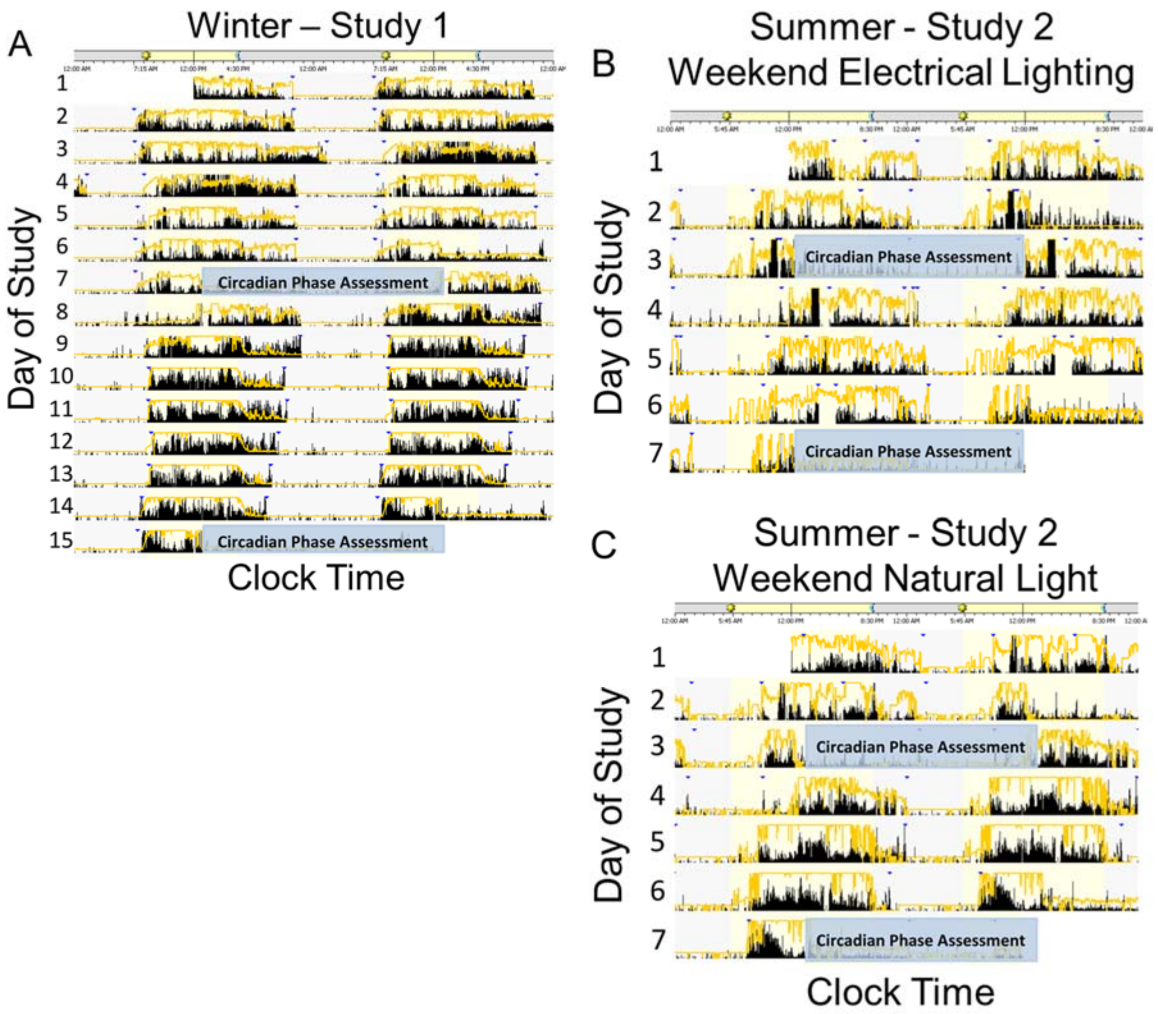

Figure S1. (A) Winter Experimental Protocol Study 1 from one Participant and (B and C) Summer Experimental Protocol Study 2 from one Participant from Each Group. Related to Figures 1, 2 and 4. Data recorded from Actiwatch Spectrum, with activity indicated by black ticks and light exposure above 1000 lux threshold denoted by the max yellow line. Clock time = local time and is indicated above and day of the study is marked to the left of figures. Sunrise and sunset are indicated on the upper abscissa with the yellow bar indicating solar day and the gray bar indicating solar darkness for the respective study. Sleep episodes are characterized by low activity levels and were marked at the start and end by the participant using an event marker button on the watch, represented by the blue arrow above the data. (A) In study 1, exposure to both electrical and natural light and sleep timing in the modern electrical lighting environment during the winter are shown on days 1-7. The initial assessment of circadian timing in the laboratory occurred on day 7-8 (denoted by blue shading). Participants slept at home on night 8 (not included in data analyses) and then were exposed to only natural light while winter camping days 9-15. On day 15 participants returned directly to the laboratory from camping for reassessment of their circadian melatonin rhythm. Conditions were sequential so sunrise and sunset would be as similar as possible between conditions. (B and C) In study 2, exposure to both electrical and natural light and sleep timing in the modern electrical environment are shown on days 1-3. The initial assessment of circadian timing in the laboratory occurred on day 3-4 (denoted by blue shading). Participants slept at home on night 4 (not included in data analyses) and then were exposed to natural light while camping or remained at home during the weekend on days 5-7. On day 7 participants returned directly to the laboratory for reassessment of their circadian melatonin rhythm. Epochs when the Actiwatch was removed (e.g., to bathe) were excluded from the analyses. One camper in study 2 was excluded from these analyses due to technical failure of the Actiwatch. In study 2, one male and four females stayed home and six males and three females went camping.

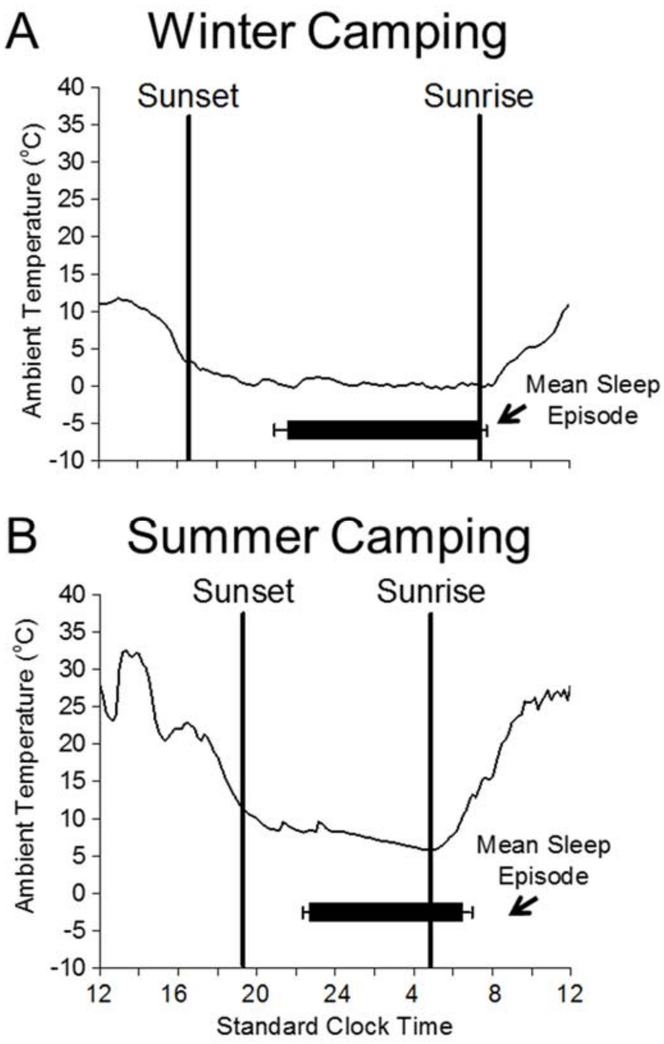

Figure S2. Ambient Temperature While Camping and Phase Relationships Between Sleep and Circadian Timing. Related to Figures 2 and 4. Temperature recordings from iButtons (Maxim) placed inside tents were averaged across each day and plotted to show the mean daily ambient temperatures during the week of exposure to the natural light-dark cycle while camping outdoors in (A) the winter study 1 and (B) the weekend summer camping study 2. Black lines denote average time of sunset and sunrise for the respective season and the black bars are average sleep episodes ± SD for all participants while camping. Consistent with our prior findings [S3], participants went to bed in the natural environment several hours after the onset of the biological night (Figures 2 and 4), in accordance with the well-known relationship between the timing of the circadian clock and sleep timing and behavior [S6, S7]. Findings from study 1 winter camping showed on average, melatonin onset occurred before sleep start (3.1 ± 1.5 hr modern environment, 3.3 ± 1.5 hr camping; $p=0.83$) and melatonin offset occurred after sleep end (1.1 ± 2.0 hr modern environment, 1.2 ± 2.4 hr camping; $p=0.96$) with similar durations across conditions. Findings for study 2 weekend camping showed on average melatonin onset occurred before sleep start for those who remained in the modern environment (1.5 ± 0.6 hr week, 2.1 ± 1.3 hr weekend; $p=0.55$) and there was a non-significant trend for melatonin onset to occur earlier relative to sleep start on the weekend after camping (1.6 ± 0.6 hr week, 2.6 ± 0.8 hr weekend; $p=0.067$). Melatonin offset occurred after sleep end for those who remained in the modern environment (0.86 ± 1.12 hr week, 0.39 ± 0.48 hr weekend; $p=0.55$) whereas melatonin offset occurred after sleep end during the week (0.34 ± 1.72 hr week) and before sleep end after camping (0.56 ± 1.00 hr), but this change was not significant ($p=0.19$). Additional research is needed to determine the stability of intra-individual differences in the phase relationship between circadian and sleep timing across seasons. The timing of sleep in Hadza, Tsimane, and San hunter-gatherers that do not have electrical lighting was reported to be initiated during decreasing ambient temperatures in the winter and summer, and based on such associations, the decline in ambient temperature was hypothesized to be a major determinant of sleep timing [S8]. Our findings of an association between sleep timing and the decline in ambient temperature in the summer are consistent with the latter report, but in the winter we found that participants initiated sleep after the ambient temperature decline was complete. Thus, additional research is needed to investigate the relative strength of known and potential drivers of sleep behavior, alone or in combination, such as internal circadian timing—strongly driven by the external light-dark cycle, sleep homeostasis, and other environmental factors (i.e. ambient temperature) in different natural environments. How these factors interact to influence individual differences in sleep timing is an important future direction for research of altered sleep patterns in modern society. The master SCN clock in homeotherms is however not entrained by ambient temperature cycles [S9, S10, S11], and thus exposure to cold ambient temperature at night while camping is unlikely to have contributed to the changes in circadian timing observed in the current studies.

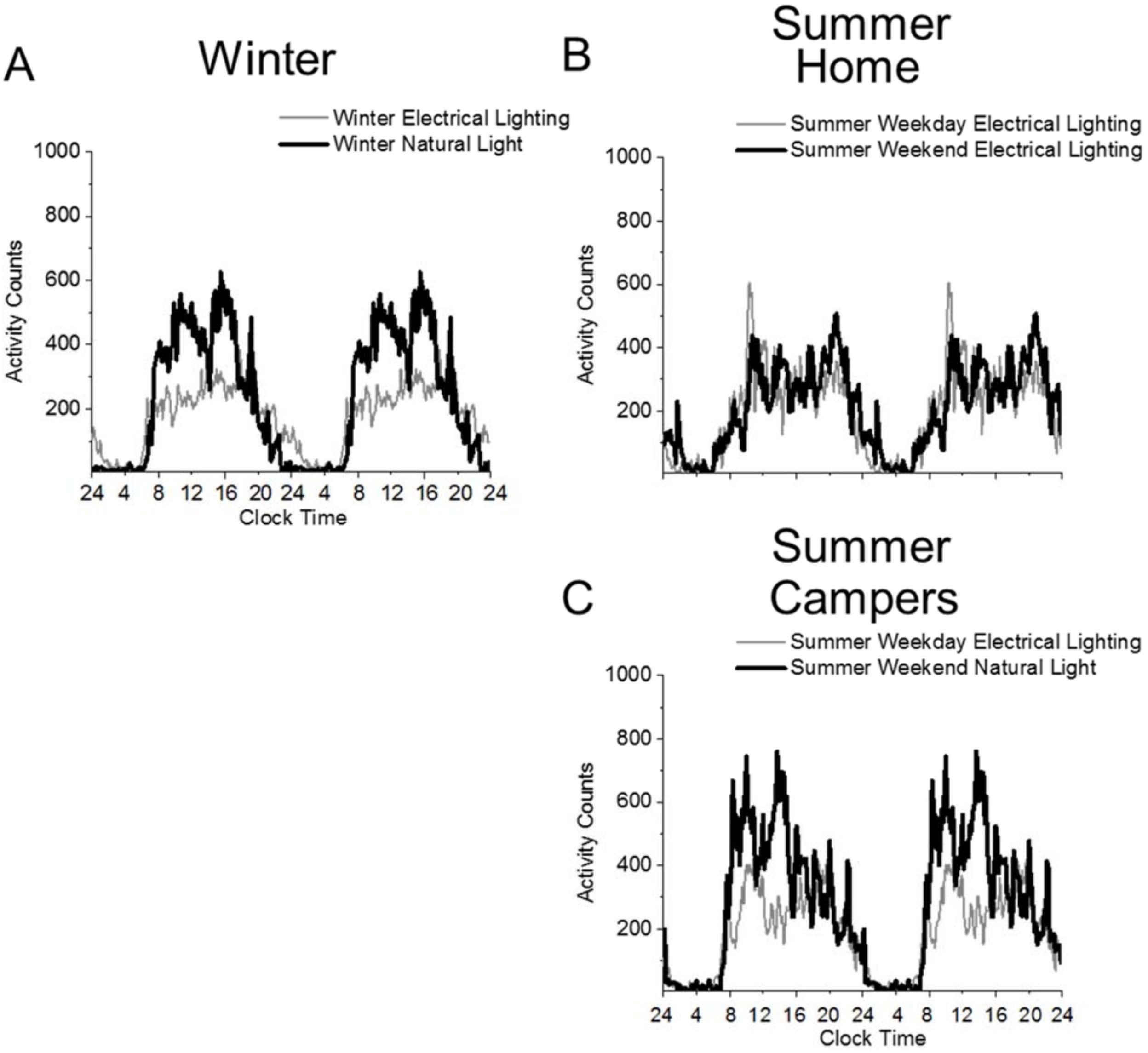

Figure S3. Winter (Study 1) and Weekend Summer (Study 2) Physical Activity Levels. Related to Figures 2 and 4. (A) Average activity levels across 24 hr in study 1 for one week of living in the modern electric lighting environment versus the natural light-dark cycle while winter camping. Activity levels were significantly higher while camping (231 ± 62, mean arbitrary units ± SD) than in the modern environment (174 ± 37; $p<0.05$). Average activity levels across 24 hr in study 2 for (B) weekdays and weekend days in the modern environment and for (C) weekdays in the modern environment versus weekend days while summer camping. Activity levels in study 2 were increased during weekend days while camping (300 ± 38 mean arbitrary units ± SD) compared to weekdays (173 ± 45; $p<0.00005$; within group) and weekend days living in the modern environment (219 ± 74; $p<0.05$; between group). Total 24 hr sleep duration in study 2 was similar in both groups throughout the study (modern environment: 8.1 ± 0.7 hr weekday versus 7.7 ± 1.0 hr weekend; weekend natural light exposure 8.0 ± 1.1 hr weekday versus 7.9 ± 0.5 hr weekend; all $p>0.40$). Sleep efficiency was also similar throughout the study in both groups (modern electrical lighting environment: 84.2 ± 2.4% weekday versus 81.4 ± 5.0% weekend; weekend natural light exposure 80.1 ± 9.2% weekday versus 81.8 ± 6.8% weekend; all $p>0.36$). Campers often hiked, which contributed to higher 24 hr activity levels. Three 45 min bouts of moderate exercise every night for a week has been shown to have a significant, but relatively small influence compared to light on circadian timing in humans [S12]. Thus, changes in physical activity level may have had a small contribution to changes in circadian timing in the current study, although additional research is needed to examine effects of daytime exercise on the human circadian clock while controlling light exposure. Activity from Actiwatch Spectrum are double plotted to more easily see changes over midnight (24 hr local time). Clock time = local time.

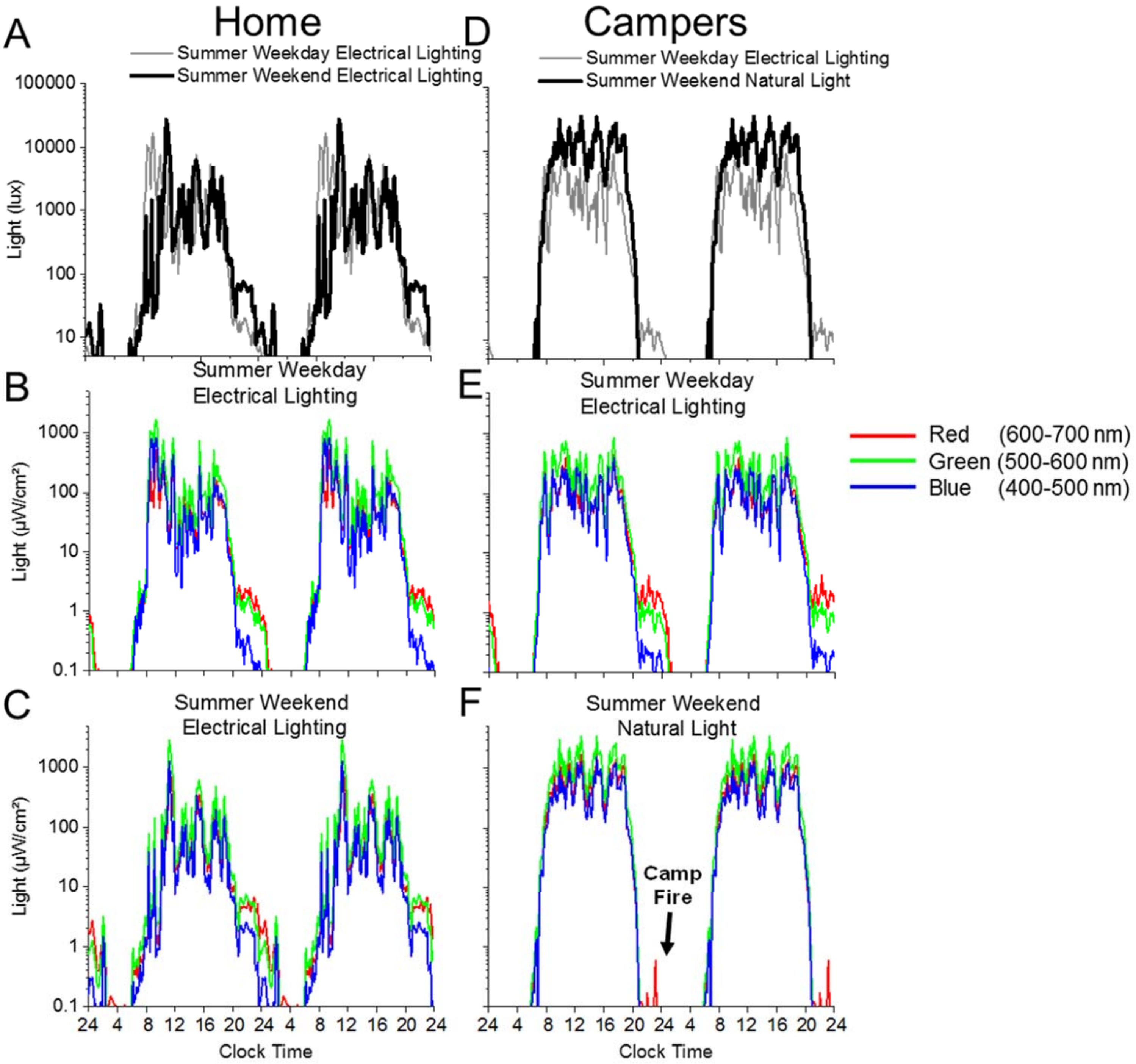

Figure S4. Summer Light Exposure Study 2. Related to Figure 4. (A) Average white light exposure (lux) and (B and C) light exposure of different wavelengths during the weekdays and weekends of exposure to the modern electrical lighting environment. (D) Average white light exposure (lux) and (E and F) light exposure of different wavelengths during the weekdays of exposure to the modern electrical lighting environment and the weekend of exposure to the natural light-dark cycle while summer camping. Average exposure to white light levels was increased during a weekend spent camping compared to weekdays spent in the modern environment. Light exposure levels were not different on the weekend compared to weekdays in the modern environment (see main text) and were qualitatively similar to those observe by other groups using the same device [S13]. Light from campfires can be seen in the red spectrum. For reference, 1 lux is equivalent to the light received by the eye when gazing at a candle 1 m away. Moonlight is ~0.1 lux, typical indoor electrical lighting is ~200 lux, natural light at sunrise or sunset is ~10,000 lux, and a bright blue midday sky is >100,000 lux. Light data are plotted on a log scale. Light from Actiwatch Spectrum are double plotted to more easily see changes over midnight (24 hr local time). Clock time = local time.

Light exposure above circadian-derived thresholds	Exposure to electrical plus natural light in the modern electrical lighting environment (± SD)	Exposure to only natural light while camping (± SD)	p value, two tailed
Percent of Waking Day Spent Above			
1000 lux	8 ± 3	53 ± 6	0.00006
550 lux	15 ± 5	58 ± 7	0.00008
100 lux	44 ± 5	67 ± 9	0.01
50 lux	54 ± 6	69 ± 10	0.08
Hours of Waking Day Spent Above			
1000 lux	1.3 ± 0.5	6.4 ± 1.1	0.0002
550 lux	2.3 ± 0.8	6.9 ± 1.1	0.0006
100 lux	7.0 ± 1.0	8.0 ± 0.9	0.005
50 lux	8.5 ± 1.2	8.2 ± 0.9	0.10
Average μW/cm^2 Level During Waking Day			
Red (600-700 nm)	278 ± 177	432 ± 139	0.11
Green (500-600 nm)	300 ± 184	1259 ± 307	0.003
Blue (400-500 nm)	273 ± 179	561 ± 130	0.07
Average μW/cm^2 Level in the First Two Hours After Waking			
Red (600-700 nm)	75 ± 97	344 ± 377	0.16
Green (500-600 nm)	147 ± 190	844 ± 956	0.16
Blue (400-500 nm)	68 ± 89	381 ± 409	0.13
Average μW/cm^2 Level Between Sunset and Sleep Start			
Red (600-700 nm)	4.3 ± 1.8	0.5 ± 0.3	0.006
Green (500-600 nm)	4.6 ± 2.8	0.8 ± 0.4	0.04
Blue (400-500 nm)	1.3 ± 0.9	0.4 ± 0.2	0.08

Table S1. Winter Light Exposure Study 1. Related to Figure 1. Participants' exposure to light intensities during waking hours (averaged for each week of the study) for light levels with known effects on the circadian system based on the intensity response curve [S1, S2]. Using wrist actigraphy, 1000 lux is commonly used as the lower threshold for exposure to outdoor light (reviewed in [S3] Supplemental Information). Phase-shifting to electrical lighting in the laboratory shows 550 lux as the point of saturation for phase delay responses over a range of light intensities from 3 to ~9100 lux. Half of the phase delay seen in maximal (~9100 lux) light exposure can be achieved by light as low as 100 lux while light as little as 50 lux is sufficient for phase shifting to occur [S1]. Light exposure during the waking day was decreased in the modern electrical lighting environment with reduced exposure to light over 100 lux and to green light when compared to the natural light-dark cycle. During the first two hours of the waking day, when exposure to light most strongly shifts the clock earlier [S4, S5], participants were exposed to more light while camping (Median 3117 ± 4941 lux natural light compared to 88 ± 71 lux electrical lighting; Wilcoxon; $p<0.05$) but not statistically different levels of red, green, or blue light. After sunset in the winter, participants were exposed to increased white (Median 0.6 ± 0.6 lux natural light compared to 28.0 ± 25.1 lux electrical lighting; Wilcoxon; $p<0.05$), red and green light in the electrical lighting environment before sleep. These changes in exposure to white light were qualitatively similar to those found when comparing weeklong exposure to natural versus electrical lighting in summer [S3].

Light exposure above circadian-derived thresholds	Exposure to electrical plus natural light in the modern electrical lighting environment during the weekdays and on the weekend (± SD)			Exposure to electrical plus natural light in the modern electrical lighting environment during the weekday and exposure to natural light on the weekend camping (± SD)		
	Weekdays	Weekend	p value	Weekdays	Weekend	p value
Percent of the Waking Day Spent Above						
1000 lux	11 ± 5	10 ± 5	0.88	18 ± 8	64 ± 5*	0.000001
550 lux	13 ± 5	13 ± 5	1.00	23 ± 9	68 ± 5*	0.000002
100 lux	37 ± 6	35 ± 5	0.65	47 ± 11*	74 ± 4*	0.00007
50 lux	52 ± 10	48 ± 8	0.45	56 ± 9	76 ± 3*	0.0004
Hours of the Waking Day Spent Above						
1000 lux	1.7 ± 0.8	1.6 ± 0.8	0.87	2.8 ± 1.2	10.2 ± 0.9*	<0.000001
550 lux	2.1 ± 0.9	2.1 ± 0.8	0.97	3.6 ± 1.4	10.8 ± 0.8*	<0.000001
100 lux	6.0 ± 0.9	5.7 ± 0.9	0.77	7.4 ± 1.7	11.8 ± 0.7*	0.00002
50 lux	8.4 ± 1.5	7.9 ± 1.0	0.58	8.8 ± 1.5	12.1 ± 0.7*	0.0002
Average μW/cm^2 Level During Waking Day						
Red (600-700 nm)	67 ± 40	76 ± 60	0.84	98 ± 57	486 ± 117*	<0.00001
Green (500-600 nm)	177 ± 172	165 ± 140	0.92	201 ± 108	894 ± 221*	<0.00005
Blue (400-500 nm)	87 ± 97	62 ± 37	0.66	88 ± 56	376 ± 102*	<0.0001
Average μW/cm^2 Level in the First Two Hours After Waking						
Red (600-700 nm)	40 ± 27	27 ± 14	0.29	151 ± 209	318 ± 103*	0.053
Green (500-600 nm)	86 ± 62	64 ± 37	0.48	294 ± 349	532 ± 193*	0.15
Blue (400-500 nm)	35 ± 25	26 ± 16	0.34	120 ± 154	232 ± 84*	0.12
Average μW/cm^2 Level After Sunset						
Red (600-700 nm)	1.8 ± 0.5	3.3 ± 2.8	0.27	2.2 ± 1.4	0.5 ± 0.1*	0.01
Green (500-600 nm)	1.2 ± 0.4	3.3 ± 3.5	0.25	1.1 ± 0.5	0.8 ± 0.3	0.24
Blue (400-500 nm)	0.3 ± 0.1	1.1 ± 1.3	0.22	0.2 ± 0.1	0.4 ± 0.2	0.01

Table S2. Summer Light Exposure Study 2. Related to Figure 4. Participants' exposure to light during waking hours (averaged for each condition) for light levels with known effects on the circadian system based on the intensity response curve [S1, S2] (also see Table S1). Light exposure during the waking day was decreased in the modern electrical lighting environment with reduced exposure to light over the 50 lux threshold and to red, green, and blue light compared to summer camping on the weekend. During the first two hours of the waking day, participants were exposed to more white light while camping on the weekend (Median 2160 ± 1138 lux weekend natural light versus 227 ± 447 lux weekday electrical lighting; Wilcoxon; $p<0.05$). Light exposure in the first two hours of the waking day was similar for those who spent the week and the weekend in the modern electrical lighting environment (Median 40 ± 23 lux weekend 49 ± 32 lux weekday; Wilcoxon; $p=0.50$). Light exposure was greater in the first two hours after awakening when camping on the weekend compared to spending the weekend in the modern electrical lighting environment (Kolmogorov-Smirnov; $p<0.005$) and was similar between groups in the modern electrical lighting environment during the weekdays (Kolmogorov-Smirnov; $p>0.10$). After sunset, participants were exposed to more white (Median 0.2 ± 0.2 lux natural light versus 7.1 ± 5.2 lux electrical lighting; Wilcoxon; $p<0.05$) and red light, but less blue light, before sleep in the modern electrical lighting environment during the week than while camping on the weekend. Light exposure after sunset was similar for those who spent the weekdays and the weekend in the modern electrical lighting environment (Median 11.2 ± 4.2 lux weekend 8.8 ± 2.7 lux weekday; Wilcoxon; $p>0.13$). White and red light exposure after sunset were also greater on the weekend in the modern electrical lighting environment compared to a weekend spent camping (Kolmogorov-Smirnov; $p<0.005$) and was similar between groups in the modern electrical lighting environment during the weekdays (Kolmogorov-Smirnov; $p>0.10$). Significant differences between groups ($p<0.05$) denoted by an asterisk (*) and within groups denoted by p values.

SUPPLEMENTAL EXPERIMENTAL PROCEDURES

Participants

Participants, recruited from the university and local community, were healthy, non-smokers, physically active, and females were not pregnant, based on self-report. Participants were instructed to maintain typical daily activities in the modern environment with no restrictions other than the proscription of staying up all night. Activities while camping were also not scheduled, but participants often went hiking, prepared meals and sat around the campfire together; although, not all campers went hiking together nor did they go to bed at the same time.

Activity, Sleep, Ambient Temperature and Light Exposure Assessment

Data were continuously collected at 1 min intervals across days with Actiwatch Spectrums (Philips). Light exposure data included assessment of red (600-700 nm), green (500-600 nm), blue (400-500 nm) and white light (400-700 nm) levels. Actiwatch spectrum silicon photodiode has an illuminance range of 5-100000 lux with an accuracy of 10% at 3000 lux. The upper range of the Actiwatch Spectrums is higher than prior models used in our previous research [S3] (i.e. Actiwatch-L, Philips = 32000 lux), therefore we did not compare observed light levels between the current study and our past study [S3]. The irradiance for the color sensitive photodiodes has a range of 0.1-5500 microwatts/centimeter squared ($\mu W/cm^2$) and an accuracy of 10% at 1500 lux. Sleep start and wake times were manually selected and sleep was scored based on 10 consecutive min of 0 activity denoting the start and end of each sleep episode (Philips Actiware 6, version 6.0.4). Sleep duration, sleep efficiency (percent time asleep divided by time in bed) and number and duration of awakenings were scored using the medium sensitivity threshold of the Actiwatch Spectrum analysis program. Actigraphic assessment of sleep has limitations as it is only ~90% concordant with polysomnography [S14]. Two participants that remained in the modern environment and one camper in the summer study 2 napped once each during weekdays. These sleep data are included in the total 24 hr sleep duration (Figure S3). Sunrise and sunset times were obtained from United States National Oceanic and Atmospheric Association. Ambient temperature was recorded every min for descriptive purposes the week of camping using iButtons (Maxim) placed inside tents.

Salivary Melatonin Circadian Phase and Phase Angle of Entrainment Assessments

Internal circadian time of participants was assessed under controlled laboratory conditions after each light exposure condition. Specifically, circadian phase was assessed under dim lighting, ~1.9 lux (~0.6 watts/m^2) in the angle of gaze from ceiling-mounted fluorescent lamps (Sylvania OCTRON 32W T8 bulbs) of broad-spectrum white-light with a color temperature similar to sunlight at midday (6500 K) and controlled posture conditions. No food or fluid intake was permitted 30 min prior to saliva samples and participants were not allowed any water intake and maintained their posture for 15 min prior to collection. Caffeine, alcohol, and over the counter medications were proscribed three days prior to each circadian phase assessment [S15-S21]. Participants also refrained from recreational drugs, determined by self-report. Napping was permitted between samples to minimize the effect of sleep restriction on activity the following day [S3, S22]. Saliva samples were stored at ~-70 degrees Celsius until assayed via radioimmunoassay (Study 1-LDN Melatonin Direct RIA; Rocky Mountain Diagnostics, Study 1-Direct Saliva Melatonin RIA; BUHLMANN Diagnostics Corporation). The timing of the dim-light melatonin onset (DLMO), mid-point (MP) and dim-light melatonin offset (DLMOff) were calculated as these are commonly used as markers of the beginning, middle and end of biological night [S3, S23-S26], respectively. We also calculated phase relationships between circadian and sleep timing. Specifically, the duration between melatonin onset and sleep start and between melatonin offset and sleep end.

Data Analysis

Average sleep-wake timing and duration, sleep efficiency, and activity and light levels were determined. For descriptive purposes, the hours and percentage of the waking day and of the solar day (solar photophase) spent above light thresholds of 50, 100, 550, and 1000 lux were calculated. We also calculated the light exposure during the first two hours awake for light in white and colored spectrums, as light exposure at this time of day is thought to be most important for circadian advances needed to entrain the human circadian clock of the majority of individuals to the 24 hr day. Further, we calculated the average light exposure after sunset in white and colored spectrums as this is thought to be an important contributor to phase delays in modern society [S1]. Activity counts, light exposure and ambient temperature were also averaged into 10 min bins for graphing. Data were transformed to standard time for seasonal comparisons. Mixed model ANOVA and dependent t-tests or Wilcoxon for test of medians (when noted), were used to test for differences in light exposure, circadian timing, sleep timing, duration, and efficiency, and activity levels between each week of assessment. Independent t-tests or Kolmogorov-Smirnov test for medians (when noted) were used to compare between groups in the summer weekday and weekend study. Further, we also compared circadian data from the current winter study to that from our prior summer study that used similar methods [S3] to examine whether there were seasonal changes in circadian rhythms in response to exposure to the natural light-dark cycle; as three subjects participated in our original summer and current winter study, we included subject as a random factor in the statistical model. When noted, directional one-tailed mixed model ANOVA/t-tests with Bonferroni corrections were used to examine changes in melatonin timing after exposure to the natural light-dark cycle [S3] and whether melatonin duration increased after exposure to the winter versus summer natural light-dark cycle—based on predictions from Wehr and colleagues [S24, S27].

Effect Size Analyses Using Generalized Eta Squared (η^2G)

Effect sizes using η^2_G, accounting for variance due to individual differences, were computed using sum of squares from the mixed-effects ANOVA models and were evaluated using Cohen's general cutoffs for η^2 of 0.02 as small, 0.13 as medium, and 0.26 as large. Measures of η^2_G are generally smaller than the more common reported partial eta-squared (η^2p) [S28, S29].

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