**Latent Variable Model Does Not Capture Actigraph-Assessed Sleep Quality Indices**

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Purpose:
Most sleep quality research utilizes single, global indices of sleep quality, typically total sleep time during a given time interval (Tomfohr et al., 2011). Reliance on a single index of sleep quality provides an incomplete examination of an individual's sleep given the nuanced information that is afforded by modeling multiple sleep indices, including sleep efficiency and movement. Although objective measures of sleep, such as Actigraphy monitoring, are often employed to gather a more accurate estimate of total sleep time (Hanson et al., 2010), relatively little attention is allocated toward the wealth of other potentially relevant sleep indices available via Actigraphy monitoring (Doane et al., 2014; Lee et al., 2017, Yap et al., 2020). It is unclear if these multiple sleep quality indices correlate so significantly and operate so similarly as to fall under a single factor or latent variable. We aimed to uncover the interrelations of various Actigraphy-assessed sleep quality indices to inform whether future research should model sleep quality indices separately or together.

Procedure:
260 undergraduate students participated. The sample ($M_{age}$ = 19.60) was mostly female (69.1%) and racially diverse (53.2% non-Hispanic White). For 14 consecutive days, participants wore Actigraph monitors that provided daily values for the following sleep quality indices: **total sleep time, sleep efficiency, wakefulness after sleep onset, movement index, and sleep fragmentation index**. Operational definitions of these sleep indices are included below. A multilevel confirmatory factor analysis (CFA) was conducted to determine if a model in which the five sleep quality indices load onto a single latent variable fit the data well. The between- and within-persons parts of the CFA were estimated separately before an overall CFA incorporating between- and within-persons parts was estimated.

| Sleep Quality Index | Operational Definition |
|---|---|
| Total Sleep Time | Daily duration of sleep in minutes during a major sleep period window |
| Sleep Efficiency | Percentage of time spent in bed that a participant is asleep |
| Wakefulness After Sleep Onset | Number of awakenings after sleep initiation |

| | |
|---|---|
| Movement Index | Number of limb motions divided by a participant's time in bed in minutes |
| Sleep Fragmentation Index | calculated using the sum of the number of minutes of sleep during which movement occurred and is expressed as a percentage of a participant's total sleep involving both movement and immobility. |

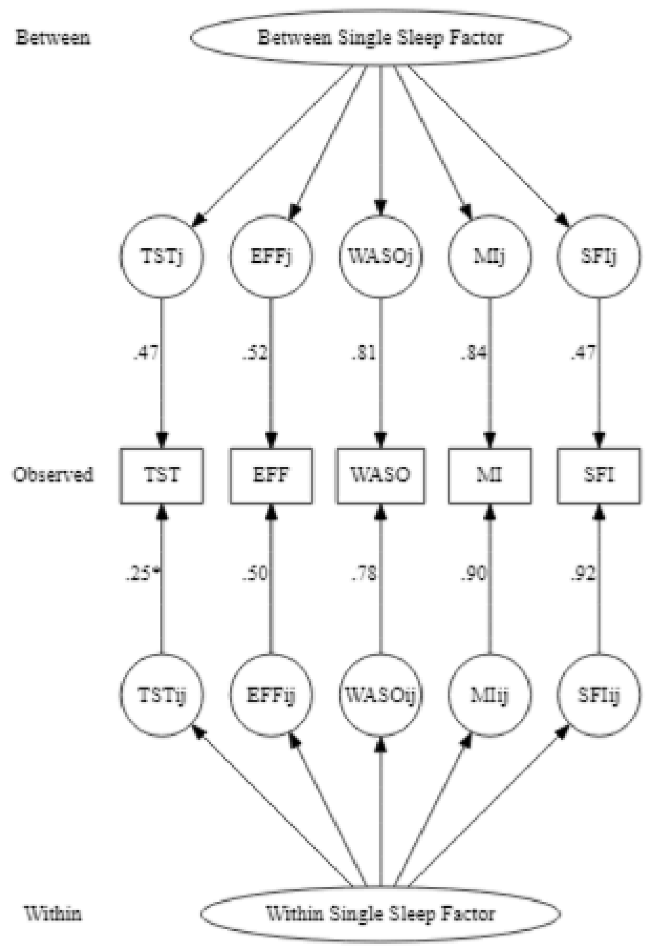
* Note. With no established criteria on how to classify major sleep periods, the present study used the following approach, which was informed by theory and prior research. Major sleep periods were treated as nocturnal periods during which participants got the majority of their sleep. Nocturnal periods were considered as any sleep that started anytime after 6:00pm and before 9:00am. For instance, if a participant slept from 10pm-7am and then 7:30am-10:00am, both periods of sleep were merged to reflect this participant's major sleep period, because the 7:30am period began before the 9am threshold. This approach to establishing a discrete sleep period window has been used in previous research (Yoon et al., 2003) and aligns with personal correspondence from researcher Joshua Wiley (Wiley, personal communication, January 23, 2023). Participants whose major sleep period consisted of over 725 minutes were labeled as odd sedentary behavior and were deleted from analyses, which resulted in the removal of 7.5% of total observations. Participants whose sleep patterns fell outside of this nocturnal pattern were deleted, resulting in the deletion of 23 time points and the retention of 99.4% of collected data.

Results:

Intraclass correlations for sleep quality indices ranged from .11 to .34, suggesting that modeling should be treated in a multilevel approach due to non-independence of observations (Hox et al., 2010). A CFA of the five sleep quality indices loading onto a single latent variable fit the data poorly, CFI = .23, SRMR = .13, RMSEA = .32, TLI < .01.

At the within level, all five sleep quality indices had significant loadings onto a within-person general factor of sleep, $p < .0001$. The within model fit poorly, although better than the overall model, CFI = .59, SRMR = .13, RMSEA = .42, TLI = .18.

At the between level, total sleep time did not significantly load onto a between-person general factor of sleep, $p = .16$; although, all other between-subjects loadings were significant, $p < .01$. The between model fit poorly, although better than the overall model and the within model, CFI = .70, SRMR = .15, RMSEA = .44, TLI = .41.




*only loading not significant, p > .05.

Conclusions & Implications:
Poor fit of a model in which five sleep quality indices loaded onto a latent variable suggests that the sleep quality indices examined in this study operate uniquely and, therefore, warrant investigation independent of one another. Superior fit of a between model compared to an overall model and a within model and superior fit of a within model compared to an overall model suggest that disentangling between- and within-subjects components of latent variable models of sleep quality indices yields more accurate results. Future research will benefit from exploring the nuances of factors contributing to sleep quality.