# How Well do School-aged Children Comply with Imposed Sleep Schedules at Home?

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**Study Objectives:** To quantitatively assess compliance and experimental success with imposed sleep schedules among healthy children involved in an experimental comparison of optimized and restricted sleep.

**Design:** We asked children to follow assigned sleep schedules at home that created optimized (at least 10 hours time-in-bed per night) and restricted (6.5 to 8 hours time-in-bed per night) sleep conditions across 2 weeks during the school year. Self-report or parent-report of bedtime and risetime was obtained daily and continuous actigraphy was recorded.

**Setting:** Home

**Participants:** 78 healthy children (41 boys, 37 girls; mean age, 10.2 years; age range, 6.5 to 12.9 years)

**Interventions:** N/A

**Measurements and Results:** We used reported time-in-bed to assess noncompliance with assigned schedules. Experimental failure was assessed with actigraphically based estimates of sleep period (time from sleep onset to sleep offset) and total sleep time (minutes of scored sleep during sleep period). Reported time-in-bed averaged 3.45 hours less per night under restricted versus optimized conditions. Sleep period and total sleep time showed similar differences (2.97 and 2.32 hours less, respectively). Four children met *a priori* criteria for noncompliance (3 for optimized nights and 1 for restricted). Eight children met *a priori* criteria for experimental failure within conditions (7 for optimized nights and 1 for restricted), but most achieved a substantial difference in sleep behavior across optimized and restricted weeks.

**Conclusions:** In general, healthy children as young as 6 years of age can maintain substantial changes in their usual schedules across several nights at home and should be considered for inclusion in experimental studies of sleep extension and restriction. This paper offers a methodologic "road-map" for scientists interested in pursuing this goal.

**Key words:** Children; sleep deprivation; methods; actigraphy

## INTRODUCTION

PREVIOUS LABORATORY RESEARCH INDICATES THAT SCHOOL-AGED CHILDREN AND YOUNG ADOLESCENTS MAY REQUIRE AT LEAST 9.2 HOURS OF SLEEP FOR OPTIMAL ALERTNESS.[1] Yet, children in many developed countries generally do not obtain that much sleep and indeed, they reduce their habitual amount of sleep on school nights at the rate of an hour per night every 3 years.[2] In spite of the ubiquity of this pattern of diminished sleep, our understanding of the consequences of prolonged sleep reduction in young people is limited. One reason for the paucity of data is that studies are difficult, time-consuming, and labor intensive when performed in the sleep laboratory. Furthermore, many parents are reluctant for children to spend extended time in the sleep laboratory, and few investigators are equipped to perform such assessments of young people. In general, therefore, most sleep laboratory studies of children and adolescents are limited to school breaks or to weekends during the school year. As a result, sleep restriction protocols with children have been limited to assessing acute effects across 1 to 3 nights in relatively small samples and with highly variable outcomes.[3-7] Studies of sleep restriction in adults have demonstrated that effects are more pronounced as the duration of sleep restriction is extended,[8-10] so experimental methods to extend sleep restriction in young people could allow us to better understand the predictable effects of sleep loss in this vulnerable population.

Home-based protocols may enhance the potential for such investigations by allowing data collection on larger samples of children, with prolonged experimental sleep manipulation, and examination of the "real-world" effects of increased or decreased sleep. Such protocols may also increase the ecologic validity of the results. Nevertheless, the utility of home-based protocols could be undermined by difficulties both in maintaining compliance with prescribed schedules and in judging experimental success with study goals. In other words, will participants really do what they are asked? Our ongoing research into the developmental manifestations of daytime sleepiness allows us to address this question using a combination of daily behavior documentation by a child or parent to assess schedule compliance and actigraphy to provide valid and reliable measures of objective sleep/wake patterns (ie, experimental success).[11-13]

This report includes our experience with healthy children aged 6 to 12 years in a 3-week home-based protocol under conditions of self-selected, optimized, and restricted sleep. We evaluated behavioral compliance and experimental success using children's sleep diaries, telephone messages, and actigraphy records. Children were expected to comply with instructions to get into bed at their assigned bedtimes (not before or after), to try to sleep while they were in bed, and to get out of bed at their assigned risetimes (not before or after). Experimental success, as defined here, is distinguished from compliance by the specific sleep objectives within and across conditions. The restricted sleep condition was designed to limit sleep and to create separation of sleep-related variables relative to the optimized sleep condition. The optimized sleep condition was designed to allow an amount of sleep consistent with the estimated sleep need for school-age juveniles[1] without reducing a child's usual sleep amount.

The objectives of this report are to provide a quantitative assessment of whether young children can substantially alter sleep patterns over an extended period of time and to provide a methodologic "road map" for others who might be interested in pursuing home-based sleep manipula-

tion. Our approach includes examining overall success and describing individuals who met *a priori* criteria for noncompliance. We hope to determine whether noncompliance predicts experimental failure and whether the *a priori* cut-offs ultimately identify children with outlying values relative to our entire sample.

## METHODS

We recruited participants from local schools and communities in Rhode Island and southeastern Massachusetts and collected background information through interviews and rating scales completed by the volunteer and a parent or guardian. Our recruiting methods included distribution of brochures to large numbers of children at local schools. We selected healthy young people who were functioning well and who were not at increased risk for sleep, mood, or behavioral disorders* for participation in the study. Eligible volunteers and their parents received a description of study procedures and provided informed consent at an information meeting in accordance with procedures approved by the Lifespan Institutional Review Board for the protection of human subjects. Participants received monetary compensation.

Study weeks were scheduled to avoid extended holidays. Each participant began the study on a school night and followed a self-selected school-night schedule at home for a week. We asked the children to follow their normal school-night sleep schedule even if a school day was cancelled during the self-selected week. Individually determined experimental schedules were counterbalanced for the second and third weeks. The restricted sleep schedule differed for younger (grades 1 and 2) and older (grades 3 through 7) children. Younger children were restricted to 7 or 8 hours time-in-bed a night and older children to 6.5 hours, generally by delaying bedtime. Our goal with the restricted schedule was to reduce sleep to a level that would substantially increase daytime sleepiness. The first four children in grades 1 and 2 completed a restricted schedule of 7 hours per night for 5 nights. Due to the very late bedtimes this schedule required, the restricted sleep schedule was extended to 8 hours per night for 7 nights for subsequent first and second graders. Regardless of grade in school, no child was assigned fewer than 10 hours time-in-bed per night for the optimized condition; otherwise, the optimal schedule was as long as the child's usual time-in-bed on school nights or weekends, whichever was longer. Scheduled bedtimes and risetimes for the restricted and optimized condition are summarized in Figure 1.

We provided parents and children with specific recommendations for managing both experimental schedules, including suggestions for time-management on optimized nights and active activities on restricted nights. We instructed all participants to be in bed trying to sleep and wearing eye shades during assigned time-in-bed and to keep out-of-bed periods (eg, toilet trips) to a minimum in frequency and duration. In addition, children were asked to avoid taking daytime naps and ingesting substances (eg, decongestants, caffeine, chocolate) that might affect the sleep/wake cycle or daytime alertness during their participation in the study. Children (parents of grade-1 and grade-2 children) completed a daily sleep diary and called our time-stamped telephone answering machine before bedtime and after risetime. Laboratory staff also telephoned participants twice each week to ask the children a series of questions about study compliance and to remind them about upcoming lab visits. Additional reminder calls were made if answering-machine messages revealed protocol inconsistencies; however, few such calls were required, and the number did not differ by age or condition. Telephone records provided values for reported bedtime in the evening and reported risetime in the morning. Reported time-in-bed was computed from these responses. On rare occasions when the telephone records were not available, the diary data were substituted.

Each participant also wore an actigraph (Mini-motionlogger; Ambulatory Monitoring Inc, Ardsley, NY) on the nondominant wrist throughout the day and night, except when the actigraph might get wet or while engaging in a contact sport. Such "off" periods were documented in the sleep diary. Actigraph and diary data were reviewed with the participant each week. Actigraph data were scored for sleep and wake using our standard method,[13] which applies a validated algorithm[11] to the portions of the records identified as nocturnal sleep episodes by the participant. We excluded individual nights of actigraphy data if the actigraph was off or not working for all or part of the documented nocturnal sleep episode or if the actigraph record included unusual external motion. Our senior research team (GF, CA, MAC) examined such questionable records and made consensus judgments regarding acceptability of the data. We examined the following variables from nightly actigraphy scoring: sleep-onset time, sleep-offset time, sleep period (the number of minutes from sleep-onset time to sleep-offset time), and total sleep time (minutes of scored sleep during sleep period). To assess experimental success of the restricted sleep condition, those nights were also examined for the number of minutes scored as sleep in designated pre-bedtime and post-risetime intervals

Analyses included Pearson correlations, analysis of covariance (ANCOVA), and independent-sample and paired-samples t-tests. T-tests were conducted with significance level set at .01 to correct for multiple comparisons. Except where otherwise indicated, data are reported as mean value ± standard deviation.

## RESULTS

Of the 84 children who began the study, only 6 failed to complete one or both experimental conditions. Three dropped out of the study due to illness and 3 for personal reasons, and no differential effect of experimental condition was apparent when drop-out occurred. Those children were excluded from our analyses. The final sample of 78 children included 41 boys (aged 6.5 to 12.8 years) and 37 girls (aged 6.6 to 12.9 years), of which 63 children were in grades three through seven and 15 in grade one or two. Reported race indicated that this was a primarily Euro-American sample (82%; n = 64), typical of our local community. We used the Hollingshead Four-Factor Index of Social Status to assess the socioeconomic status of participating families using information about parental education and employment status.[16] The average Index of Social Status for study participants was 44 (SD = 10; range = 27-66), which is upper middle class according to the Hollingshead categories.

We successfully recorded actigraphy in all three conditions for 72 of these participants. Technical problems resulted in the loss of actigraphy data for 6 participants from either the optimized or the restricted condition. In all, children completed an average of 5 nights (range = 4 to 6 nights) on the self-selected schedule, with successful actigraphy for 386 nights; an average of 6 nights (range = 4 to 8 nights) on optimized sleep schedules, with successful actigraphy for 448 nights; and an average of 6 nights (range = 5 to 8 nights) on restricted sleep schedules, with successful actigraphy for 460 nights.



**Figure 1**—Assigned sleep schedules for restricted and optimized sleep conditions by grade category (1st and 2nd graders vs. 3rd to 7th graders). Boxes indicate assigned time-in-bed from mean bedtime to mean risetime. Ranges for assigned bedtimes and risetimes are also indicated. Time is in 24-hour local clock time.

*The following personal exlusion criteria were used: report of sleep or psychiatric disorder, report of academic difficulties or classroom behavior problems in the past year, outside normal limits on the Child Behavior Checklist (CBCL[14]) or a self-report of morningness/eveningness[15], or 3 or more hours of variance between school-day and weekend sleep schedules. We also excluded volunteers if a first-degree relative was reported to have been diagnosed with a sleep disorder or was in treatment for a psychiatric disorder.

Sleep data from the self-selected condition were consistent with developmental trends and sex differences.[12,17] The average self-selected school-night sleep period from actigraphy was negatively correlated with age of participant (Pearson $r = -.65$, $P <.01$) and ANCOVA controlling for age revealed that girls had significantly longer sleep period than did boys (girls: mean = 544 ± 35 minutes; boys: mean = 532 ± 34 minutes; $F(2, 73) = 31.9$; $P < .01$). To obtain a sense of the differences between the children's usual schedules and our experimentally assigned schedules, we compared each child's average reported time-in-bed from self-selected nights to his or her assigned optimized and restricted schedules. The assigned optimized schedule was 0 to 117 minutes longer (mean = 47 ± 29 minutes), with only 1 girl assigned no change in her average self-selected schedule (10.5 hours) for the optimized nights. For the remaining children, the increased time-in-bed imposed by the optimized schedule was almost entirely due to an earlier assigned bedtime, as indicated by a mean difference of 45 minutes between assigned bedtime (mean = 20:35 ± 24 minutes) and average self-selected bedtime (mean = 21:20 ± 33 minutes). By contrast, the restricted schedule was 89 to 240 (mean = 164 ± 36) minutes shorter than the average self-selected time-in-bed. As with the optimized schedule, the decreased time-in-bed imposed by the restricted schedule was almost entirely accounted for by the change in bedtime, which averaged 162 ± 34 minutes later than self-selected.

At the group level, separation of sleep-related variables during optimized and restricted conditions supports the overall success of our experimental manipulation. Paired t-test comparisons of optimized and restricted conditions revealed differences in expected directions for reported time-in-bed, sleep period, and total sleep time (optimized > restricted) (Table 1). Similar comparison of optimized values to data obtained from self-selected nights showed no reduction in reported time-in-bed, sleep period, and total sleep time from usual schedules during that experimental condition. On the contrary, our sample as a whole achieved significant increases in these variables under optimized conditions (Table 1). T-test comparisons within conditions failed to reveal significant differences that could be attributed to the order of experimental schedules.

### Individual Protocol Compliance: Deviations of Self-Report from Assigned Schedules

At the individual level, we assessed compliance with the assigned sleep schedules by calculating the difference between the assigned and reported time-in-bed for each night. Because of our experimental expectations that the schedules would separate the amount of sleep obtained, we decided to define noncompliance in a directional manner. Thus, noncompliance for the optimized conditions was identified when the reported schedule for any night was shorter than assigned, and noncompliance for the restricted condition was identified when the reported schedule for any night was longer than assigned. In order to identify those participants who would be considered outliers on these dimensions, we made an *a priori* decision regarding reasonable expectations for schedule compliance. If reported time-in-bed deviated by 90 minutes or more for any experimental night or by at least 60 minutes for 2 or more nights in either experimental condition, we classified the child as noncompliant. Children classified as noncompliant were examined with regard to whether the deviation occurred at bedtime (ie, bedtime schedule deviation), rise-

time (ie, risetime schedule deviation), or both.

**Optimized:** Figure 2A illustrates the frequency distribution of deviations for reported time-in-bed from the schedule for all nights under optimized condition. Reported time-in-bed was shorter than assigned on 115
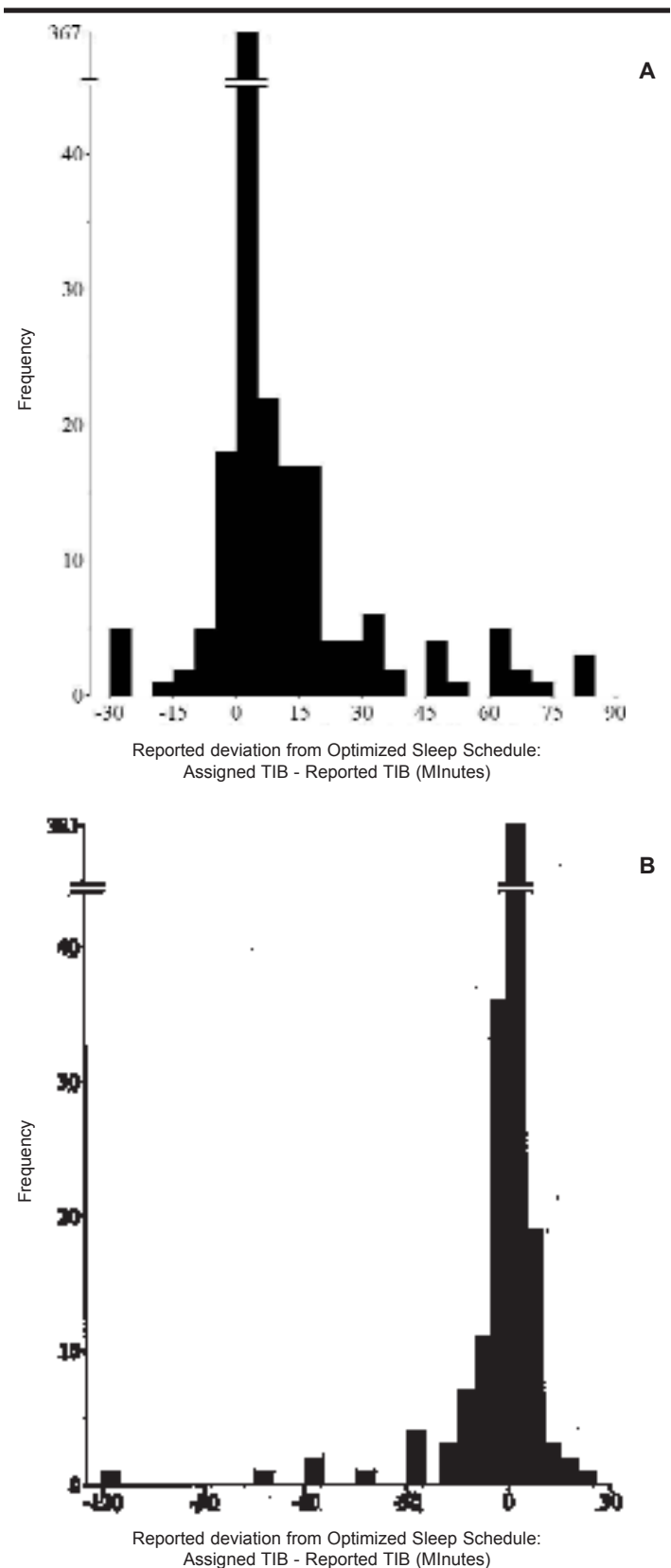


Figure 2—Frequency distributions for reported schedule deviations (assigned time-in-bed – reported time-in-bed) for experimental nights. Figure 2A shows difference scores for all nights under optimized conditions, and Figure 2B shows difference scores for restricted nights.

Table 1—Outcomes of experimental sleep manipulation [Mean ± SD (Range)]

| Condition: | Reported time-in-bed (n = 78) | Sleep period (n = 72) | Total sleep time (n = 72) |
|---|---|---|---|
| Self-selected | 568 ± 39 (483 - 656) | 538 ± 35 (468 - 619) | 483 ± 48 (341 - 567) |
| Optimized | 612 ± 25 (562 - 684) | 576 ± 23 (523 - 637) | 509 ± 48 (308 - 593) |
| Restricted | 405 ± 31 (384 - 481) | 398 ± 32 (338 - 475) | 370 ± 38 (234 - 463) |

Optimized > Self-selected > restricted for all variables according to paired *t* tests with significance level $P = .01$

of 486 nights (24%), with a mean difference of 18 ± 21 minutes. As illustrated, most of these differences were small (78% below 30 minutes). The schedule deviations on these 115 "short" nights included bedtimes that were 10 ± 19 minutes late on average and risetimes 8 ± 19 minutes early. Only 3 children met one of our *a priori* criterion for noncompliance. A nine-year-old girl and an 11-year-old boy both reported 2 nights that were short by at least 60 minutes, due entirely to early risetimes (girl) or late bedtimes (boy). An eight-year-old boy reported 1 night that was short by 90 minutes due to early risetime.

**Restricted:** Figure 2B shows the distribution of deviations between reported and assigned time-in-bed for the restricted nights. Reported time-in-bed was longer than assigned time-in-bed for 66 out of 475 nights (14%), with a mean difference of 13 ± 20 minutes for the "long" nights (range = 1 to 120 minutes). Again, the figure illustrates that overall deviations from protocol on the "long" nights were generally small and consisted of bedtimes that were 5 ± 16 minutes early on average and risetimes 8 ± 14 minutes late. Only 1 participant met our *a priori* criterion for noncompliance: an 11-year-old boy reported 1 night that was

long by 120 minutes due to early bedtime.

**Individual Experimental Success: Deviations of Actigraphic Variables Within Conditions**

**Optimized:** As with our compliance assessments, we examined experimental success with a directional perspective, but differences in the nature of the data obtained via self-report versus actigraphy dictated different thresholds for determining experimental success. The reliability of actigraphic estimates of sleep increases across several nights of recording,[13] so we required a pattern of behavior across several nights when categorizing a child as an experimental failure. For the optimized condition, our *a priori* criterion for experimental success was also influenced by our previous experience with adolescents following assigned schedules that extended sleep.[5] These earlier results suggested that scheduled time-in-bed usually did not exceed the actigraphically estimated sleep period by 75 minutes or more. Therefore, we classified a child as an experimental failure for the optimized condition if the scheduled time-in-bed was longer than the actigraphically estimated sleep
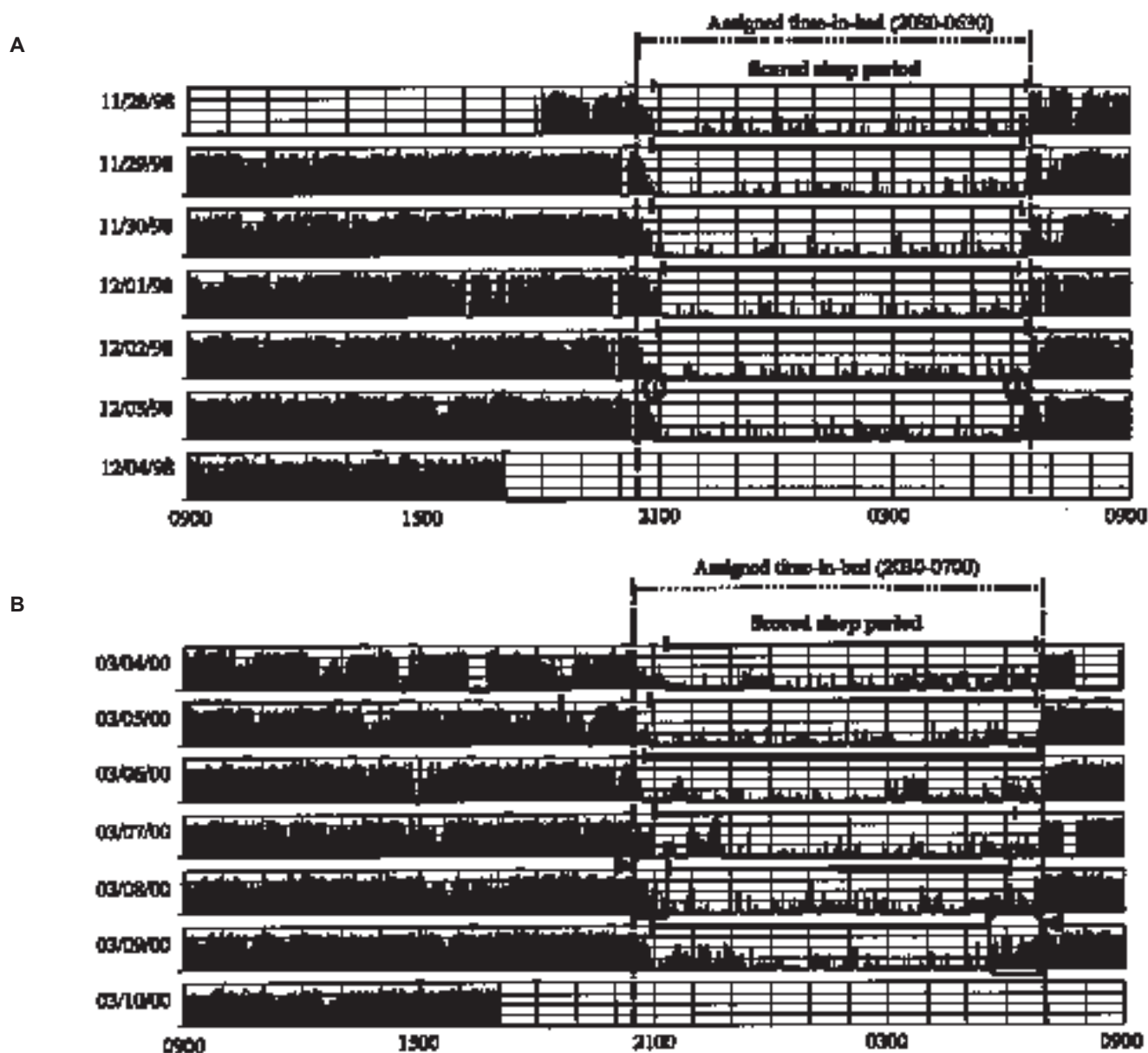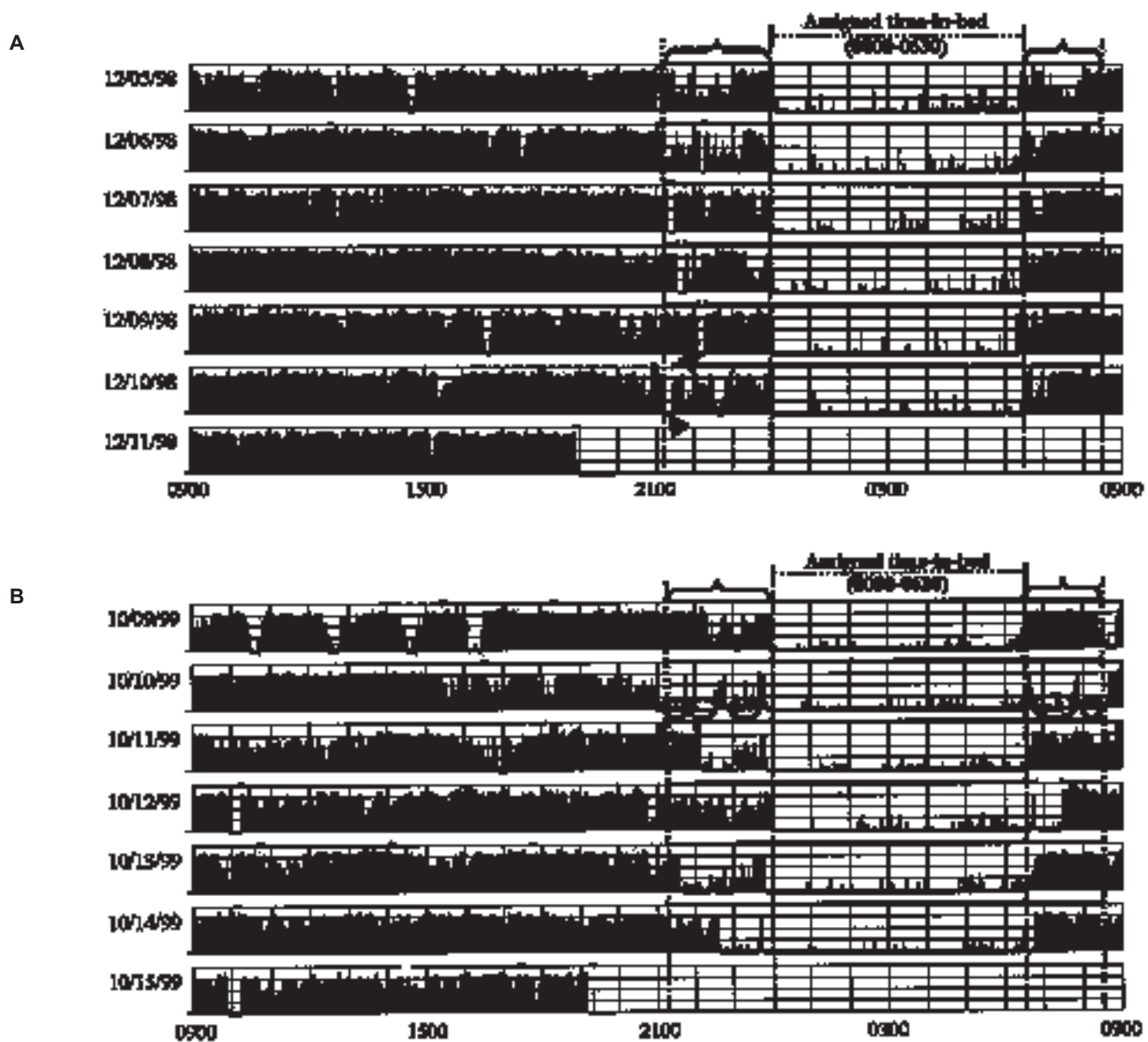


**Figure 3**—Examples of actigraphy scoring for the optimized sleep condition showing assigned time-in-bed and scored sleep period. Time is in 24-hour local clock time. Figure 3A is the record from an 11-year-old boy classified as an experimental success for both experimental conditions (also shown in 4A). Circled points on the scored sleep period identify sleep onset and sleep offset. Figure 3B is the record from an 8-year-old boy classified as an experimental failure for this condition. Markers show reported bedtime and risetime, and circled areas identify deviations from reported bedtime to sleep onset and from sleep offset to reported risetime.

period by 75 minutes or more for 3 or more nights. Figure 3 illustrates our actigraphy scoring method for optimized nights, highlighting the scheduled time-in-bed, the difference between scheduled time-in-bed and scored sleep period, interval from scheduled bedtime to scored sleep onset, and interval from scored sleep offset to scheduled risetime. Figure 3A shows the actigraphy record of an 11-year-old boy classified as an experimental success, and Figure 3B, an 8-year-old boy classified as an experimental failure. Of the 73 children with actigraphy from the optimized condition, 7 (5 boys, 2 girls; aged 6 - 12 years) met our criterion for experimental failure. Our threshold captured only 1 of the children classified as noncompliant (11-year-old boy). Each of the other 3 noncompliant children fell just below the threshold, with only 2 nights where the scheduled time-in-bed exceeded the recorded sleep period by 75 minutes or more.

**Restricted:** For the restricted condition, we defined experimental failure using actigraphic estimates of sleep that occurred outside of the assigned time-in-bed, thus indicating that the child may have fallen asleep before the scheduled bedtime or slept in past the scheduled rise-

time. Even though children were routinely queried when the actigraph record revealed scored sleep outside of the scheduled time-in-bed, recall of sleep onset could become less reliable as a child becomes increasingly sleepy. Therefore, we disregarded self-reports of sleep and wake in these pre-bedtime and post-risetime periods and simply tallied the number of minutes scored as sleep by the actigraphy algorithm. This is a liberal approach to estimating sleep, as the actigraph does not necessarily discriminate between waking periods of very low activity and brief sleep episodes (eg, quietly watching television vs. dozing briefly in front of the television). Our *a priori* decision regarding reasonable expectations for scored sleep outside of the scheduled window reflected the liberal bias of this approach, setting the criterion for experimental failure at 3 or more nights where pre-bedtime and post-risetime sleep totaled 60 minutes or greater.

We tallied minutes of scored sleep occurring within 165 minutes before assigned bedtime and 120 minutes after assigned risetime for each restricted night. The former interval was calculated based on the mean difference between the children's self-selected bedtime and the



**Figure 4**—Examples of actigraphy scoring for the restricted sleep condition showing assigned time-in-bed. Pre-bedtime and post-risetime intervals are indicated by brackets. Time is in 24-hour local clock time. Figure 4A is the restricted record from the boy identified in Figure 3A. Markers show periods when the actigraph was "off" (removed). Figure 4B is the record from an 11-year-old girl classified as an experimental failure for this condition. Examples of scored sleep epochs during pre-bedtime and post-risetime intervals are circled.

scheduled restriction bedtime. The latter interval was selected to capture "sleeping in" past risetime. A few children napped at other times, but these instances were too few to add to the analysis. We manually removed intervals corresponding to reported "actigraph off" periods because the actigraphy algorithm does not automatically discriminate between sleep and periods when the actigraph is removed. As a result, the average number of minutes analyzed in these intervals was a bit less than the full window, averaging 159 ± 14 minutes for the pre-bedtime interval and 115 ± 11 minutes for the post-risetime interval. Figure 4 illustrates these actigraphy scoring parameters.

Actigraph records from restricted nights indicated that children slept an average of 7 ± 16 minutes of the pre-bedtime interval (range = 0 - 109 minutes) and 3 ± 10 minutes in the post-risetime interval (range = 0 - 90 minutes). Of the 78 children with actigraphy from the restricted condition, only 1—an 11-year-old girl—had 60 minutes or more of scored sleep outside of the assigned sleep period for at least 3 nights. Adding together sleep epochs recorded during the pre-bedtime, scheduled time-in-bed, and post-risetime periods, she averaged 452 minutes of sleep on restriction versus her scheduled 390 minutes time-in-bed. Her actigraphy record is shown in Figure 4B. This experimental failure captured by actigraphy was not consistent with our threshold for compliance based upon self report: her telephone calls indicated going to bed and rising on schedule. The only child we had classified as noncompliant for the restricted sleep condition was not captured by the *a priori* criterion for experimental failure; his sleep during the pre-bedtime and post-risetime intervals exceeded 60 minutes on only 2 of the nights.

### Individual Experimental Success: Deviations of Actigraphic Variables Across Conditions

In summary, our *a priori* criteria for experimental failure classified 8 children as protocol outliers based on reasonable expectations for optimized (7 children) or restricted (1 child) conditions. Next, we examine these children in the context of the overall objectives of our experimental design. First and foremost, we had hoped to create distinct experimental sleep conditions that would lead to substantially less sleep on restricted nights relative to optimized nights. Although our analysis of group data clearly demonstrated this separation, did we manage to achieve this objective with the children classified as experimental failures? Examining differences in average total sleep time across experimental nights revealed that 7 of 8 children classified as experimental failures still showed considerably less sleep (an average of at least 100 minutes less per night) on restricted nights relative to optimized nights (Table 2). The remaining child, a 7-year-old girl, averaged only 26 minutes less sleep on restricted nights—the smallest difference in average total sleep time across experimental conditions in our sample. Second, we had hoped to create an optimized sleep condition that did not reduce the child's usual sleep amount. Examining differences in average total sleep time across self-selected and optimized nights revealed that 4 of the 7 children classified as experimental failures for the optimized condition averaged less sleep on optimized nights relative to self-selected

nights, but for 3 of these children, the difference was small (<30 minutes average per night). The remaining child, an 8-year-old boy, averaged 116 minutes less total sleep time on optimized nights relative to his self-selected nights—the largest optimized sleep deficit relative to self-selected nights in our sample (his actigraphy record from the optimized condition is shown in Figure 3B).

### DISCUSSION

These analyses support the use of home-based manipulations to alter sleep patterns of healthy school-aged children as young as 6 years of age. The combination of optimized and restricted conditions altered time-in-bed by an average of 3.5 hours per night across several weeks during the academic year. Furthermore, children from 6 to 12 years of age and their parents showed remarkable compliance with the experimental protocol. Only 7% of our eligible volunteers failed to complete the home-based protocol, and of the remaining participants, only 5% met our *a priori* criteria for noncompliance. Within optimized and restricted conditions, 11% of children with actigraphy data met *a priori* criteria for experimental failure, and no child met criteria for experimental failure in both experimental conditions. While the majority of these children ultimately behaved in accordance with the overall objectives of our experimental design, our criteria for experimental failure were effective in identifying several individuals with extreme values for sleep measures relative to their peers.

We emphasize that our study goals were achieved with healthy young people who were without significant functional deficits prior to study participation. The study protocol involved assessment of cognitive, mood, and behavioral function in multiple settings (ie, home, school, laboratory) under variable sleep conditions so we set exclusion criteria to minimize potential confounds on these domains, such as clinical or subclinical learning difficulties, behavior or mood problems, or sleep problems. We can not determine whether these criteria excluded children and families less able to manage the home-based schedules, but we suspect they did. We are also unable to estimate how many parents refused to allow their children to participate in the protocol due to concerns about schedule requirements. Thus, our results may represent an optimistic view of study outcomes.

The overall goal of this research program was to compare and contrast the functioning of school-aged children under distinct sleep conditions, and, therefore, our methods were designed to support success with the home-based protocol. While we provided parents and children with specific recommendations for managing both experimental schedules, we paid more attention to the restricted schedule assuming children faced greater risk for difficulty keeping the short-sleep schedule. As it turned out, identification of only 1 experimental failure from the restricted condition and 7 from the optimized condition suggests that we should have provided a similar level of attention to potential problems with the optimized schedule as with restricted.

But is "failure" the appropriate term for describing these children? They appeared to be motivated to adhere to our protocol requirements: (1) no one met criteria for experimental failure for both conditions; and (2) when evaluated across conditions, most satisfied the relative objectives of our experimental design. Alternatively, these putative "failures" may have been our greatest "successes," reaching their physiologic limits for sleep restriction or extension, respectively. The somewhat arbitrary criteria offered here for classifying experimental failure should not be taken as an answer to this question. Rather, they are intended to help other researchers in developing *a priori* guidelines for the most difficult decision surrounding home-based studies—namely, is someone really doing what she or he says (or what a parent says) she or he is doing? The importance of actigraphy in this regard was demonstrated by the child who met criteria for experimental failure even though her reported bedtimes and risetimes were consistent with the assigned schedule.

While actigraphy can be particularly useful for monitoring experimental sleep schedules with children, we reiterate what others have said regarding the limitations of this technology.[18] Without further validation

**Table 2**—Children classified as experimental "failures"

| Age (yrs) | Grade | Sex | Condition failed | Avg. total sleep time (min) | |
|---|---|---|---|---|---|
| | | | | O - R[a] | O - S |
| 6.5 | 1 | M | O | 127 | 34 |
| 7.5 | 2 | M | O | 108 | 68 |
| 7.7 | 2 | F | O | **26** | -20 |
| 8.9 | 3 | M | O[b] | 130 | **-116** |
| 9.0 | 3 | F | O | 108 | -11 |
| 9.5 | 3 | M | O | 101 | -29 |
| 11.3 | 6 | F | R[c] | 122 | 57 |
| 11.8 | 6 | M | O | 100 | 22 |
| | | | Sample Mean ± SD | 133 ± 36 | 27 ± 37 |

O = optimized; R = restricted; S = self-selected. [a]Average restricted total sleep time including sleep epochs from pre-bedtime and post-risetime intervals. [b]Figure 2B. [c]Figure 3B. Values in **BOLD** are extremes for sample.

of the technology with children on extended and restricted schedules, we are hesitant to conclude that wake epochs scored from reported bedtime to sleep onset and from sleep offset to reported risetime on optimized nights truly represent wakefulness and that sleep epochs scored during the pre-bedtime and post-risetime periods on restricted nights truly represent sleep. This report also highlights more practical limitations to actigraphy technology. While our overall actigraphy success rate across all study nights was 95%, 5 out of the 78 participants who completed the home-based protocol experienced complete loss of actigraphic data due to mechanical failure during an experimental condition, eliminating them from repeated-measures analysis of actigraphically related variables and also from examination of experimental failure. Loss of actigraphic data during "actigraph off" periods in the pre-bedtime and post-risetime intervals on restricted nights was another problem. Problems related to actigraphic data loss and "actigraphy off" periods are likely to be minimized by advancing actigraph technologies which offer "non-volatile" memory and true water resistance, thus eliminating the need to remove the actigraph for showers or baths.

This study has important implications for both research and clinical practice. Scientists interested in examining the effects of sleep manipulation with school-aged children should view home-based protocols as a viable alternative to laboratory-based studies and no longer consider compliance as a major obstacle to implementing experimental paradigms. We have demonstrated that children (with a few notable exceptions) can comply with significant alterations of sleep schedule and duration and that actigraphy, a widely available technology, can be used in combination with self-report or parent report to monitor compliance with assigned schedules and experimental success. Results presented here should also be encouraging to clinicians who may need to recommend alterations in sleep schedule for school-aged patients.

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