American Journal on Intellectual and Developmental Disabilities

# Challenges in using parent-reported bed and wake times for actigraphy scoring in Rett-related syndromes

--Manuscript Draft--

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| **Manuscript Number:** | AJIDD-D-24-00054 |
| **Article Type:** | Technical Notes |
| **Keywords:** | Rett syndrome; actigraphy; sleep; parent burden |
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| **Manuscript Region of Origin:** | UNITED STATES |
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# Challenges in using parent-reported bed and wake times for actigraphy scoring in Rett-related syndromes

Running title: Challenges for actigraphy scoring in Rett-related syndromes

**Abstract**

Sleep problems are common in Rett syndrome and other neurogenetic syndromes. Actigraphy is a cost-effective, objective method for measuring sleep. Current guidelines require caregiver-reported bed and wake times to facilitate actigraphy data scoring. The current study examined missingness and consistency of caregiver-reported bed and wake times from paper sleep diaries and actigraphy event mark button presses in a sample of 38 individuals with Rett and related syndromes (aged 2-36 years, mean = 13.1) across two 14-day collection time points. Rates of missingness and discrepancy between the two sources were relatively high and correlated with clinical severity and quality of life. Overall, the results suggest a need for alternative actigraphy scoring methods that do not rely on caregiver report in this population.
Key words: Rett syndrome, actigraphy, sleep, parent burden

**Challenges in using parent-reported bed and wake times for actigraphy scoring in Rett-related syndromes**

Rett syndrome (RTT) is an X-linked genetic disorder that affects primarily females and results from loss-of-function mutations of the methyl-CPG binding protein 2 (MECP2) gene in most cases (Amir et al., 1999). Historically, the diagnosis of RTT has been based on a set of clinical diagnostic criteria differentiating the classic phenotype that occurs in most cases of MECP2 mutations from atypical phenotypes now known to be caused, in many cases, by mutations in other genes (Neul et al., 2010). The most common of these RTT-related disorders are cyclin-dependent kinase-like 5 (CDKL5) deficiency disorder, and forkhead box G1 (FOXG1) syndrome, although there are multiple case studies of RTT-like phenotypes resulting from mutations in other genes (Cogliati et al., 2019; Henriksen et al., 2018). Common features of these syndromes include epilepsy, intellectual disabilities, differences in socialization and communication, breathing dysfunction, and sleep problems (D'Mello, 2023). Although sleep problems are common among individuals with intellectual and developmental disabilities (IDD) in general, and may be more common among those with identified genetic syndromes (Browne et al., 2024), they appear to be a nearly ubiquitous feature in RTT-related disorders, with an 80% estimated prevalence and worse sleep quality reported in younger children relative to adolescents and adults (Tascini et al., 2022).

Sleep is a critical component of health and it is well-recognized that sleep problems among individuals with IDD can have a profound impact on quality of life for the affected individuals and their families (Ikeda et al., 2012; Reddihough et al., 2021). As a result, there is an increasing focus on describing sleep patterns and developing and testing sleep interventions for populations with IDD. Actigraphy (ACT) is a widely used tool for assessing sleep patterns and quality using a small watch-like device with an embedded accelerometer typically placed on the wrist or ankle and worn for multiple consecutive days, allowing for sleep measurement in the natural home environment. ACT is a useful tool for assessing sleep in IDD populations

because it is relatively cost effective, non-invasive, and can be collected without disruption to the individual's daily routine. The movement captured by the accelerometer is converted into sleep and wake intervals using one of several available algorithms. These data are then converted to sleep variables within the software, including total nighttime sleep, amount of time awake after falling asleep, and sleep efficiency (% of time asleep while in bed).

In most cases, the daily ACT data are hand-scored by trained researchers within the software to identify the bedtime (onset) and wake time (offset) of the nighttime rest interval. Accurate identification of bedtimes, in particular, is critical to evaluating variables such as sleep onset latency, the time between when an individual goes to bed and when they actually fall asleep. Although there is some disagreement in the literature on the correct definition for onset latency (i.e., should the onset time be when the individual gets into bed or when they actually try to fall asleep), it is generally well recognized that some type of self-reported (or proxy-reported in the case of young children or individuals with IDD) information on timing of bed and wake time is necessary to determine the accurate rest interval from which the sleep variables and related information are extracted. For this reason, participants in studies using ACT to measure sleep are typically asked to complete a daily sleep diary that includes recording of bed and wake times and/or push an ACT event mark button on the watch to mark the start and end times of the nighttime rest interval in the analysis file. This information is then used to support decision-making by the research team in setting the nighttime rest interval.

A challenge to the typical protocol of using sleep diaries or ACT event marks for the scoring of nighttime rest intervals is that of missing data. Many studies report the average number of useable/collected nights recorded per participant, but most do not formally report the proportion of days with no noted bedtime or wake time on the sleep diary or associated ACT event mark. Thus, it is largely unknown making it difficult to know what proportion of missing data should be anticipated, or how different groups handle nights without reported bed and/or wake times. In a study evaluating ACT data from three samples of children and adolescents

without disabilities, Acebo et al. ( 1999) reported an average data loss of up to 28% for reasons that included illness, technical problems, and participant noncompliance including failure to complete the diary regularly and accurately.

It is currently unclear whether studies including parents of individuals with IDD would result in similar rates of data loss, but there is reason to believe that the problem may be exacerbated in this population. Evidence suggests that parents of individuals with IDD, including those with RTT, experience increased parental stress relative to parents of typically-developing children (Pari et al., 2020). Further, parenting stress has been shown to decrease adherence with a range of intervention protocols among parents of children with IDD (Loader et al., 2019; Rone-Adams et al., 2004). Parents of individuals with IDD, including RTT-related syndromes, may therefore have more difficulty in implementing at home research protocols such as ACT, particularly if they require sustained participation over time (both within and across collection timepoints). To our knowledge, however, no studies have specifically reported the proportion of missing data or the consistency of parent-reported bed and wake times among samples of individuals with IDD.

Therefore, the goals of the current study were to a) determine the degree to which parents of individuals with RTT-related syndromes consistently reported bed and wake times using two methods (a paper sleep diary and ACT event marks button pushes) by evaluating the frequency of missing data in both methods and the correspondence between the methods when both were available, b) determine whether consistency changed between an initial recording period and a follow-up period approximately 4-6 weeks later, and c) evaluate whether participant demographic or clinical features were associated with missingness and consistency (between ACT event marks and sleep diary) of parent-reported times.

## Methods

### Participants

Participants (N=40) were recruited as part of a larger IRB-approved study designed to evaluate the utility of potential outcome measures for use in RTT and related syndromes. Parents/legal guardians for all individuals with RTT-related syndromes provided informed consent for participation. Participants were recruited through a regional RTT syndrome medical clinic and via the International Rett Syndrome Foundation's myRett Trial Finder. Eligibility criteria for the study included a diagnosis of RTT, CDKL5 deficiency disorder, or FOXG1 syndrome with or without genetic confirmation. Individuals of all ages were eligible for participation. For the purposes of the current analysis, individuals who lived away from their parent/guardian, such as those residing in group homes, were excluded due to the sleep diaries and ACT event markers being completed by staff rather than parents. Demographic and clinical information for the participants with RTT-related syndromes who provided at least one usable ACT collection timepoint (i.e., ACT device was worn for at least 3 nights and data were recoverable) are reported in Table 1. The participants with RTT ranged in age from 1 to 36 years (mean = 13.7, SD = 9.0). Participants were predominantly white and not Hispanic (N = 37, 94.8%), with the other participants reporting more than one race and not Hispanic (N = 2, 5.1%). The mother completed the questionnaires and sleep diaries for most the participating families (N = 36, 94.7%), with the father completing the questionnaires and both parents participating in sleep diary completion in two families (5.3%).

**Procedures and Measures**

***Sleep Diaries and ACT Event Markers***

All materials for the sleep collection were mailed to the participants' homes. Before the first collection, a member of the research team provided face-to-face (in-person or on Zoom) instructions for both the ACT watch and sleep diary, demonstrating appropriate watch placement and the event mark button. Parents were given the chance to ask any questions and direct contact information to a member of the study team for any questions or trouble-shooting during

the collection. A directions sheet with the information described below was also provided to the parents in the package.

**Actigraphy.** Philips Actiwatch 2 (Philips Respironics, Bend, Oregon) devices were used to collect actigraphic sleep data. For each recording period, a pre-programmed ACT watch was mailed to the participant's home address, arriving approximately 8-24 hours prior to the beginning of the collection period. Parents were instructed to place the sleep watch snuggly on their child's non-dominant wrist or their ankle if 3 years or young (or if the sleep watch was too large on their wrist for a snug fit). They were also instructed to push the ACT event mark button when putting their child to bed at "lights off" in the evening (bedtime) and upon getting their child out of bed in the morning (wake time).

**Sleep diaries.** A paper sleep diary was provided to parents with the ACT watch. The sleep diary consisted of a series of 24-hour timelines with vertical lines at 30-min intervals corresponding to each day of the collection. Parents were instructed to mark the exact time at which the individual was put in bed ("lights off") and got up from bed each night using arrows (i.e., rest interval), aligning to the time the buttons were pushed, or write the clock times. They were then instructed to indicate periods of sleep by shading in the relevant boxes between the bed and wake times.(i.e., nighttime rest interval). The paper direction provided included an example night of filling in the sleep diary, showing the arrow for bedtime, shaded sleep times, and wake time.

***Measures***

**Clinical Severity Scores.** RTT-specific clinical severity scores were calculated using the criteria outlined in Kerr et al. (2001). This provides an overall estimate of the severity of a range of symptoms and comorbidities commonly associated with RTT and related syndromes. Each of 20 items is scored on a 0 to 2 scale, with 0 representing an absence of that symptom and 2 representing severe symptoms, for a total score range of 0 to 40. Items were scored by the first

author based on information from observation, medical records, and caregiver report. In the current sample, scores ranged from 9 to 34, and the internal consistency for the scale was .82.

Other health-relevant questionnaires were completed independently by the parent either in-person at a larger study visit or online via Qualtrics if they chose virtual-only study visits (typically due to COVID restrictions or living outside of the metro area). Not all parents completed all questionnaires due to limited clinical time or failure to complete the full Qualtrics battery.

**Quality of life.** The Quality of Life Inventory – Disability (QI-Disability; Downs et al., 2018) was used to evaluate parent-reported quality of life (QOL) among the individuals with RTT-related syndromes. The QI-Disability is composed of 41 items scored on a 1 (“never”) to 5 (“very often”) scale, with higher scores representing better quality of life. Previous studies have demonstrated a 6-factor structure with subscales associated with social interaction, positive emotions, physical health, negative emotions, leisure and the outdoors, and independence. In the current sample, the social interaction and positive emotion subscales were highly correlated (i.e., $r > .80$) with each other and with the total QOL score. Therefore, these subscales were not evaluated in the current study. The physical health subscale was also excluded due to poor internal consistency. In the current sample, total QOL scores ranged from 91 to 148 for the full scale (possible range = 41-205; $\alpha = .88$); 19 to 34 for negative mood (possible range = 8-40, $\alpha = .63$); 11 to 25 for leisure and outdoors (possible range = 5-25, $\alpha = .76$), and 7 to 23 for independence (possible range = 6-30, $\alpha = .67$). Data from the QI-disability were missing for four families.

**Parent-reported sleep problems.** The SNAKE sleep scale (Blankenburg et al., 2013) was used to evaluate parent’s perceptions of sleep problems prior to the first actigraphy collection. The snake includes 54 items scored on a scale from 1 (“never”) to 4 (“at least three times per week”). The SNAKE includes 5 subscales (comprised of 3 to 5 items), of which the “disturbances remaining asleep” or sleep maintenance (score range = 5-20), and the daytime

sleepiness (score range = 3-12) subscales were examined in the current study. In the current sample, scores ranged from 5 to 17 and 3 to 12 for the sleep maintenance and daytime sleepiness scales, respectively. Internal consistency for the subscales were .61 and .73, respectively. Data were missing for the SNAKE for two families.

***Extraction of Parent-Reported Bed and Wake Times***

Information on parent-reported bed and wake times were extracted from the sleep diaries and the ACT event marks from the software. For ACT event marks, the exact time of the event mark was extracted from the Philips Actiware software. ACT event marks were categorized as credible if they occurred within 90 minutes of the start or end of the individual's typical reported nighttime rest interval (based on average times across the recording period from the sleep diary). If more than ACT event mark occurred within the 90-minute interval, the event closest to the corresponding time reported on the sleep diary was selected. If no information was available on the sleep diary, the ACT event mark with the time closest to the average bed/wake time based on the other nights of the diary or the average time of credible event marks from other nights was used to select a single time. ACT event marks were excluded if the parent noted on the sleep diary that they pressed the button accidentally or in a way that was inconsistent with the instructions (e.g., they forgot to press it at bedtime and pressed it when they remembered an hour later).

For the diaries, bed/wake times were recorded in increments of 15 minutes. If an arrow or shaded area was within the box for a 30-min interval, the time was recorded as the corresponding 15-min increment (e.g., an arrow within the box spanning 8:00 to 8:30 am would be recorded as 8:15). For diaries in which a gap occurred between two or more separate recorded sleep intervals (e.g., sleep from 10pm to 5 am and from 6 am to 8 am) in which no arrow indicated a specific bed or wake time, the intervals were counted as part of the nighttime rest interval if it a) was separated from the main interval by no more than 60 minutes, or b) was

during the individual's typical reported nighttime rest interval (i.e., the reported nighttime rest interval spanned that time on at least two other nights during the collection).

***Data Analysis***

Each night of actigraphy collection was reviewed and the missing information was categorized for bed and wake times (i.e., valid information from both sources, missing event mark only, missing diary time only, or missing both sources of information). For each night of actigraphy collection with valid information from both sources, the average absolute difference (in minutes) between the time of the actigraphy event marker and the diary-reported time was calculated. Because these discrepancy values were not normally distributed, descriptive statistics are reported as medians and interquartile ranges (IQRs). To further elucidate patterns, each night was categorized as having a discrepancy of 15 min or less, 16-30 min, 31-45 min, or 46-60 min, or more than 60 min. To visually assess the discrepancies and identify any systematic bias, we created modified Bland-Altman plots (Altman & Bland, 1983), with 45 minutes set as arbitrary limits of agreement. The 45-min criterion was selected because the sleep diary times have a maximum resolution of approximately 15 minutes so more stringent criteria seemed overly conservative, but differences of more than 45 minutes would be expected to result in clinically meaningful differences.

The descriptive statistics for the measures of concordance (i.e., proportion of events with discrepancies of 45 min or less), discordance (proportion of events with discrepancies > 45 min), missingness (proportion of events with no valid actigraphy event marker/diary event), and median discrepancy were calculated separately for each family to determine whether data loss and inconsistency were widespread across the sample or attributable to a small number of individuals. Finally, to evaluate differences in missingness across time points, chi-square analyses were conducted to test whether there were systematic differences in missingness and/or concordance/discordance between Time 1 and Time 2 . Wilcoxon signed rank non-parametric paired t-tests were used to evaluate change in median discrepancies from Time 1 to

Time 2. Non-parametric Spearman ranked correlation coefficients were calculated to evaluate the degree to which missingness and discrepancies were associated with clinical features (i.e., age of the participant, clinical severity score, SNAKE subscale scores, QOL subscale scores, and average bed and wake times [according to sleep diaries]). P-values were corrected for multiple comparisons for each analysis using the Benjamini-Hochberg false discovery rate correction (Benjamini & Hochberg, 1997). Single-sided p-values were used for all analyses.

## Results

In total, 40 eligible participants and their parents attempted at least one actigraphy collection timepoint. Among these, one family never returned the watch following the first collection, and one participant did not tolerate wearing the watch during the first collection, resulting in a total of 38 participating families with usable data for at least one collection (95.0%). Participant characteristics presented in Table 3. All 38 of these participant families completed both 14-day collection timepoints (N=76 collections). Across all timepoints, three recordings were lost due to actigraphy device errors (N = 2) or noncompliance (i.e., watch was not worn during the collection period; N = 1), resulting in a total of 73 usable recordings (93.8%).

The average number of usable nights across all collections was 13.6 (median = 14, SD = 1.33). Across participant families, the total number of usable nights ranged from 6 to 29 (mean = 26.1, median = 28, SD = 5.0) At the level of collections, most included 14 nights of analyzable data for parent-reported times (N = 55, 75.3%), 2 recordings included 15 nights of data (2.7%), 12 had 13 nights (16.4%), and 1 each had 12, 11, 7, and 6 nights (1.4% each) for a total of 992 nights of data, divided approximately evenly between Time 1 and Time 2 (494 and 498 nights, respectively). Within-recording data loss was exclusively due to participant noncompliance (i.e., failure to wear the watch).

### Concordance, Missingness, and Discrepancies Across All Nights

Across the 992 nights analyzed, a total of 697 bedtimes (70.7%) and 680 wake times (68.5%) had valid ACT event marks and diary times. Among the nights with missing information,

missed ACT event marks were much more common than missing diary times, accounting for 250 bedtimes (82.8%), and 266 wake times (84.2%). Among the events with both sources of information, most nights had discrepancies of less than 15 minutes (N = 407 bedtimes, 58.4% of nights with both sources; N = 363 wake times, 53.4%). Nevertheless, events with discrepancies greater than 45 minutes occurred for a substantial proportion of nights with both pieces of information (N = 103 for bedtimes, 10.4% of all nights; N = 154 for wake times, 15.5%). Across all available nights, the median discrepancy was 12.0 min (IQR = 7.5, 18.9) for bedtimes, and 16.2 min for wake times (IQR = 9.6, 34.3). Bland Altman plots of all nights with both ACT event marks and diary-reported bed- and wake times are shown in Figures 1 and 2, respectively. The mean differences between the diary time and event marker time were -0.13 and -0.23 hours (or -7.8 and -13.8 in minutes) for bed and wake times, respectively, suggesting that, on average, the ACT event marks were slightly later than the diary-reported times, but these patterns were not consistent.

**Discordance, Missingness, and Discrepancies by Family**

Although rates of missingness for diary times clustered clearly within participating families (i.e., 11 [28.9%] and 16 [42.1%] of families accounted for 100% of the missing diary times for bedtimes and wake times, respectively), only 1 (2.6%) family had valid ACT event marks for all bedtimes, and 5 (13.2%) families had valid ACT event marks for all wake times. The median percentage of nights with missing ACT event marks was 16.7% for bedtimes and 19.6% for wake times (it was 0% for diary times for both). Nevertheless, families in the lowest 25% for completeness accounted for 57.2% and 63.7% of missing bed- and wake time ACT event marks, respectively.

Overall, 10 participating families (26.3%) had concordance for at least 75% of the bedtimes across their recordings. For wake times, 11 families (28.9%) had 75% or greater concordance. The median discrepancy between ACT event marks and diary times by family ranged from 2.4 to 54.6 minutes for bedtimes and from 3.6 to 83.4 for wake times. Non-

parametric correlations showed that the median discrepancies between ACT event marks and diary times at bedtime were associated with the proportion of missing ACT event marks at bedtime ($r$ = .335, $p$ = .048) and at wake time ($r$ = .452, $p$ = .012), but wake time discrepancies were not associated with ACT event mark missingness (bedtime $r$ = .144, $p$ = .201; wake time $r$ = .220, $p$ = .132).

**Discordance, Missingness, and Discrepancies by Time Point**

Results of chi-square analyses examining proportion of events with missing values and magnitude of discrepancy by collection time are reported in Table 2. For bedtimes, there was a significant increase in missingness overall from Time 1 to Time 2, although only proportions of events with both sources missing increased significantly among the separate sources. For wake times, there were significant increases in the proportion of missing ACT event marks and diary times. When categories of the magnitude of discrepancies were analyzed, there were no significant changes over time for bedtimes, but the proportion of wake times with discrepancies less than 15 min showed a significant decrease from Time 1 to Time 2. Among families who completed two valid collections, median discrepancy for bedtimes was 11.7 min (IQR = 5.3, 17.7) at Time 1 and 14.4 min (IQR = 6.1, 22.8) at Time 2 (Z = 0.91, p = .181). For wake times, median values were 15.0 min (IQR = 7.2, 28.7) at Time 1 and 15.2 min (IQR = 8.3, 31.7) at Time 2 (Z = 1.910, p = .056).

**Association Between Clinical Features and Missingness/Discrepancies**

Discrepancies for bedtimes were moderately negatively correlated with parent-reported leisure-related QOL, total QOL, and daytime sleepiness, whereas discrepancies for wake time were not significantly correlated with any of the variables examined. The proportion of ACT event marks missing at bedtime was moderately negatively correlated with independence-related and total QOL, and the proportion of ACT event marks missing at wake time was moderately negatively correlated with age and total QOL.

## Discussion

The primary goal of the current study was to evaluate the degree to which parents of individuals with RTT-related syndromes were able to provide consistent estimates of their children's bedtimes and wake times, as measured by proportion of missing data and discrepancies between sleep diaries and ACT event marks. Overall, the results showed that parents were more likely to provide information in the form of the sleep diary relative to the ACT event marks, but the results overall raise questions about the reliability and accuracy of both methods. Rates of discordance of 45 minutes or greater between the diary and ACT event marks times were high, accounting for approximately 14.8% of bedtimes and 22.6% of wake times when both sources of information were available.

The direction of the difference between diary times and ACT event marks times was highly variable, as evidenced by the Bland-Altman plots. This suggests that there is not a clear pattern to how parents are choosing to determine the two sources. Intuitively, it seems that ACT event marks times should be the more accurate method, as the parent needs to be physically present when they decide to press the button, eliminating the possible error associated with recall if the parent completed the diary after the child was in bed or the following morning, but additional work is needed to confirm this assumption. It is possible that some parents misinterpreted the instructions and pressed the ACT event mark button when they determined that their child had fallen asleep for bedtimes rather than when they put them to bed at "lights out." but the fact that there is no consistent bias toward ACT event marks being later than diary-reported times suggests otherwise. Because families who had more missing information also had greater discrepancies when they did report both sources of information, the reported results likely overestimate the total agreement between the methods.

Among families who completed two separate actigraphy collections, rates of missingness increased during the second collection relative to the first. This finding raises concerns for the prospect of using actigraphy in combination with parent-reported times for measuring change over time in the context of clinical trials. This finding is consistent with

declines in compliance with research protocols over time in other populations and study methods (Tonkin et al., 2023). The finding that rates of missed ACT event marks and bedtime discrepancies were associated with parents' reports of QOL among the individuals with RTT-related syndromes supports the hypothesis that parental stress may be an important factor in compliance. The negative association between age and proportion of missing wake time events also supports this hypothesis, as parents of younger children often report more parenting stress than parents of adolescents and adults (Biswas et al., 2015). It is likely that additional parent education could improve overall levels of implementation but given potential link between poor adherence and parental stress or burden, asking parents to do more to improve the quality of the data seems ethically questionable.

A more practical and appropriate path forward may be to develop actigraphy scoring methods that do not rely on parental report on a day-to-day basis, as has been done in other populations (Adams et al., 2019; Burkart et al., 2023), although the overall low levels of activity and daytime somnolence may pose challenges to the development of scoring rules based on changes in movement alone. The finding that daytime sleepiness was positively associated with discrepancies in reported bedtimes in the current sample suggests that some parents may have difficulty in ascertaining their child's bedtime if the child is often sleepy in the evening before going to bed. Therefore, scoring guidelines based on standard times or first sleep onset may be necessary to ensure consistency in scoring and estimation of sleep times.

The main limitation of "no diary" methods is that there is no clear method for identifying bedtimes (as opposed to time of sleep onset), generally making it difficult to impossible to evaluate sleep onset latency. On the other hand, the construct of sleep onset latency needs special consideration when being applied to populations in which self-report is unavailable. Guidelines published by the Society of Behavioral Sleep Medicine (Ancoli-Israel et al., 2015) state that "Because 'bedtime' can be interpreted in multiple ways, it is useful to have individuals identify both the time they got into bed and the time they *attempted to fall asleep*." (p. S16).

Because most individuals with RTT-related syndromes are unable to indicate when they are ready for bed or attempting to fall asleep, the construct of sleep latency as it is generally applied in the literature on sleep in typically developing adolescents and adults may not be appropriate for this population. Nevertheless, a method that uses diary-agnostic decision rules to establish reliable estimates of total sleep time, sleep efficiency, and wake after sleep onset should be attainable, in theory, and would reduce the burden on parents while simultaneously improving overall data quality.

The study had several important limitations. Because no 'gold standard' of bed and wake times was available for the nights analyzed, it is unclear whether discrepancies represent inaccuracy in ACT event mark times, diary times, or both, although we suspect that both methods are subject to substantial error. Further, the sample was a small convenience sample and therefore is not likely to reflect the overall population of parents of individuals with RTT-related syndromes. As such, the results should be considered specific to this sample and would not be expected to generalize to other samples/populations. No demographic information was collected on the parents, making it impossible to evaluate associations between parent characteristics including parental stress or burden and protocol implementation/consistency. Finally, some of the actigraphy recording periods occurred during the first several months of the COVID-19 lockdowns in the USA when families were forced to adjust to new routines and likely experienced greater than typical levels of stress.

In conclusion, the results of the study suggest that relying on ACT event marks for identifying bed- and wake times among individuals with RTT-related syndromes was not feasible, and that researchers should use caution when relying on parent-completed sleep diaries. Future research should examine alternative methods for establishing sleep intervals for actigraphy data scoring in this population. Work is needed in other severe neurodevelopmental disability populations to determine the degree to which the issues with missingness and discrepancies are common in these populations and to evaluate possible solutions.

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Figure captions.

Figure 1. Bland-Altman plot of parent-reported bedtimes (a) and wake times (b) across all nights with both diary and ACT event marks times available. The heavy solid horizontal line represents no difference between the two methods; the lighter solid horizontal lines represent the range designated as concordance (+/- 45 minutes); the dashed line represents the mean difference between the two measures.

Table 1. Demographic and clinical characteristics of the sample

| Characteristic | N | % |
|---|---|---|
| Diagnosis by sex | | |
| Females | | |
| Rett syndrome (MECP2 mutation) | 33 | 86.8% |
| CDKL5 deficiency disorder | 1 | 2.6% |
| FoxG1 syndrome | 1 | 2.6% |
| MEF2C haploinsufficiency | 1 | 2.6% |
| Total | 36 | 94.7% |
| Males | | |
| Rett syndrome (MECP2 mutation) | 1 | 2.6% |
| CDKL5 deficiency disorder | 1 | 2.6% |
| Total | 2 | 5.3% |
| Age | | |
| 5 and under | 7 | 18.4% |
| 6 to 12 | 11 | 28.9% |
| 13 to 18 | 12 | 31.6% |
| 19 and older | 8 | 21.1% |
| Ambulation status | | |
| Does not walk | 18 | 47.4% |
| Walks with support | 3 | 7.9% |
| Walks without support | 17 | 44.7% |
| Seizures | | |
| Never | 11 | 28.9% |
| Controlled or previously | 14 | 36.8% |
| Current | 13 | 34.2% |

Table 2.

| Category of agreement/disagreement | Bedtimes | | | | | | Wake times | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | | T2 | | Difference T1-T2 | | T1 | | T2 | | Difference T1-T2 | |
| | *N* | *%* | *N* | *%* | $\chi^2$ | *p* | *N* | *%* | *N* | *%* | $\chi^2$ | *p* |
| **Missing at least one source of information** | **128** | **24.7** | **167** | **33.5** | 6.9 | .026 | **119** | **24.1** | **193** | **38.1** | **24.7** | **<.001** |
| ACT event mark missing | 102 | 19.2 | 126 | 25.3 | 3.0 | .170 | 91 | 18.4 | 140 | 28.1 | 13.0 | .015 |
| Diary missing | 23 | 4.8 | 29 | 5.8 | 0.7 | .454 | 15 | 3.0 | 35 | 7.0 | 7.6 | .016 |
| Both missing | 3 | 0.7 | 12 | 2.4 | 5.4 | .050 | 13 | 2.6 | 18 | 3.6 | 0.8 | .440 |
| **Both sources available** | **366** | **75.3** | **331** | **66.5** | **6.9** | **.026** | **375** | **75.9** | **305** | **61.2** | **24.7** | **<.001** |
| Difference 15 min or less | 216 | 45.8 | 191 | 38.4 | 3.0 | .170 | 205 | 41.5 | 158 | 31.7 | 10.2 | .007 |
| 16-30 min | 66 | 11.9 | 53 | 10.6 | 1.7 | .298 | 59 | 11.9 | 44 | 8.8 | 2.6 | .198 |
| 31-45 min | 33 | 6.4 | 35 | 7.0 | 0.0 | .828 | 26 | 5.3 | 34 | 6.8 | 1.1 | .396 |
| 46-60 min | 23 | 5.1 | 16 | 3.2 | 1.4 | .346 | 28 | 5.7 | 24 | 4.8 | 0.4 | .578 |
| > 60 min | 28 | 6.2 | 36 | 7.2 | 1.0 | .396 | 57 | 11.5 | 45 | 9.0 | 1.7 | .298 |
| **Total** | **494** | | **498** | | | | **508** | | **512** | | | |

Table 3. Correlations between variables reflecting the consistency of parent-reported bed and wake times and demographic and clinical characteristics.

| Participant characteristics | | Median discrepancy - bedtimes | Median discrepancy - wake times | Proportion of missing ACT event marks - bedtime | Proportion of missing ACT event marks - wake time |
|---|---|---|---|---|---|
| Age | *r* | -.12 | -.12 | -.14 | -.42 |
| | *p* | .372 | .314 | .314 | .021 |
| | *N* | 35 | 36 | 38 | 38 |
| Clinical severity | *r* | .37 | .06 | .04 | .01 |
| | *p* | .061 | .429 | .434 | .467 |
| | *N* | 35 | 36 | 38 | 38 |
| QOL - negative emotions | *r* | -.22 | -.22 | -.23 | -.36 |
| | *p* | .222 | .222 | .214 | .070 |
| | *N* | 32 | 33 | 34 | 34 |
| QOL - leisure | *r* | -.54 | .05 | -.10 | -.10 |
| | *p* | .012 | .429 | .382 | .382 |
| | *N* | 32 | 33 | 34 | 34 |
| QOL - independence | *r* | -.05 | -.31 | -.46 | -.34 |
| | *p* | .429 | .113 | .016 | .074 |
| | *N* | 32 | 33 | 34 | 34 |
| QOL - total | *r* | -.55 | -.24 | -.48 | -.50 |
| | *p* | .012 | .212 | .015 | .013 |
| | *N* | 32 | 33 | 34 | 34 |
| Problems with sleep maintenance | *r* | .21 | .28 | .16 | .19 |
| | *p* | .225 | .131 | .292 | .236 |
| | *N* | 34 | 35 | 36 | 36 |
| Problems with daytime sleepiness | *r* | .46 | -.06 | .09 | .03 |
| | *p* | .016 | .429 | .383 | .436 |
| | *N* | 34 | 35 | 36 | 36 |