.77
Average	6.30	6.39	8.41	8.39	8.42	8.46	7.29	7.48	8.47	8.68	6.57	7.02
Sleep loss	25.89	31.19	14.39	8.28	11.87	12.98	17.99	22.00	18.88	14.82	19.38	20.78
MT_{sc}	3.03	4.48	4.39	5.26	3.51	4.62	2.96	4.09	4.29	5.59	1.35	3.61

Notes. Miller et al. (2010): 73 19-yr old US military academy cadets in spring 2004 and fall 2003, RT_{wd} 6:13 and 6:16, respectively; Shochat et al. (2019): 19 undergraduates of the University of Surrey after observing for, at least, three weeks DST and ST in late spring 2015 and late fall 2014, age 19 and 18.5 years, RT_{wd} 8:44 and 8:53, respectively; Lo et al. (2014): University of Surrey students (in total, 837 with mean age 25 years), averaging over 5 roughly equal intervals of ST preceding and following 7 roughly equal intervals of DST, RT_{wd} 7:41 and 7:48, respectively; Johnsen et al. (2013): 1064 52-yr and 1036 54-yr old employed residents of Tromsø in winter and fall 2007/2008, RT_{wd} 6:39 and 6:36, respectively; Friborg et al. (2012): Universities of Tromsø students, in August 2009, the number of students dropped from 200 to 150 with ages 23 and 22.5 years after the first assessment in January 2009, RT_{wd} 8:04 and 8:36, respectively; Lowden et al. (2019): 32 45.5-yr old office workers in northern Sweden, RT_{wd} 5:32 and 5:53, respectively; #: DST clock times were corrected (ST=DST-1h) to provide direct comparison of sun times. See also notes to Table S3, averaging in Table S14 and summary in Tables S19 and S20.

Table S14. Averaging over samples of early vs. late school start times and DST vs. ST.

Pairs of samples		School start times (Table S12)					Seasonal DST and ST (Table S13)				
	Samples	Early		Later		p for	DST		ST		p for
Sleep time		Mean	SEM	Mean	SEM	$t_{1/8}$	Mean	SEM	Mean	SEM	$t_{1/5}$
Bed-time	Weekday	22.57	0.33	23.62	0.22	0.015	22.83[#]	0.20	23.82	0.24	<0.001
	Weekend	23.75	0.38	24.00	0.51	0.211	23.47[#]	0.32	24.74	0.21	0.001
	Time-lag	1.19	0.20	0.37	0.52	0.101	0.63	0.24	0.92	0.10	0.295
Rise-time	Weekday	6.44	0.09	8.18	0.32	0.002	6.14[#]	0.50	7.35	0.51	<0.001
	Weekend	9.01	0.49	9.28	0.44	0.058	7.72[#]	0.49	9.01	0.34	0.001
	Time-lag	2.56	0.50	1.10	0.48	0.009	1.58	0.14	1.66	0.27	0.714
Time in Bed	Weekday	7.88	0.31	8.55	0.33	0.200	7.31	0.47	7.53	0.44	0.129
	Weekend	9.36	0.24	9.49	0.24	0.407	8.26	0.26	8.27	0.22	0.910
	Shortening	1.48	0.40	0.93	0.27	0.389	0.95	0.26	0.75	0.26	0.422
	Average	8.31	0.23	8.82	0.28	0.138	7.58	0.41	7.74	0.38	0.066
	Sleep loss	23.65	4.21	9.89	4.31	0.006	18.07	1.96	18.34	3.30	0.887
MT_{sc}		3.90	0.30	4.41	0.54	0.131	3.26[#]	0.45	4.61	0.30	0.001

Notes. Left and right part: Results of averaging over 9 and 6 pairs of samples (see Tables S12 and S13), respectively; p for $t_{1/8}$ and p for $t_{1/5}$: p-value from paired t-test (9 and 6 paired samples of early vs. later school start times and DST vs. ST); [#]: In DST vs. ST studies, clock times for DST were corrected to clock times for ST (ST = DST - 1h). See also notes to Table S3 and summaries in Tables S18-S20.

Table S15. Holidays, perennial DST and leaving school in “natural experiments”.

	Reference	Warner et al		Borisenkov et al		Urner et al		Lund et al	
Sleep	Division	School & Holydays		Perennial		Age		Age	
time	Samples	School	Holydays	DST	ST	18	23	17	20
Bed-time	Weekday	22.78	24.00	23.10$^{\#}$	23.89	23.40	24.03	23.03	24.28
	Weekend	24.40	24.77	24.47$^{\#}$	24.85	24.78	25.27	24.75	25.73
	Time-lag	1.62	0.77	1.37	0.96	1.38	1.23	1.72	1.45
Rise-time	Weekday	7.07	9.63	6.09$^{\#}$	7.05	6.90	7.77	6.52	8.03
	Weekend	9.37	10.07	10.11$^{\#}$	10.27	9.53	9.80	9.85	10.13
	Time-lag	2.30	0.43	4.02	3.22	2.63	2.03	3.33	2.10
Time in Bed	Weekday	8.28	9.63	6.99	7.16	7.49	7.79	7.48	7.75
	Weekend	8.97	9.30	9.64	9.42	8.75	8.52	9.10	8.40
	Shortening	0.68	-0.33	2.65	2.26	1.26	0.73	1.62	0.65
	Average	8.48	9.54	7.75	7.81	7.85	8.00	7.95	7.94
	Sleep loss	21.73	4.30	36.51	31.02	25.96	20.78	30.82	21.32
MT_{sc}		4.64	5.54	4.34	4.75	4.71	5.27	4.72	5.70

Notes. Warner et al. (2008): 380 Australian students on Holidays and, later, 310 of them at school when the classes started at 08:30 (mean age 16 years), RT_{wd} 07:04 and 09:38 for School and Holidays, respectively; Borisenkov et al. (2016): 3033 16-yr and 2436 17-yr students observing perennial (year round) DST and perennial ST in northern regions of Russia, between March 2011 and October 2014 and thereafter, RT_{wd} 7.09 and 7.05, respectively; $^{\#}$: Clock times for DST were corrected (DST-1h) to provide direct comparison of the sun times under DST and ST; Urner et al. (2009): 24 Australian students were first studied at high school and then at university, ages 18 and 23 years, RT_{wd} 06:54 and 07:46, respectively: Lund et al. (2010): Comparison of 199 17-yr school students of the highest (12th) grade from the US pole (National Sleep Foundation. 2006) with 1125 20-yr college students, RT_{wd} 06:54 and 07:46, respectively. See also notes to Table S3 and summaries in Tables S18-S20.

Table S16. Summary on comparisons of samples sorted into 4 subsets.

Subdivision into two subsets			RT_{wd}<7:00					
Sleep time	Subset	RT_{wd} <7:00	RTL <2h	RTL >2h	MTL <1.5h	MTL >1.5h	BTL <1h	BTL >1h
Bed-time	Weekday	↓***	↓***	↓***	↓***	↓***	↓***	↓***
	Weekend	↓***	↓***	↓***	↓***	↓***	↓***	↓***
	Time-lag	↑≈	↓≈	↑≈	↓≈	↑≈	↓≈	↑≈
	in minutes	2	-4	7	-4	2	-10	5
Rise-time	Weekday	↓***	↓***	↓***	↓***	↓***	↓***	↓***
	Weekend	↓***	↓***	↓***	↓***	↓***	↓***	↓***
	in minutes	-40	-47	-42	-51	-53	-42	-47
	Time-lag	↑*	↑*	↑*	↑≈	↑≈	↓**	↓**
	in minutes	12	10	15	7	1	18	10
Time in Bed	Weekday	↓***	↓***	↓***	↓***	↓***	↓***	↓***
	in minutes	-26	-27	-27	-30	-23	-34	-28
	Weekend	↓***	↓**	↓**	↓***	↓***	↓**	↓**
	in minutes	-16	-14	-20	-20	-23	-6	-23
	Shortening	↑*	↑+	↑+	↑≈	↓≈	↑**	↑**
	in minutes	10	13	7	10	-1	28	5
	Average	↓***	↓***	↓***	↓***	↓***	↓***	↓***
	in minutes	-23	-23	-25	-27	-23	-26	-26
	% to mean	-5%	-5%	-5%	-5%	-5%	-5%	-5%
	Sleep loss	↑**	↑**	↑**	↑*	↑*	↑***	↑***
	in %	2%	2%	3%	2%	1%	4%	2%
MT_{sc}		↓***	↓***	↓***	↓***	↓***	↓***	↓***

Notes. Subdivision into two subsets: The whole set of samples was divided into two subsets and the subset with earlier weekend sleep timing, RT_{wd}:<7:00, was compared with another subset. Moreover, the subsets were further subdivided into two smaller subsets with either smaller or larger time-lag and also compared (Tables S7-S9). See subset sizes in Table S2, notes to Tables 3 and S3, and Figure 4.

Table S17. Summary on comparisons of samples sorted into 4 subsets and two ages.

Subdivision into two subsets			RT_{wd}<7:00				Age
Sleep		RT_{wd}	RT_{we}		MT_{sc}		16+ 18+
time	Subset	<7:00	<9:00	>9:00	<4:00	>4:00	16+
Bed-time	Weekday	↓***	↓≈	↓≈	↓+	↓+	↓**
	Weekend	↓***	↑≈	↑≈	↓≈	↓≈	↓*
	Time-lag	↑≈	↑+	↑+	↑≈	↑≈	↑≈
	in minutes	2	20	10	11	5	12
Rise-time	Weekday	↓***	↓***	↓***	↓***	↓***	↓***
	Weekend	↓***	↓≈	↓≈	↓*	↓*	↑+
	in minutes	-40	-7	-12	-10	-34	19
	Time-lag	↑*	↑***	↑***	↑*	↑*	↑***
	in minutes	12	49	38	39	23	64
Time in Bed	Weekday	↓***	↓***	↓***	↓***	↓***	↓≈
	in minutes	-26	-40	-41	-28	-43	-12
	Weekend	↓***	↓≈	↓≈	↓≈	↓≈	↑***
	in minutes	-16	-11	-14	1	-25	40
	Shortening	↑*	↑**	↑**	↑*	↑*	↑***
	in minutes	10	29	28	28	18	53
	Average	↓***	↓***	↓***	↓**	↓**	↑≈
	in minutes	-23	-31	-34	-20	-37	3
	% to mean	-5%	-6%	-7%	-4%	-8%	1%
	Sleep loss	↑**	↑***	↑***	↑**	↑**	↑***
	in %	2%	9%	7%	7%	5%	8%
MT_{sc}		↓***	↓+	↓+	↓**	↓**	↓***

Notes. Subdivision into two subsets: Either the whole set of samples was divided into two subsets and the subset with earlier weekend sleep timing, RT_{wd}:<7:00, was compared with another subset (the same as in Table S16). Moreover, after further subdivision into two smaller subsets, with earlier and later weekend sleep timing (Tables S10 and S11), these subsets were compared. 16+ 18+: Two of 8 ages, ages 16+ (16.5-18.0 years) and 18+ (18.5-23.0 years), n = 31 and 41, respectively (Table S6, right). See also subset sizes in Table S2 and notes to Tables 3 and S16.

Table S18. Summary on comparison of school start times.

Subdivision	Early vs. later school start times									Mean	Holydays
Age	15.5	14	14	13	14	12.5	20	12.5	12.5	30.5	16
Weekday	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓*	↓
Weekend	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓≈	↓
Time-lag	↑	↑	↑	↑	↓	↑	↑	↑	↑	↑≈	↑
in minutes	-1	24	31	37	-5	24	-18	113	233	49	51
Weekday	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓**	↓
Weekend	↓	↓	↑	↓	↓	↑	↓	↓	↓	↓+	↓
in minutes	-10	-28	10	-13	-2	3	-42	-57	-8	-16	-42
Time-lag	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑**	↑
in minutes	17	170	219	106	22	149	30	25	50	88	112
Weekday	↓	↓	↓	↓	↓	↓	↓	↑	↑	↓≈	↓
in minutes	-16	-132	-118	-77	-28	-127	-34	40	130	-40	-81
Weekend	↑	↑	↑	↓	↓	↓	↑	↓	↓	↓≈	↓
in minutes	3	14	14	-8	-1	-2	14	-48	-53	-8	-20
Shortening	↑	↑	↑	↑	↑	↑	↑	↓	↓	↑≈	↑
in minutes	19	146	132	70	27	125	48	-88	-183	33	61
Average	↓	↓	↓	↓	↓	↓	↓	↑	↑	↓≈	↓
in minutes	-10	-90	-80	-58	-20	-91	-20	15	78	-31	-64
% to mean	-2%	-17%	-15%	-11%	-4%	-16%	-5%	3%	15%	-6%	-12%
Sleep loss	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑**	↑
in %	2%	24%	35%	16%	4%	22%	6%	5%	10%	14%	17%
MT_{sc}	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓≈	↓

Notes. Age: Mean age in one of samples/subsets. Early vs. later school start times: Summary on 9 pairs of samples (Swiss students, Mexican adolescents – two publications, school students in southern Brazil, US students, other students from southern Brazil, medical students in northern Brazil, other students, with and without electricity at home, in southern Brazil); Mean: Averaged over 9 pairs; Holydays: The 10th pair of samples shown in Table S15; ↑ or ↓ or =: Value in the sample characterized by early wakeups was either higher or lower or the same as in another sample with later wakeups; in minutes: This difference between samples was additionally shown in minutes, (-) indicates earlier Risetime on Weekends, smaller sleep restriction due to a smaller Bed- and Risetime-lags and Shortening, and shorter sleep due to shorter Weekday, Weekend and Average Time in Bed; % to mean: The same difference expressed in percentage to mean Average calculated for two samples; in %: The difference in actual Sleep loss measured in percentage, (-) indicates smaller loss. Level of significance for Mean is taken from Table S16. See also notes to Tables 3 and Table S20.

Table S19. Summary on DST-ST comparison.

Sleep time	Subdivision	Seasonal DST vs. ST						Mean	Perennial
	Age	19	19	25	52	22.5	45.5	30.5	16
Bed-time	Weekday	↓#	↓#	↓#	↓#	↓#	↓#	↓#***	↓#
	Weekend	↓#	↓#	↓#	↓#	↓#	↓#	↓#**	↓#
	Time-lag	↓	↑	↑	↓	=	↓	↓≈	↑
	in minutes	-22	9	2	-4	0	-87	-17	25
Rise-time	Weekday	↓#	↓#	↓#	↓#	↓#	↓#	↓#***	↓#
	Weekend	↓#	↓#	↓#	↓#	↓#	↓#	↓#**	↓#
	in minutes	-100#	-31#	-74#	-91#	-66#	-101#	-77#	-10#
	Time-lag	↓	↑	↓	↓	↑	↓	↓≈	↑
	in minutes	-37	38	-7	-28	26	-20	-5	48
Time in Bed	Weekday	↓	↓	=	↓	↓	↓	↓≈	↓
	in minutes	-1	-7	0	-5	-20	-46	-13	-10
	Weekend	↓	↑	↓	↓	↑	↑	↓≈	↑
	in minutes	-16	22	-9	-29	6	21	-1	13
	Shortening	↓	↑	↓	↓	↑	↑	↑≈	↑
	in minutes	-15	29	-9	-24	26	67	12	23
	Average	↓	↑	↓	↓	↓	↓	↓+	↓
	in minutes	-5	1	-2	-11	-13	-27	-10	-4
	% to mean	-1%	0%	0%	-3%	-2%	-7%	-2%	-1%
	Sleep loss	↓	↑	↓	↓	↑	↓	↓≈	↑
	in %	-5%	6%	-1%	-4%	4%	-1%	0%	5%
MT_{sc}		↓	↓	↓	↓	↓	↓	↓	↓**

Notes. Age: Mean age in one of two samples/subsets. Seasonal DST vs. ST: Seasonal alternations between DST and ST, summary on 6 pairs of samples in Table S14 (US military academy cadets, undergraduates from the University of Surrey, University of Surrey students, employed residents of Tromsø, Universities of Tromsø students, and office workers in northern Sweden); Mean: Averaged over 6 pairs in Table S15; Perennial: Year round DST vs. year round ST (Table S16); #: Clock times for DST were corrected (DST-1h). Level of significance for Mean was taken from Table S16. See also notes to Tables 3 and Table S20.

Table 20. Summary on "natural experiments".

Sleep time	Subdivision / One	In vs. after school, Age at school, years: 16+	18	17	School start times, Early vs.: Later	Holydays	DST and ST, DST vs. ST: Seasonal	Perennial
Bed-time	Weekday	↓**	↓	↓	↓*	↓	↓$^{\#***}$	↓$^{\#}$
	Weekend	↓*	↓	↓	↓$^{\approx}$	↓	↓$^{\#**}$	↓$^{\#}$
	Time-lag	↑$^{\approx}$	↑	↑	↑$^{\approx}$	↑	↓$^{\approx}$	↑
	in minutes	12	9	16	49	51	-17	25
Rise-time	Weekday	↓***	↓	↓	↓**	↓	↓$^{\#***}$	↓$^{\#}$
	Weekend	↑$^{+}$	↓	↓	↓$^{+}$	↓	↓$^{\#**}$	↓$^{\#}$
	in minutes	19	-16	-17	-16	-42	-77$^{\#}$	-10$^{\#}$
	Time-lag	↑***	↑	↑	↑**	↑	↓$^{\approx}$	↑
	in minutes	64	36	74	88	112	-5	48
Time in Bed	Weekday	↓$^{\approx}$	↓	↓	↓$^{\approx}$	↓	↓$^{\approx}$	↓
	in minutes	-12	-18	-16	-40	-81	-13	-10
	Weekend	↑***	↑	↑	↓$^{\approx}$	↓	↓$^{\approx}$	↑
	in minutes	40	14	42	-8	-20	-1	13
	Shortening	↑***	↑	↑	↑$^{\approx}$	↑	↑$^{\approx}$	↑
	in minutes	53	32	58	33	61	12	23
	Average	↑$^{\approx}$	↓	↑	↓$^{\approx}$	↓	↓$^{+}$	↓
	in minutes	3	-9	1	-31	-64	-10	-4
	% to mean	1%	-2%	0%	-6%	-12%	-2%	-1%
	Sleep loss	↑***	↑	↑	↑**	↑	↓$^{\approx}$	↑
	in %	8%	5%	10%	14%	17%	0%	5%
MT_{sc}		↓***	↓	↓	↓$^{\approx}$	↓	↓**	↓

Notes. Subdivision: Subdivision into samples/subsets. One: One of samples/subsets. In vs. after school: Early wakeups when being in school age compared to university/college age (16+: The same column as in Table S17 (right) for comparison with samples from two separate studies, 18: 24 students at high school and, thereafter, university, ages 18 and 23 years, respectively, and 17: School students of the highest (12th) grade compared to college students, ages 17 and 20 years, respectively, Table S15); School start times: Early vs. Later School start times (comparison with Later times or Holydays: averaging over 9 comparisons in Table S14, and the 10th study comparing Early school times with Holidays (Table S15) rather than with Later school start times; DST vs. ST: Seasonal and Perennial (averaged over 6 comparisons of seasonal alternations between DST and ST from Table S14 plus one study on year round DST and year round ST, Table S15); $^{\#}$: Clock times were corrected for DST (-1h). See also notes to Tables 3 and Tables S18 and S19.

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Supplementary Figure Legends

Figure S1. Age by M-E-type difference in time in bed.

Lines illustrate a linear relationship of Age with the difference in weekly average and weekday times in bed (A and B, respectively). Labels refer to 8 ages. See also Figure 3 (right graphs).

Figure S2. Sleep loss and time in bed in two-subset divisions in accord with risetime and time lags.

Three subdivisions of the whole set of 320 samples, depending upon RT_{wd} (weekday Risetime) and Bed- and Risetime-lags (BLT and RLT). See also legend to Figure 3, notes to Table 1, and mean (averaged over ages) sleep times in Tables 1 and S5.

Figure S3. Bed- and Risetime-lags in six two-subset divisions.

A and C, B and D. Bed- and Risetime-lags are the weekend-weekday differences in Bed- and Risetimes, respectively (Figure 1A and 1C). The same subdivision of samples as in Figures 3 and S2. See also notes in Table 1 and mean (averaged over ages) sleep times in Tables 1, 2 and S4-S6.

Figure S4. Bed- and Risetimes in six two-subset divisions.

A and C. Bedtime. B and D. Risetime. The same subdivisions of samples as in Figures S3. See also notes in Table 1 and mean (averaged over ages) sleep times in Tables 1, 2 and S4-S6.

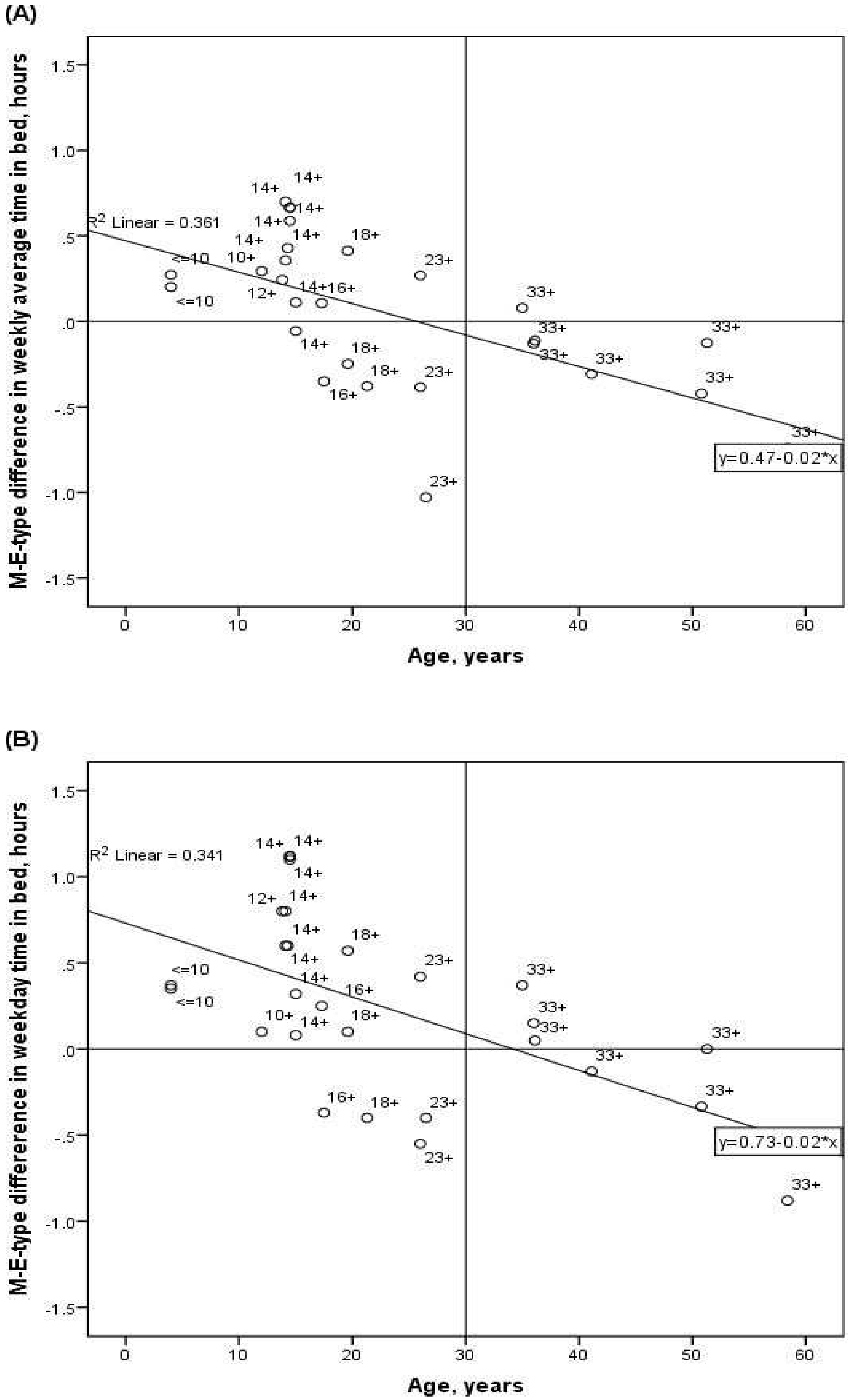
(A)
M-E-type difference in weekly average time in bed, hours
Age, years
R2 Linear = 0.361
y=0.47-0.02*x
(B)
M-E-type differerence in weekday time in bed, hours
Age, years
R2 Linear = 0.341
y=0.73-0.02*x

Figure S1

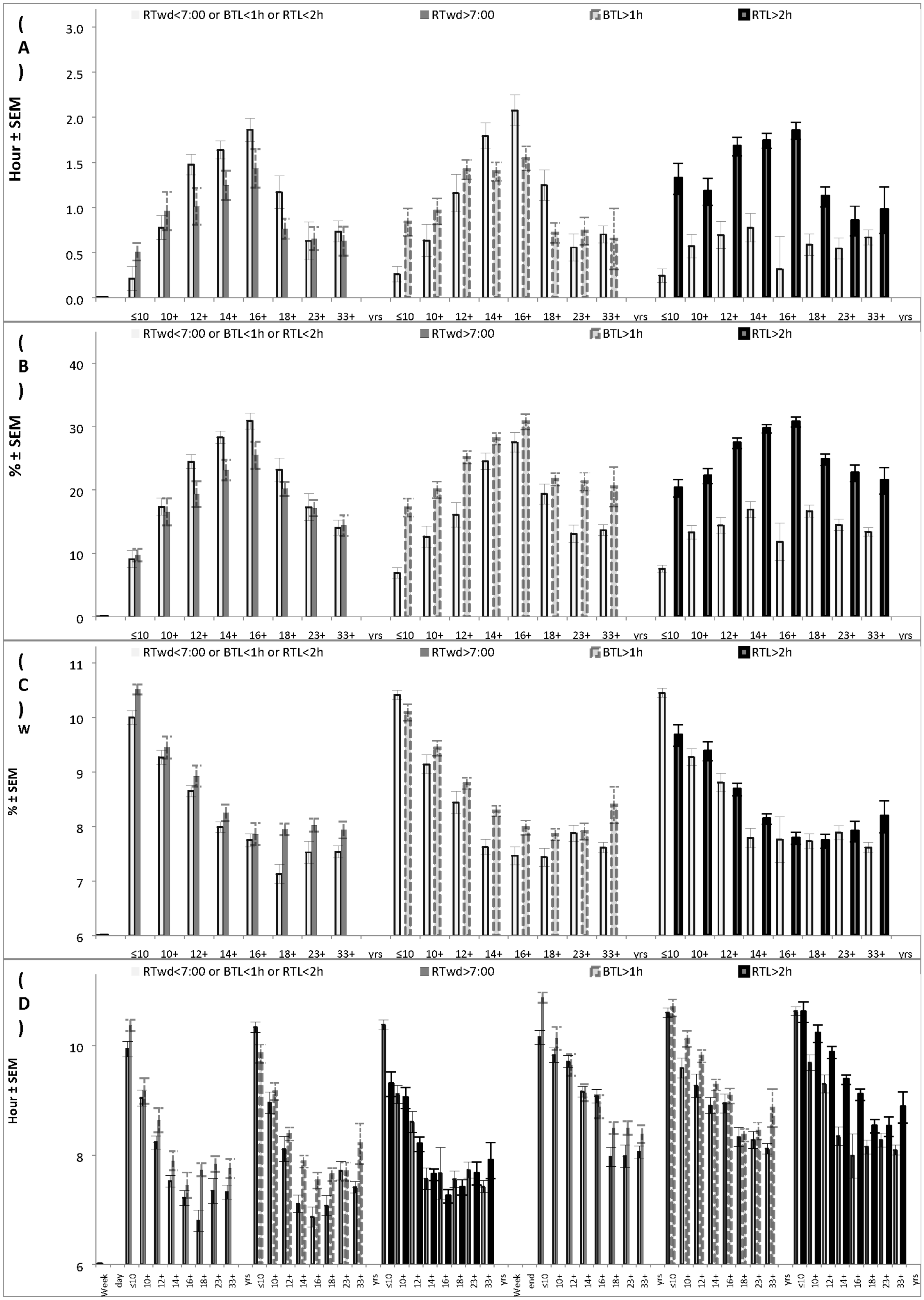
RTwd<7:00 or BTL<1h or RTL<2h
RTwd>7:00
BTL>1h
RTL>2h
(A)
Hour ± SEM
(B)
% ± SEM
(C)
W
% ± SEM
(D)
Hour ± SEM
≤10
10+
12+
14+
16+
18+
23+
33+
yrs
Week
day
end

Figure S2

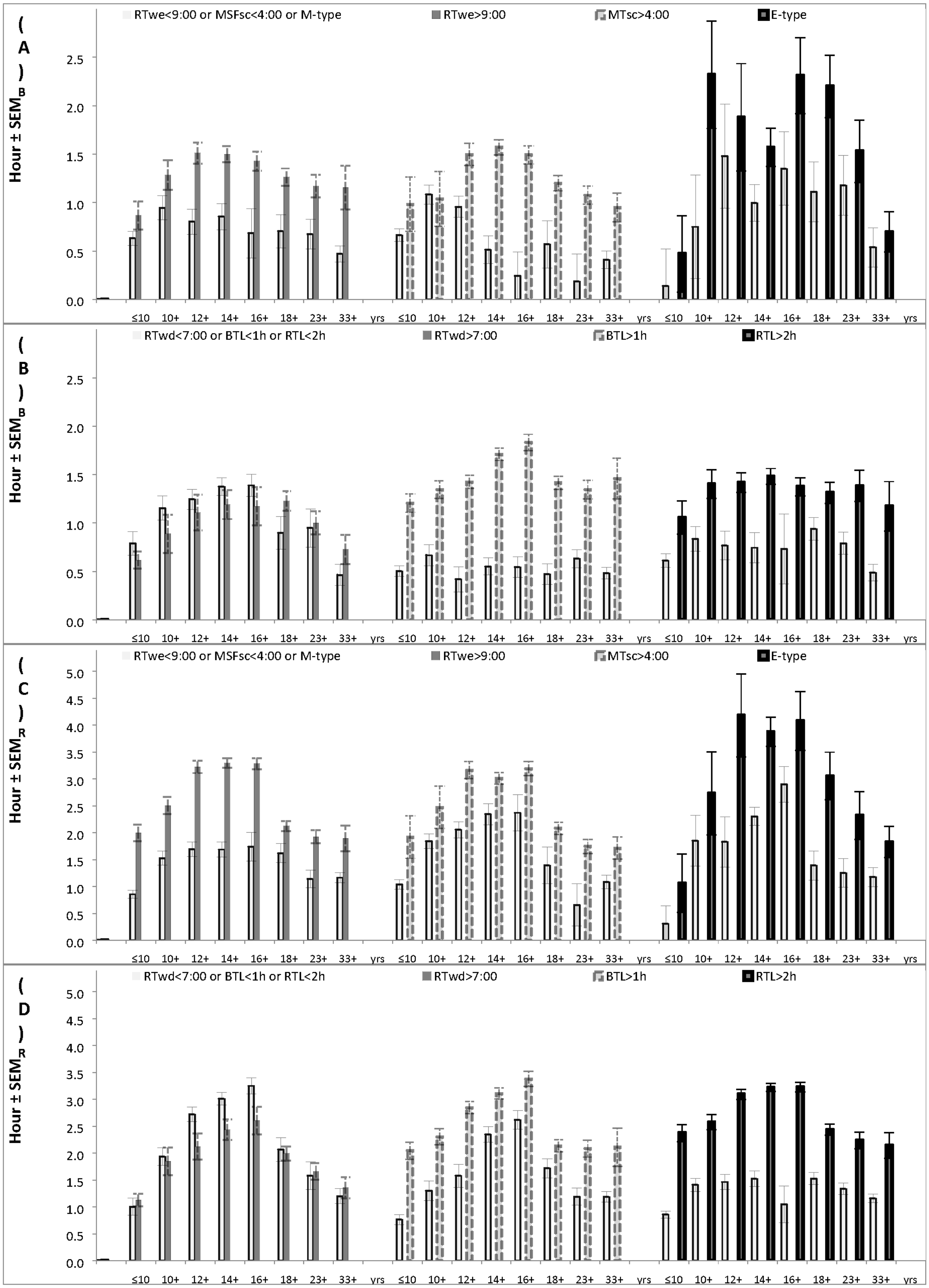
(A)
RTwe<9:00 or MSFsc<4:00 or M-type
RTwe>9:00
MTsc>4:00
E-type
Hour ± SEM$_B$
(B)
RTwd<7:00 or BTL<1h or RTL<2h
RTwd>7:00
BTL>1h
RTL>2h
Hour ± SEM$_B$
(C)
Hour ± SEM$_R$
(D)
Hour ± SEM$_R$
≤10 10+ 12+ 14+ 16+ 18+ 23+ 33+ yrs

Figure S3

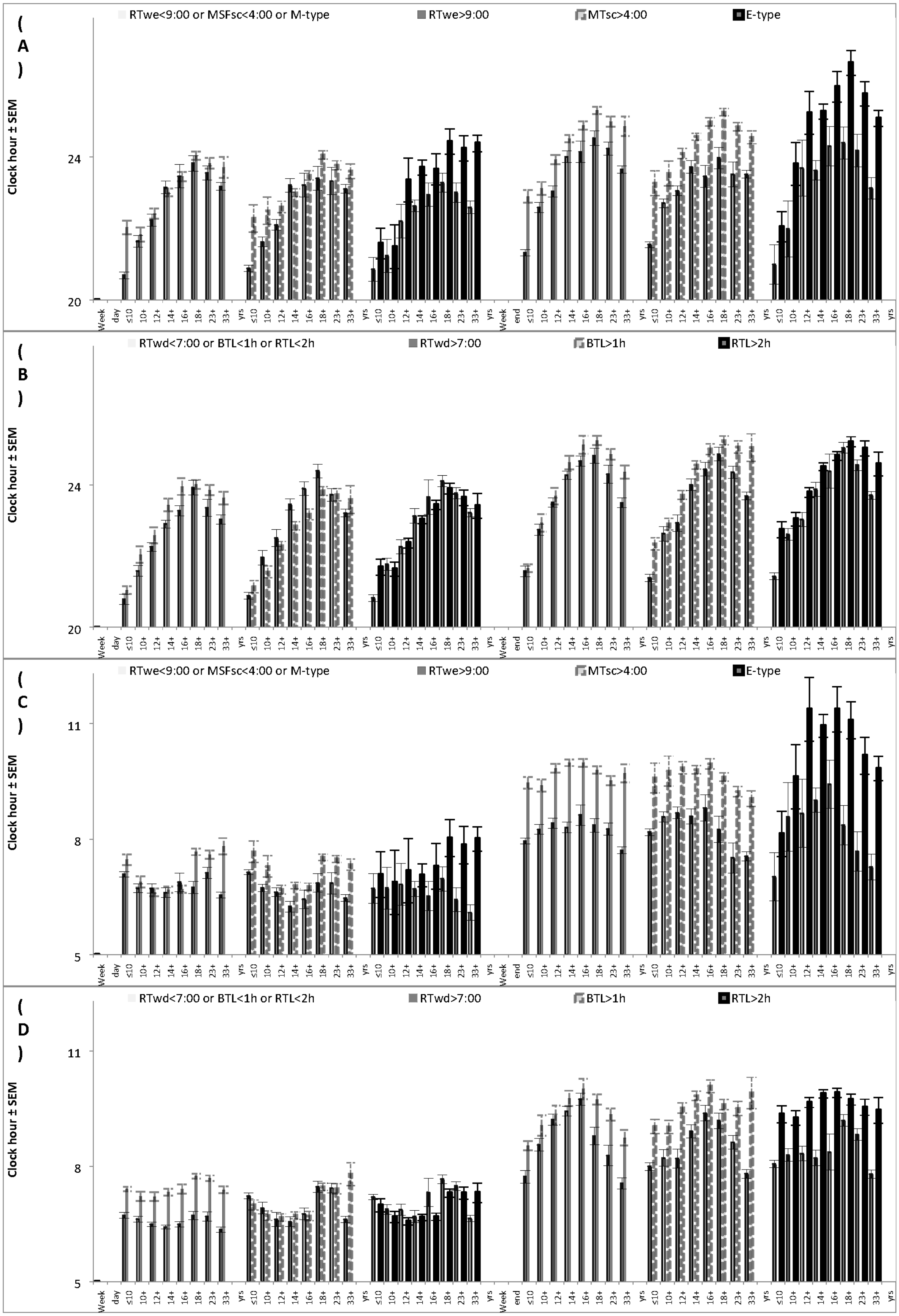
(A)
RTwe<9:00 or MSFsc<4:00 or M-type
RTwe>9:00
MTsc>4:00
E-type
Clock hour ± SEM
(B)
RTwd<7:00 or BTL<1h or RTL<2h
RTwd>7:00
BTL>1h
RTL>2h
(C)
(D)
Week day
Week end
≤10 10+ 12+ 14+ 16+ 18+ 23+ 33+ yrs

Figure S4

Supplementary2_320samples to

Evening chronotype, late weekend sleep times and social jetlag as possible causes of sleep cur

Sample	Time wher	Weekdays		Weekends		Published in		Mean	Country	Note
#	collected	BT	RT	BT	RT	Author(s)	Year	age		#
201	2	19.97	7.32	20.03	7.45	Randler et al.	2019	0.0	Germany	
1	1	20.12	7.25	20.17	7.37	Randler et al	2012	0.5	Germany	
2	1	19.90	7.15	20.07	7.37	Randler et al	2012	1.0	Germany	
202	2	19.75	7.13	19.95	7.42	Randler et al.	2019	1.0	Germany	
3	1	21.40	8.10	21.50	8.50	Thorleifsdottir et al	2002	1.5	Iceland	5
4	1	20.13	7.20	20.42	7.53	Randler et al	2012	2.0	Germany	
203	2	19.95	7.10	20.23	7.57	Randler et al.	2019	2.0	Germany	
5	1	21.10	8.30	21.60	8.75	Thorleifsdottir et al	2002	2.5	Iceland	5
6	1	19.90	7.13	20.23	7.48	Randler et al	2012	3.0	Germany	
204	2	19.73	7.03	20.12	7.52	Randler et al.	2019	3.0	Germany	
7	1	19.85	7.08	20.33	7.47	Randler et al	2012	4.0	Germany	
8	1	20.02	6.88	20.63	7.37	Touchette et al	2008	4.0	Canada	
9	1	21.16	6.95	21.46	7.53	Doi et al	2016	4.0	Japan	4
191	2	21.27	6.85	21.58	7.64	Fukuda et al.	2019	4.0	Japan	4
205	2	19.83	7.08	20.35	7.70	Randler et al.	2019	4.0	Germany	
308	2	21.70	7.82	21.18	8.85	Clara, Gomes	2019	4.0	Portugal	
10	1	21.80	8.45	22.15	8.98	Thorleifsdottir et al	2002	4.5	Iceland	5
11	1	21.60	7.10	22.00	9.20	Mishra et al	2017	4.5	India	
12	1	19.88	7.18	20.45	7.57	Randler et al	2012	5.0	Germany	
13	1	20.00	6.87	20.72	7.48	Touchette et al	2008	5.0	Canada	
206	2	19.93	7.08	20.52	7.80	Randler et al.	2019	5.0	Germany	
309	2	21.75	7.75	22.32	8.87	Clara, Gomes	2019	5.0	Portugal	
279	2	20.32	7.03	21.08	7.73	Stoner et al.	2018	5.5	New Zealand	
14	1	20.26	7.04	21.36	8.56	Spruyt et al	2005	6.0	Belgium	
15	1	19.75	6.78	20.48	7.42	Randler et al	2012	6.0	Germany	
16	1	19.83	6.70	20.73	7.43	Touchette et al	2008	6.0	Canada	
207	2	19.98	6.93	20.82	7.87	Randler et al.	2019	6.0	Germany	
310	2	21.90	7.72	22.42	8.93	Clara, Gomes	2019	6.0	Portugal	
17	1	22.20	8.50	22.70	8.01	Thorleifsdottir et al	2002	6.5	Iceland	5
18	1	20.43	6.43	21.14	6.93	Gruber et al	2018	6.5	Canada	3
287	2	21.00	6.70	21.60	7.40	Park et al.	2002	6.5	Japan	5
19	1	20.28	7.12	20.78	7.85	Werner et al	2009	6.7	Switzerland	
20	1	20.37	7.05	21.57	8.69	Spruyt et al	2005	7.0	Belgium	
208	2	20.23	6.82	21.20	8.08	Randler et al.	2019	7.0	Germany	
285	2	22.50	6.87	22.92	7.76	Weaver et al.	2019	7.0	USA	7
311	2	21.95	7.72	22.63	9.05	Clara, Gomes	2019	7.0	Portugal	
21	1	21.83	7.25	22.87	10.27	Russo et al	2007	8.0	Italy	
22	1	20.47	7.02	21.64	8.67	Spruyt et al	2005	8.0	Belgium	
23	1	21.90	6.90	22.50	8.90	Mishra et al	2017	8.0	India	
209	2	20.43	6.73	21.57	8.13	Randler et al.	2019	8.0	Germany	
312	2	21.97	7.65	22.65	9.10	Clara, Gomes	2019	8.0	Portugal	
24	1	22.50	8.45	23.10	9.20	Thorleifsdottir et al	2002	8.5	Iceland	5
25	1	20.83	6.43	21.69	7.25	Gruber et al	2018	8.5	Canada	3
288	2	21.40	6.60	21.70	7.40	Park et al.	2002	8.5	Japan	5
26	1	21.97	7.18	23.00	10.22	Russo et al	2007	9.0	Italy	
27	1	20.67	7.05	21.86	8.79	Spruyt et al	2005	9.0	Belgium	
28	1	20.95	5.88	22.18	7.97	Arora et al	2018	9.0	Qatar	
29	1	21.98	7.33	23.08	9.27	Esposito et al	2014	9.0	Italy	

30	1	21.97	7.27	23.13	9.33	Esposito et al	2014	9.0	Italy	
31	1	22.18	7.27	23.43	9.47	Esposito et al	2014	9.0	Italy	
32	1	21.47	6.63	22.05	7.25	Crowley et al	2014	9.0	USA	
210	2	20.47	6.73	21.92	8.47	Randler et al.	2019	9.0	Germany	
313	2	22.07	7.67	22.75	9.15	Clara, Gomes	2019	9.0	Portugal	
33	1	22.35	7.52	22.92	8.98	Zhang et al	2010	9.2	Hong Kong	
34	1	20.48	6.98	21.43	7.84	Laberge et al	2001	10.0	Canada	3
35	1	22.15	7.30	23.25	10.10	Russo et al	2007	10.0	Italy	
36	1	20.79	7.07	22.04	8.89	Spruyt et al	2005	10.0	Belgium	
37	1	21.73	6.77	22.43	7.37	Crowley et al	2014	10.0	USA	
211	2	20.62	6.67	22.30	8.73	Randler et al.	2019	10.0	Germany	
314	2	22.12	7.42	22.80	9.25	Clara, Gomes	2019	10.0	Portugal	
38	1	22.60	7.75	23.45	9.40	Thorleifsdottir et al	2002	10.5	Iceland	5
39	1	21.53	6.56	22.62	7.76	Gruber et al	2018	10.5	Canada	3
289	2	21.70	6.80	22.60	7.80	Park et al.	2002	10.5	Japan	5
40	1	21.50	7.08	22.37	8.42	Carskadon	1990	11.0	USA	
41	1	21.40	6.70	22.52	8.88	Carskadon	2011	11.0	USA	1
42	1	20.78	6.98	21.76	8.13	Laberge et al	2001	11.0	Canada	3
43	1	22.37	7.08	23.48	9.98	Russo et al	2007	11.0	Italy	
44	1	20.96	7.04	22.19	8.96	Spruyt et al	2005	11.0	Belgium	
46	1	21.98	6.65	22.63	7.52	Crowley et al	2014	11.0	USA	
47	1	21.28	6.77	22.78	9.82	Kubiszewski et al	2014	11.0	France	
212	2	20.93	6.47	22.75	9.03	Randler et al.	2019	11.0	Germany	
246	2	21.75	6.83	23.17	8.75	Roth et al.	2019	11.0	Israel	7
315	2	22.20	7.33	22.92	9.32	Clara, Gomes	2019	11.0	Portugal	
48	1	22.70	7.30	23.00	8.10	Yang et al	2005	11.2	Korea	
49	1	22.10	6.18	22.58	7.38	Komada et al	2016	11.3	Japan	
268	2	21.26	6.53	22.83	8.73	Foley et al.	2018	11.5	USA	3
50	1	21.50	7.08	22.37	8.42	Carskadon	1990	12.0	USA	
51	1	21.87	6.58	23.08	9.20	Carskadon	2011	12.0	USA	1
52	1	21.62	6.17	23.18	8.78	Manber et al	1995	12.0	USA	
53	1	21.02	6.97	22.11	8.32	Laberge et al	2001	12.0	Canada	3
54	1	22.52	7.05	23.67	9.92	Russo et al	2007	12.0	Italy	
55	1	21.12	6.97	22.34	9.08	Spruyt et al	2005	12.0	Belgium	
56	1	22.53	6.57	23.73	9.17	Gau & Merikangas	2004	12.0	Taiwan	
57	1	22.12	6.33	22.82	7.47	Crowley et al	2014	12.0	USA	
58	1	21.36	6.81	22.89	9.10	Arora &Taheri	2015	12.0	UK	4
200	2	21.56	6.6	22.78	8.50	Mireku et al.	2019	12.0	UK	3
213	2	21.35	6.42	23.15	9.33	Randler et al.	2019	12.0	Germany	
59	1	23.22	7.53	23.87	8.68	Hasler et al	2012	12.3	USA	
60	1	23.15	7.95	24.50	10.30	Thorleifsdottir et al	2002	12.5	Iceland	5
61	1	23.00	6.95	24.05	9.83	Chung et al	2008	12.5	Hong Kong	
290	2	22.40	6.90	23.50	8.20	Park et al.	2002	12.5	Japan	5
62	1	22.10	6.83	23.33	8.75	Carskadon	1990	13.0	USA	
63	1	21.88	6.60	23.43	9.35	Carskadon	2011	13.0	USA	1
64	1	21.49	6.93	22.57	8.76	Laberge et al	2001	13.0	Canada	3
65	1	22.55	7.13	23.70	10.13	Russo et al	2007	13.0	Italy	
66	1	21.12	7.09	22.31	8.98	Spruyt et al	2005	13.0	Belgium	
67	1	21.56	6.92	22.96	9.65	Van den Bulck	2004	13.0	Belgium	3
68	1	22.10	6.80	21.90	8.70	Mishra et al	2017	13.0	India	
69	1	22.50	6.33	23.33	7.92	Crowley et al	2014	13.0	USA	
214	2	21.72	6.38	23.67	9.70	Randler et al.	2019	13.0	Germany	

229	2	22.30	6.20	23.20	8.60	Yeo et al.	2018	13.0	Singapore	5
244	2	22.62	6.63	24.08	9.53	Zerbini et al.	2017	13.0	The Netherlands	
252	2	21.60	6.28	23.07	8.86	Thoma et al.	2019	13.0	Germany	7
70	1	21.85	6.60	22.07	6.88	Peixoto et al	2009	13.1	Brazil	10
71	1	23.20	7.00	23.50	8.90	Yang et al	2005	13.3	Korea	
72	1	21.77	6.20	23.80	9.72	Randler et al	2016	13.4	Germany	
73	1	22.43	6.50	23.58	10.00	Brandalize et al	2011	13.4	Brazil	11
74	1	22.08	5.98	23.90	9.37	Wolfson & Carskadc	1998	13.5	USA	
75	1	22.22	6.25	22.47	8.30	Liu et al	2008	13.5	China	
240	2	21.90	6.20	23.10	9.20	Temkin et al.	2018	13.5	USA	
253	2	22.30	7.08	23.43	8.27	Hanish & Han	2018	13.5	USA	7
317	2	21.65	6.37	23.32	9.52	Weidenauer et al.	2019	13.5	Germany	
76	1	22.78	7.01	24.46	10.02	Russo et al	2007	13.8	Italy	4
77	1	22.68	6.22	23.08	7.57	Komada et al	2016	13.9	Japan	
78	1	22.25	6.47	23.88	9.90	Carskadon	2011	14.0	USA	1
79	1	22.17	5.93	23.95	9.23	Carskadon	1990	14.0	USA	
80	1	22.72	7.03	23.95	10.33	Russo et al	2007	14.0	Italy	
81	1	23.38	6.98	24.48	10.25	Chung et al	2008	14.0	Hong Kong	
82	1	22.17	7.07	23.45	8.35	Short et al	2013	14.0	Australia	
83	1	22.00	6.75	23.77	10.32	Kubiszewski et al	2014	14.0	France	
84	1	23.37	6.88	24.53	9.63	Boergers et al	2014	14.0	USA	11
215	2	22.17	6.40	24.15	10.07	Randler et al.	2019	14.0	Germany	
230	2	22.40	6.40	23.40	8.90	Yeo et al.	2018	14.0	Singapore	5
255	2	23.10	6.19	24.61	10.52	Arrona-Palacios	2017	14.0	Mexico	9, 11
256	2	22.82	6.08	24.42	9.88	Arrona-Palacios & D	2017	14.0	Mexico	11
85	1	20.33	6.93	23.78	9.52	Gariépy et al	2017	14.1	Canada	
86	1	23.13	7.34	24.66	10.63	Collado et al	2012	14.1	Spain	4
87	1	23.45	7.80	24.42	10.33	Arrona-Palacios	2015	14.1	Mexico	4
88	1	23.23	7.30	25.06	10.71	Diaz-Morales et	2007	14.3	Spain	4
89	1	23.80	7.95	25.55	10.50	Thorleifsdottir et al	2002	14.5	Iceland	5
90	1	23.32	6.73	24.27	10.20	Li et al.	2018	14.5	Hong Kong	4
195	2	22.86	6.61	24.79	10.23	Koscec et al.	2013	14.5	Croatia	4, 11
227	2	22.87	6.52	23.66	8.42	Harvey et al.	2018	14.5	USA	7
248	2	23.33	7.70	24.57	8.78	Martin et al.	2016	14.5	Canada	4
291	2	23.70	7.00	24.60	8.80	Park et al.	2002	14.5	Japan	5
91	1	22.40	6.08	24.18	9.40	Carskadon	2011	15.0	USA	1
92	1	22.33	6.00	24.10	9.67	Wolfson & Carskadc	1998	15.0	USA	
93	1	22.53	6.38	24.05	9.85	Carskadon	2011	15.0	USA	1
94	1	22.79	6.92	24.46	9.92	Giannotti et al.	2002	15.0	Italy	4
95	1	23.43	7.02	24.52	10.38	Chung et al	2008	15.0	Hong Kong	
96	1	24.00	6.80	23.60	9.50	Yang et al	2005	15.0	Korea	
97	1	22.50	7.20	23.62	8.63	Short et al	2013	15.0	Australia	
98	1	22.57	6.37	23.32	7.85	Crowley et al	2014	15.0	USA	
99	1	23.50	6.97	24.90	9.90	Boergers et al	2014	15.0	USA	11
196	2	23.21	5.69	23.65	7.62	Pande et al.	2018	15.0	India	4
216	2	22.45	6.37	24.62	10.38	Randler et al.	2019	15.0	Germany	
231	2	23.50	6.00	24.10	9.10	Yeo et al.	2018	15.0	Singapore	5
272	2	22.99	5.60	23.31	7.25	Pande et al.	2018	15.0	India	
100	1	23.85	6.45	24.23	9.38	Seo et al	2017	15.3	Korea	
101	1	23.73	7.13	24.94	10.24	Borisenkov et al.	2016	15.4	Russia	
102	1	22.57	6.62	24.98	10.75	Perkinson-Gloor et a	2013	15.4	Switzerlar	11
242	2	23.37	6.33	24.51	9.73	Mathew et al.	2019	15.5	USA	3

254	2	21.25	6.53	23.33	10.50	Brand et al.	2009	15.5	Switzerlan	7
275	2	23.76	6.31	25.10	8.39	Quante et al.	2018	15.5	USA	
103	1	24.10	7.09	25.47	11.11	Borisenkov et al.	2016	15.6	Russia	
104	1	22.52	6.63	25.10	10.32	Preckel et al	2013	15.6	Germany	
45	1	22.35	6.53	22.37	8.42	Warner et al	2008	16.0	Australia	6
105	1	22.65	6.13	23.93	9.25	Manber et al	1995	16.0	USA	
106	1	22.87	6.22	24.47	9.35	Carskadon	1990	16.0	USA	
107	1	22.62	6.08	24.50	9.77	Wolfson & Carskadc	1998	16.0	USA	
108	1	22.85	6.38	24.42	10.10	Carskadon	2011	16.0	USA	1
109	1	22.36	6.46	22.80	9.44	Knutson & Lauderda	2009	16.0	USA	2
110	1	22.50	6.91	25.94	10.22	Van den Bulck	2004	16.0	Belgium	3
111	1	23.58	6.97	24.67	10.32	Chung et al	2008	16.0	Hong Kong	
112	1	22.70	7.30	23.93	8.53	Short et al	2013	16.0	Australia	
113	1	22.77	6.33	24.28	9.67	Wolfson et al	2003	16.0	USA	8
114	1	22.90	6.38	24.13	8.77	Wolfson et al	2003	16.0	USA	8
115	1	22.98	6.30	24.18	8.72	Wolfson et al	2003	16.0	USA	8
116	1	22.88	6.47	23.78	8.13	Crowley et al	2014	16.0	USA	
117	1	24.60	6.65	25.25	9.73	Kim et al	2011	16.0	Korea	
118	1	23.90	6.42	23.95	7.90	Komada et al	2016	16.0	Japan	
119	1	24.02	7.08	24.58	9.95	Boergers et al	2014	16.0	USA	11
197	2	23.23	7.32	24.63	9.63	Harbard et al.	2016	16.0	Australia	6
217	2	22.63	6.37	24.92	10.42	Randler et al.	2019	16.0	Germany	
232	2	23.70	6.10	24.30	9.30	Yeo et al.	2018	16.0	Singapore	5
249	2	22.50	6.50	24.50	10.00	Garmy & Ward	2018	16.0	Sweden	
281	2	23.73	7.35	24.20	8.45	Tashjian et al.	2019	16.0	USA	
120	1	23.28	7.33	24.63	9.62	Bei et al	2014	16.2	Australia	6
121	1	22.24	6.90	23.10	9.04	Agostini et al	2017	16.2	USA	9
122	1	22.63	6.00	22.80	8.77	Liu et al	2008	16.4	China	
123	1	22.73	5.92	24.68	9.85	Link & Ancoli-Israel	1995	16.5	USA	
124	1	24.01	8.08	26.20	10.80	Thorleifsdottir et al	2002	16.5	Iceland	5
199	2	23.32	6.89	24.80	10.31	Short et al.	2019	16.5	Finland	9
292	2	23.90	6.90	25.00	9.00	Park et al.	2002	16.5	Japan	5
125	1	23.89	7.05	24.85	10.27	Borisenkov et al.	2016	16.6	Russia	
126	1	23.08	6.20	24.35	9.33	Sousa et al	2013	16.8	Brazil	7
127	1	22.97	6.43	24.65	9.35	Carskadon	1990	17.0	USA	
128	1	23.03	6.52	24.75	9.85	Carskadon	2011	17.0	USA	1
129	1	23.07	6.57	24.02	8.13	Crowley et al	2014	17.0	USA	
130	1	24.58	6.63	25.23	9.63	Kim et al	2011	17.0	Korea	
131	1	23.03	6.48	25.38	10.82	Kubiszewski et al	2014	17.0	France	
132	1	24.58	7.22	25.13	9.92	Boergers et al	2014	17.0	USA	11
218	2	22.73	6.28	25.18	10.47	Randler et al.	2019	17.0	Germany	
233	2	23.80	6.40	24.60	9.50	Yeo et al.	2018	17.0	Singapore	5
269	2	24.53	7.45	25.61	10.37	Friborg et al.	2018	17.0	Norway	12
133	1	24.90	6.30	23.90	9.30	Yang et al	2005	17.1	Korea	
134	1	22.52	6.25	24.53	10.12	Randler et al	2016	17.1	Germany	
135	1	22.77	6.33	24.28	9.67	Wolfson & Carskadc	1998	17.5	USA	
136	1	23.00	6.80	25.42	10.30	Giannotti et al.	2002	17.5	Italy	4
137	1	23.59	7.03	24.84	10.50	Lehto et al	2016	17.5	Finland	4
198	2	23.5	7.00	25.00	10.00	Cabré-Riera et al.	2019	17.5	Spain	
138	1	23.28	6.78	25.52	11.22	Sivertsen et al	2013	17.8	Norway	7
139	1	21.85	6.17	24.82	9.53	Wolfson & Carskadc	1998	18.0	USA	
140	1	23.78	6.87	24.77	10.43	Chung et al	2008	18.0	Hong Kong	

141	1	24.23	8.07	24.75	8.60	Crowley et al	2014	18.0	USA	
142	1	24.80	6.52	25.38	9.55	Kim et al	2011	18.0	Korea	
219	2	23.10	6.53	25.40	10.45	Randler et al.	2019	18.0	Germany	
234	2	24.20	6.60	24.70	9.40	Yeo et al.	2018	18.0	Singapore	5
143	1	24.30	8.08	26.20	10.60	Thorleifsdottir et al	2002	18.5	Iceland	5
283	2	23.40	6.90	24.78	9.53	Urner et al.	2009	18.5	Switzerland	
293	2	23.80	6.80	24.90	8.40	Park et al.	2002	18.5	Japan	5
144	1	24.42	6.30	25.18	8.58	Miller et al	2010	18.8	USA	
220	2	23.25	7.02	25.22	10.30	Randler et al.	2019	19.0	Germany	
262	2	23.03	7.47	24.77	9.38	Porcheret et al.	2018	19.0	Australia	
235	2	24.64	6.63	24.73	8.73	Kato et al.	2018	19.5	Japan	
145	1	23.73	7.11	25.30	9.59	Korczak et al.	2008	19.6	Brazil	4
146	1	23.99	7.81	25.50	9.95	Kabrita et al	2014	19.6	Lebanon	4
147	1	24.28	8.03	25.73	10.13	Lund et al	2010	20.0	USA	
148	1	24.00	8.07	25.02	9.75	Zavada et al	2005	20.0	The Netherlands	
221	2	23.33	7.47	25.30	10.23	Randler et al.	2019	20.0	Germany	
264	2	23.02	7.00	24.77	9.17	Porcheret et al.	2018	20.0	New Zealand	
271	2	23.20	6.85	23.80	8.88	Tomažič1 & Randler	2019	20.0	Slovenija	
277	2	23.78	6.52	24.30	8.20	Lima et al.	2002	20.0	Brazil	11
149	1	24.25	8.25	25.70	9.98	Thorleifsdottir et al	2002	20.5	Iceland	5
243	2	22.92	6.50	23.95	7.90	Sargent et al.	2014	20.5	Australia	15
263	2	24.20	7.33	24.98	9.75	Porcheret et al.	2018	20.5	Australia	
278	2	25.56	8.55	25.55	9.43	Tsai & Li	2004	20.5	Taiwan	3
294	2	23.90	6.70	24.90	8.20	Park et al.	2002	20.5	Japan	5
150	1	24.18	7.52	24.72	9.82	Jankowski et al	2014	20.8	Poland	
151	1	25.56	8.55	25.55	9.43	Tsai & Li	2004	21.0	Taiwan	3
222	2	23.43	7.48	25.18	10.10	Randler et al.	2019	21.0	Germany	
259	2	24.70	7.92	25.50	9.87	Porcheret et al.	2018	21.0	UK	
282	2	23.77	7.63	24.83	9.30	Umemura et al.	2018	21.0	Brazil	
152	1	23.84	7.58	25.74	9.63	Vitale et al	2015	21.3	Italy	4
260	2	24.32	8.03	25.23	9.88	Porcheret et al.	2018	21.5	The Netherlands	
153	1	23.90	7.87	24.90	9.88	Jankowski et al	2014	21.7	Germany	
154	1	24.38	7.78	24.92	9.60	Lo et al	2014	21.8	Singapore	
155	1	24.32	7.12	25.37	9.68	Kim et al	2010	22.0	Korea	
156	1	24.62	6.90	25.87	10.20	Teixeira et al	2012	22.0	Brazil	
223	2	23.50	7.52	25.28	10.02	Randler et al.	2019	22.0	Germany	
157	1	24.20	8.02	25.80	9.98	Thorleifsdottir et al	2002	22.5	Iceland	5
261	2	24.03	7.50	25.15	9.68	Porcheret et al.	2018	22.5	Germany	
318	2	23.70	7.59	23.83	8.04	Appleman et al.	2013	22.5	USA	
158	1	23.88	8.33	25.15	10.05	Friborg et al	2012	22.7	Norway	12
239	2	23.78	8.00	25.22	9.90	Zerbini et al.	2019	22.7	The Nethe	7
267	2	24.43	8.06	25.57	9.02	Zerbini et al.	2019	22.7	The Nethe	7
159	1	24.46	6.98	25.51	9.70	Mirghani	2017	23.0	Sudan	3
224	2	23.62	7.62	25.33	9.95	Randler et al.	2019	23.0	Germany	
295	2	24.00	6.80	25.10	8.30	Park et al.	2002	23.0	Japan	5
160	1	23.75	7.75	24.13	8.51	Friborg et al	2014	23.4	Norway	12
238	2	23.70	7.18	25.05	9.97	Zerbini et al.	2019	23.5	The Nethe	7
266	2	24.34	7.65	25.52	9.58	Zerbini et al.	2019	23.5	The Nethe	7
284	2	24.03	7.77	25.27	9.80	Urner et al.	2009	23.5	Switzerland	
225	2	23.67	7.83	25.33	9.90	Randler et al.	2019	24.0	Germany	
257	2	23.70	7.77	24.65	9.37	Santisteban et al.	2018	24.0	Canada	14
258	2	24.95	8.40	25.08	8.75	Santisteban et al.	2018	24.0	Canada	14

161	1	24.27	7.95	25.75	9.80	Thorleifsdottir et al	2002	24.5	Iceland	5
270	2	23.47	6.98	24.22	8.10	Kayaba et al.	2018	24.5	Japan	16
162	1	23.85	7.83	24.93	9.95	Björkqvist et al	2014	24.9	Finland	7
163	1	23.30	7.34	24.87	9.52	Randler et al	2014	25.0	Germany	3
164	1	23.52	7.93	24.47	9.18	Lo et al	2014	25.0	UK	
226	2	23.62	7.65	25.18	9.67	Randler et al.	2019	25.0	Germany	
250	2	23.17	7.08	24.22	9.02	Bijlenga et al.	2011	25.0	The Nethe	7
276	2	24.45	7.48	25.15	9.03	Rahafar et al.	2018	25.0	Germany	
165	1	22.58	6.47	22.53	6.64	Friborg et al	2012	25.4	Gana	12
320	2	23.38	7.42	24.66	9.38	Kasaeian et al.	2019	25.5	Germany	
166	1	23.53	7.74	24.44	9.26	Santhi et al	2016	25.6	UK	3
167	1	23.60	7.93	24.21	8.68	Rosenthal et al	2001	26.0	USA	4
193	2	23.75	6.79	25.25	9.36	Sexton-Radex & Har	1992	26.0	USA	4
168	1	24.35	8.00	25.45	9.95	Thorleifsdottir et al	2002	26.5	Iceland	5
192	2	23.50	6.70	25.45	8.75	Takahashi et al.	2018	26.5	Singapore	4
280	2	23.88	7.50	24.63	9.80	Suh et al.	2018	27.0	Korea	
296	2	23.70	6.70	24.60	8.10	Park et al.	2002	27.0	Japan	5
169	1	23.80	7.63	24.80	9.22	Zavada et al	2005	27.5	The Netherlands	
170	1	24.20	7.80	25.10	9.20	Thorleifsdottir et al	2002	28.5	Iceland	5
171	1	23.07	6.38	24.23	8.63	Soehner et al	2011	31.5	USA	
245	2	23.70	7.50	23.90	8.10	Chang et al.	2009	32.0	USA	7
297	2	23.70	6.60	24.10	7.80	Park et al.	2002	32.0	Japan	5
172	1	23.05	6.93	24.02	8.82	Randler et al	2015	32.8	Poland	
237	2	23.82	9.07	25.60	11.38	Waleriańczyk et al.	2019	33.5	Poland	
173	1	23.72	7.57	24.48	9.17	Randler et al	2015	34.0	Spain	
174	1	23.57	7.10	24.33	8.48	Zavada et al	2005	35.0	The Netherlands	
194	2	23.88	7.93	25.31	9.70	Miller-Mendes et al.	2019	35.0	Portugal	4
273	2	23.60	7.28	24.47	9.28	Pilz et al.	2018	35.0	Brazil	17
274	2	23.48	7.23	24.42	9.03	Pilz et al.	2018	35.0	Brazil	17
286	2	24.25	7.00	24.47	7.37	Zhang et al.	2019	35.0	China	9
175	1	23.82	7.48	24.34	8.91	Roepke&Duffy	2010	36.0	USA	4
176	1	23.20	7.03	24.03	8.99	Taillard et al	1999	36.1	France	4
298	2	23.70	6.40	24.00	7.60	Park et al.	2002	37.0	Japan	5
177	1	23.07	6.38	24.23	8.63	Borchers et al	2015	38.6	Côte d'Ivoire	
251	2	23.00	6.70	23.68	7.60	Bijlenga et al.	2011	40.0	The Nethe	7
178	1	23.35	6.82	23.85	8.45	Gau & Merikangas	2004	41.0	Taiwan	
179	1	23.20	6.58	23.68	8.00	Paine & Gander	2016	41.1	New Zeala	4
180	1	23.40	7.19	23.73	8.69	Zhang et al	2010	41.2	Hong Kong	3
299	2	23.50	6.30	24.00	7.50	Park et al.	2002	42.0	Japan	5
181	1	22.60	6.68	23.32	8.33	Randler et al	2015	42.6	Germany	
182	1	23.15	6.50	24.03	8.51	Ursin et al	2005	43.0	Norway	3
183	1	24.02	7.13	24.18	7.83	Campanini et al	2017	45.0	Brazil	13
184	1	23.97	6.60	24.35	7.97	Campanini et al	2017	45.0	Brazil	13
265	2	23.33	5.71	23.58	7.33	Lowden et al.	2018	45.5	Sweden	12
228	2	23.47	6.00	23.67	7.15	Islam et al.	2018	46.0	Japan	9
241	2	22.78	6.40	23.15	7.80	Hulsegge et al.	2019	46.0	The Nethe	7
300	2	23.60	6.30	23.90	7.40	Park et al.	2002	47.0	Japan	5
185	1	23.77	6.53	24.20	7.43	Hashizaki et al	2015	47.9	Japan	
186	1	23.70	7.07	24.32	7.80	Zavada et al	2005	50.0	The Netherlands	
187	1	24.43	6.87	24.53	8.59	Chan et al	2014	50.8	Hong Kong	4
188	1	23.14	6.49	23.55	7.95	Taillard et al	2004	51.3	France	4
236	2	23.49	6.08	23.65	7.08	Kato et al.	2018	52.0	Japan	

247	2	22.50	6.5	23.25	7.72	Mokhlesi et al.	2019	52.0	USA	
301	2	23.20	6.20	23.70	7.30	Park et al.	2002	52.0	Japan	5
189	1	23.73	6.61	24.50	8.20	Johnsen et al	2013	54.3	Norway	3
319	2	22.20	6.00	22.50	7.00	Mota et al.	2019	56.0	Brazil	
302	2	22.70	6.00	23.60	7.10	Park et al.	2002	57.0	Japan	5
190	1	22.70	7.00	23.26	7.73	Reutrakul et al	2013	58.4	Mexico	4
316	2	23.70	7.33	24.09	8.02	Kelly et al.	2019	61.5	Ireland	
303	2	22.50	6.10	23.20	6.90	Park et al.	2002	62.0	Japan	5
304	2	22.20	6.10	22.30	6.60	Park et al.	2002	67.0	Japan	5
305	2	21.90	6.20	22.20	6.70	Park et al.	2002	72.0	Japan	5
306	2	21.80	6.20	22.10	6.40	Park et al.	2002	77.0	Japan	5
307	2	21.50	6.20	21.60	6.60	Park et al.	2002	85.0	Japan	5

1 - averaged and simulated in the previous reports

2 - more recently added

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Explanation	Three methods
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Taken from a g	0
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Averaged over	0
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Taken from a g	0
Averaged over	2
Taken from a g	0
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Data of control	2
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Taken from a g	0
Averaged over	2
Taken from a g	0
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Averaged over	0
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Taken from a g	0
Averaged over	2
Taken from a g	0
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Sleep in Americ	0
Averaged over	0
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Data of control	2
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Averaged over	0
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Sleep in Americ	0
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Averaged over	0
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Averaged over	0
Averaged over	0
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Taken from a g	0
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Taken from a g	0
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Sleep in Americ	0
Averaged over	0
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Taken from a g	0
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Data of control	1
Living with elec	2
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Early school sta	0
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Data of control	2
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Averaged over	0
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Sleep in Americ	0
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Early school sta	0
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Taken from a g	0
Averaged over	0
Early school sta	0
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Averaged over	0
Averaged over	2
Averaged over	0
Taken from a g	0
Averaged over	0
Averaged over	0
Data of control	1
Averaged over	2
Taken from a g	0
Sleep in Americ	0
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Sleep in Americ	0
Averaged over	0
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Averaged over	0
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Early school sta	0
Averaged over	0

Data of control	1
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Free days are h	0
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Sleep in Americ	0
Averaged over	0
Averaged over	0
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Data of Survey,	0
Data of Survey,	1
Data of Survey,	2
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Early school sta	0
Free days are h	0
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Taken from a g	0
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Free days are h	2
Averaged over	2
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Averaged over	0
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Data of control	1
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Early school sta	0
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Taken from a g	0
Averaged over	1
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Data of control	0
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Taken from a g	0
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Taken from a g	0
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Averaged over	2
Averaged over	0
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Early school sta	0
Taken from a g	0
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Averaged over	1
Taken from a g	0
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Averaged over	1
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Averaged over	2
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Taken from a g	0
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Averaged over	1
Data of control	0
Data of control	0
Averaged over	0
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Taken from a g	0
Averaged over	1
Data of control	0
Data of control	0
	2
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Data of Survey,	0
Data of Survey,	2

Taken from a g	0
Narcolepsy dia	0
Data of control	2
Averaged over	0
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Data of control	0
	0
Averaged over	1
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Averaged over	2
Averaged over	0
Averaged over	0
Taken from a g	0
Averaged over	0
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Taken from a g	0
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Taken from a g	0
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Data of control	2
Taken from a g	0
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;	0
Averaged over	0
Data of Survey,	1
Data of Survey,	0
Averaged over	2
Averaged over	0
Averaged over	0
Taken from a g	0
	0
Data of control	0
	0
Averaged over	2
Averaged over	0
Taken from a g	0
	0
Averaged over	0
Data of Diary, A	2
Data of Diary, A	1
Averaged over	2
Averaged over	0
Data of control	2
Taken from a g	0
	2
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Averaged over	0
Averaged over	0
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Taken from a g	0
Averaged over	0
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Taken from a g	0
Averaged over	0
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Taken from a g	0
Taken from a g	0
Taken from a g	0
Taken from a g	0
Taken from a g	0

2 - Actigra
1 - Dairy
0 - Survey

ng perennial DST: ain't they as black as they are painted?

Reference in more details

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Supplementary3. Simulation

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Evening chronotype, late weekend sleep times and social jetlag as possible causes of sleep curtailment after maintaining perennial DST: ain't they as black as they are painted?

1. Model and Simulations

In order to perform simulations of sleep times, the previously proposed variant of two-process model of sleep-wake regulation was used (Putilov, 1995). If *t1* and *t2* are the initial times for the buildup and decay phases (rise- and bedtime, respectively), the sleep-wake regulating process can be simulated using the following equations:

$$X(t) = [X_u + C(t)] - \{[X_u + C(t)] - X_b\} * e^{-(t-t1)/[Tb - k * C(t)]} \quad (1a)$$

$$X(t) = [X_l + C(t)] - \{X_d - [X_l + C(t)]\} * e^{-(t-t2)/[Td - k * C(t)]} \quad (1b),$$

where

$$C(t) = A * sin(2\pi * t/\tau + \varphi_0) \quad (2)$$

is a periodic function with a period τ assigned to 24 hours (Putilov, 1995).

The parameters of this model listed in Table S2-1 were initially derived from data on the durations of recovery sleep after 6 gradually increasing intervals of extended wakefulness (Åkerstedt & Gillberg, 1981) and on the levels of Slow-Wave Activity (SWA) calculated for 10 naps and two recovery sleep episodes (see Putilov, 1995, for more details). The simulation of these data provided possibility to express X in relative SWA units and to perform the present simulations by utilizing slightly modified initial parameters of the model (Table S2-1 and Figure S2-1A).

The estimates of sleep times (mostly as simple self-reports provided by study participants) were collected from more than 80 previously published papers (see Supplementary2_320Samples). The participants of the reported studies represented various ages, between 0.5 and 58.4 years. Simple averaging over these 190 samples provided weekday and weekend sleep times reported in Table S2-2 and illustrated in Figure 1. Mean age obtained by averaging over ages was 17.04 years with 95% confidence interval between 15.53 and 18.55 years.

Rise- and bedtimes on weekends were included as parameters (*t1* and *t2*, the initial times) in the simulations. For the sake of simplicity and clarity, these sleep times were rounded off to obtained 9.1 h and 23.7 h for *t1* and *t2*, respectively, and 7.0 h for risetime on weekdays (see Table S2-1).

Tables S2-1 and S2-2 and Figure S2-1 illustrate a model-based prediction of sleep times from rise- and bedtime on weekends and risetime on weekdays used as initial time parameters of the model.

2. Tables S2-1 and S2-2

Table S2-1. List of parameters of the model utilized for simulation of sleep times in 190 samples.

	Simulated data	Initial	190 samples
Sine wave-form circadian modulation (2):			
A (circadian amplitude), relative SWA		0.50	0.50
φ_0 (initial circadian phase), radians		4.13	3.66
τ (entrained circadian period), hours		24.00	24.00
k (two fold increase of the circadian term)		2.00	2.00
Reverse exponential buildup and exponential decay phases (1a,b):			
SWA_l (lower asymptote), relative SWA		0.70	0.70
SWA_b (lowest decay), relative SWA		0.75	0.755
SWA_d (highest buildup), relative SWA		2.50	2.75
SWA_u (upper asymptote), relative SWA		4.50	5.00
T_d (decay phase constant), hours		1.95	2.58
T_b (buildup phase constant), hours		27.04	23.32
Initial times for buildup (1a) and decay phases (1b):			
t2 (bedtime), clock hours		23.00	23.70
t1 (risetime), clock hours		7.00	9.10
t1 (risetime for 5 weekdays), clock hours			7.00

[1] Notes. Parameters of the model (Putilov, 1995) used for simulation of sleep times illustrated in Figure 1. Initial: Initial parameters were derived in Putilov (1995) by using data on sleep duration after extended wakefulness and on SWA in naps and extended sleep episodes (mean SWA=1 in baseline night episode). 190 samples: Data on sleep times were obtained by averaging over 190 samples (mean age of 17.04 years) and simulated in Putilov, Verevkin, 2018, and Putilov et al., 2019.

Table S2-2. Discrepancies between empirical and simulated sleep times.

Sleep	times	Mean	-95%CI	+95%CI	Simulation	Discrepancy
Weekdays	Bedtime	22.64	22.46	22.82	22.64	0.00
	Risetime	6.98	6.90	7.07	7.00	-0.02
	Time in bed	8.35	8.17	8.53	8.36	-0.01
Weekends	Bedtime	23.67	23.47	23.87	23.66	0.01
	Risetime	9.08	8.94	9.23	9.18	-0.10
	Time in bed	9.41	9.27	9.55	9.52	-0.11
Shift in	Bedtime	-1.04	-1.13	-0.95	-1.03	-0.01
	Risetime	-2.10	-2.25	-1.95	-2.18	0.08
	Time in bed	-1.07	-1.18	-0.95	-1.16	0.09

[1] Notes. Discrepancies were calculated by subtracting simulated sleep times from Mean (sleep times averaged over 190 samples). CI: Confidence Interval; Time in bed: Difference between risetime and bedtime.

3. Figure S2-1

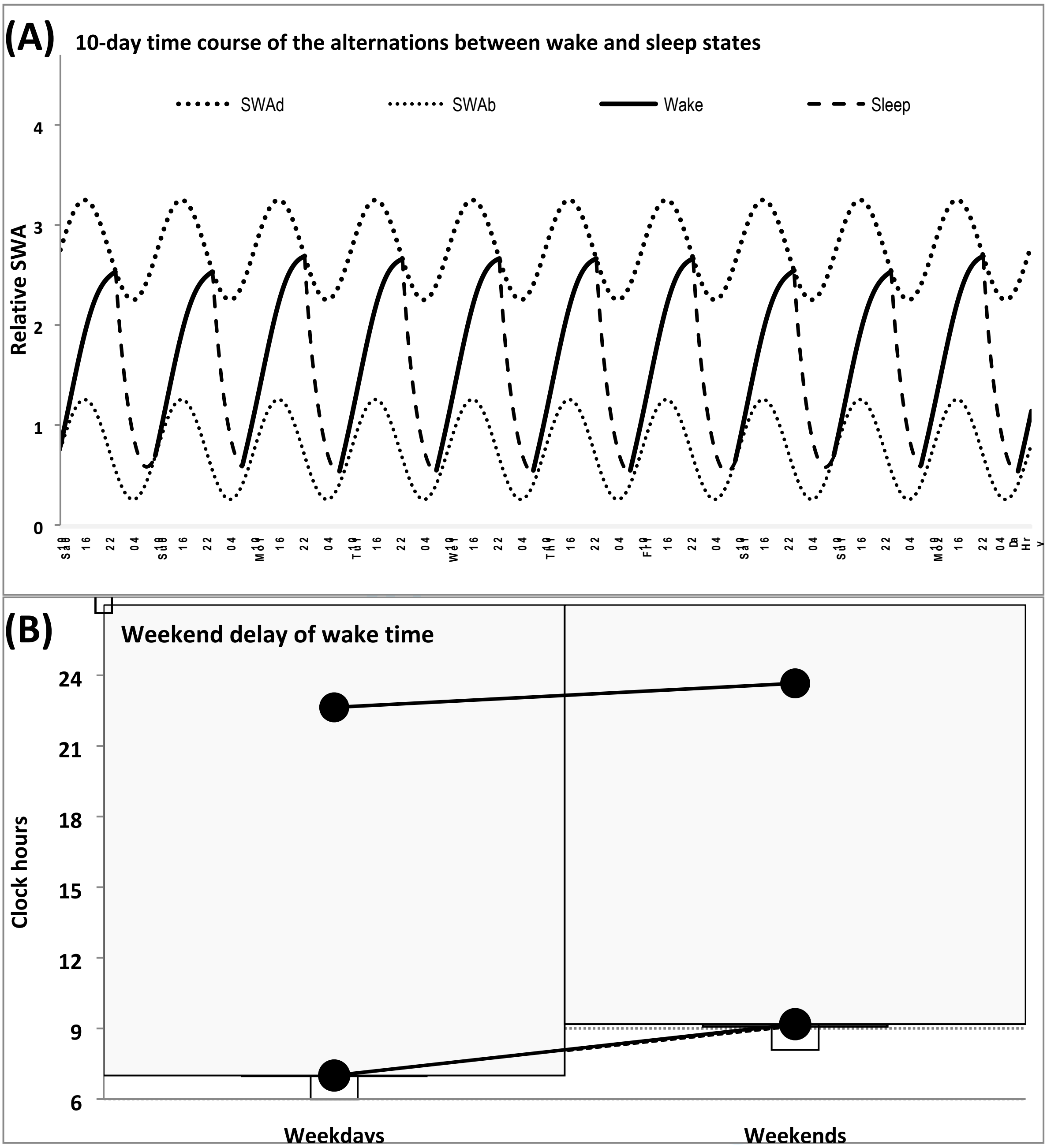

Figure 1. Graphical representation of the model-based simulation and simulated dataset.

A. Simulation of the sleep-wake cycle for ten consecutive days including two last free (e.g., vacation) days, Sa0 and Su0, and the following workdays (Mo1-Fr1) and weekends (Sa1 and Su1). Phases of the sleep-wake regulating process were simulated as alternations between exponential buildups and decays of SWA that are additionally modulated by sine-form function with 24-hour period (see the list of parameters in Table S2-1). SWAd and SWAb: Highest buildup and lowest decay of relative SWA, respectively; DfS: Further buildup of SWA expected in the case of Deprivation from Sleep.

B. Empirical and simulated wake and sleep times for weekdays and weekends. Rise- and bedtimes and time in bed, respectively, on weekdays and weekends. Empirical and simulated times are represented by open squares with dashed lines and closed circles with solid lines, respectively.

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