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Measurement properties of the minimal insomnia symptom scale (MISS) in adolescents

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Abstract

Background: The Minimal Insomnia Symptom Scale (MISS) is a three-item screening instrument that has been found to be psychometrically sound and capable of screening for insomnia among adults and older people. This study aimed to test the measurement properties of the MISS together with an additional item focusing on daytime functioning among adolescents using the Rasch measurement model.

Methods: A cross-sectional design was used, and data from adolescents (age 13–17 years, $n = 3022$) were analyzed using the Rasch measurement model.

Results: The MISS had good measurement properties. When adding the item "daytime disturbance", the measurement properties deteriorated. When replacing the original MISS item "not rested by sleep" with the item "daytime disturbance", the measurement properties slightly improved. We label this new scale the MISS-Revised (MISS-R). The reliability was better for the MISS-R (0.55) compared to the MISS (0.50). The optimal cut-off was found to be ≥6 points, both for the MISS and the MISS-R.

Conclusions: This study provides general support that both the MISS as well as the MISS-R have good fit to the Rasch model. At this stage, neither the MISS nor the MISS-R can be advocated over the other for use among adolescents, although the MISS-R had slightly better reliability than the MISS. Additional studies are needed to determine the clinically optimal cut-score for identification of insomnia.

Keywords: Adolescents, Insomnia, MISS, Psychometric analysis, Rasch measurement model, Reliability

Introduction

Insomnia includes difficulties initiating sleep, difficulties maintaining sleep, and/or waking up too early (Association AP 2013; Ohayon and Reynolds 3rd 2009). The prevalence of insomnia varies in different studies, which may be due to including persons in different development periods and to the use of different assessment criteria (Ohayon 2002). For example, in Sweden, 10% among adults ($n = 1115$, aged 18–84 years) had an insomnia disorder, defined as the presence of at least one symptom of disturbed sleep and daytime symptoms for at least 1 month (Sandlund et al. 2016). In another Swedish study among adults ($n = 1128$, aged 18–84 years), 25% reported insomnia symptoms, defined as sleep initiation problems at least 3 times per week and/or sleep maintenance problems at least 3 times per nights (Mallon et al. 2014). The prevalence of difficulties getting to sleep every week among European and Canadian school-aged children ($n = 220{,}000$, aged 11, 13, and 15 years) was found to be 24% (Inchley 2020). Insomnia not only causes considerable distress but can also negatively affect daytime mood and cognition (Sarris and Byrne 2011). For example, a

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Swedish study found that adolescents with severe insomnia experienced impaired academic, behavioral, and occupational functioning (Bauducco et al. 2015). A longitudinal community study in Sweden also found that insomnia is associated with increased risk for anxiety and depression (Johansson et al. 2021). Insomnia symptoms have a strong tendency to become persistent (Morin et al. 2009). Early detection of possible insomnia is therefore warranted.

Adolescence is marked by changes in sleep. Carskadon (Carskadon 2011) described several factors that have impact on the changes in sleep and sleepiness in adolescents, e.g., a somewhat reduced sleep need and increasingly delayed sleep timing (Colrain and Baker 2011) and labeled these "the perfect storm". The perfect storm relates to developmental trajectories of biopsychosocial factors among adolescents that limit the quantity of sleep resulting in several negative consequences (Carskadon 2011). Younger adolescents go to bed earlier, have less preference for evening activities, and sleep more than older adolescents (Colrain and Baker 2011). Delayed bedtimes combined with earlier rise times for school are what often contribute to insomnia and sleep loss in adolescents (Carskadon 2011). Changes in sleep quality, quantity and composition interact with increased societal demands. Societal demands can be increased academic demands and workload, and promotion of independence from the family together with increased extent and amount of external social interactions (Colrain and Baker 2011). In addition, after sleep deprivation, younger adults show more cognitive impairment such as attentional failure than older adults (Taillard et al. 1999). Thus, there are differences in sleep experiences and reported sleep patterns between adolescents and adults.

Various instruments, such as the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989), the Insomnia Severity Index (ISI) (Morin et al. 2011), Sleep Condition Indicator (SCI) (Espie et al. 2014), and the Minimal Insomnia Symptom Scale (MISS) (Broman et al. 2008), are available to discover and assess sleep problems. The 19-item PSQI is a self-reported questionnaire that assesses sleep quality over a one-month time interval (Buysse et al. 1989). The ISI is a seven-item self-reported questionnaire that was designed to assess the severity of both nighttime and daytime components of insomnia (Morin et al. 2011). The SCI is a useful instrument for detecting cases of insomnia. It is an eight-item rating scale screening for getting to sleep, remaining asleep, sleep quality, daytime personal functioning, daytime performance, duration of sleep problems, nights per week having a sleep problem and extent troubled by poor sleep (Espie et al. 2014). The MISS is a brief three-item insomnia-screening tool (Broman et al. 2008) that has been found useful among both adults and the elderly (Westergren et al. 2015). However, there is a lack of information regarding the performance of these instruments when used among adolescents. Given the potential differences in adolescent sleep, relative to adult sleep, there is a need for insomnia symptom screening tools that are tailored and tested for use among adolescents (Bromberg et al. 2020).

An advantage of the MISS over other instruments is its brevity and ease of use, possibly making it appropriate for use among adolescents. MISS includes three cardinal symptoms of insomnia: difficulty falling asleep, difficulty maintaining sleep, or non-refreshing sleep (Broman et al. 2008; Hellström et al. 2010). Since the MISS was first proposed (Broman et al. 2008) the diagnostic criteria for insomnia have been revised to some extent in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (Association AP 2013), with a stronger emphasis on daytime functioning compared to when the MISS was developed. Therefore, there might also be room to modify the MISS by adding an item focusing on daytime disturbance.

The psychometric properties of the MISS have been evaluated in two studies using the classical test theory (CTT) among adults (age 20–64) and older people (age > 65) (Broman et al. 2008; Hellström et al. 2010). These studies provide support for the measurement properties of the MISS according to CTT criteria. For instance, all response categories were adequately endorsed, which limited floor/ceiling effects, and it exhibited acceptable reliability and sensitivity/specificity (Broman et al. 2008; Hellström et al. 2010). Later, based on the above-mentioned samples, Westergren et al. (Westergren et al. 2015) found that MISS item response data were in general accordance with the Rasch measurement model. The Rasch model allows for testing of measurement properties and makes it possible to investigate aspects of measurement beyond those that can be found from the CTT (Cano and Hobart 2011), such as response category functioning, whether items work the same way in different subgroups of respondents, and the linear relationships between items on a latent continuum from less to more of the target variable (e.g., insomnia) (Andrich and Marais 2019). Analyses according to the Rasch model are thus more rigorous and provide more detailed information in determining rating scale measurement properties than CTT based analyses do (Stemler and Naples 2021; Hagell 2019).

Since the MISS has exhibited good measurement properties according to CTT and Rasch measurement criteria among both adults and older people, it seems desirable to explore its measurement properties also among adolescents as this would provide the foundations for a unified insomnia screening tool across all relevant age groups. However, to the best of our knowledge, the MISS has not been psychometrically tested among adolescents. Therefore, this study aimed to test the measurement properties of the MISS along with an additional item focusing on daytime functioning among adolescents using the Rasch measurement model.

Methods

This cross-sectional questionnaire survey with a purposive sampling is part of a larger project focusing on sleep and lifestyle among adolescents, including questions about, for example, substance use, electronic media, physical activity, health, and wellbeing. There were no other sleep questions included than those used in this study (Garmy 2008).

Sample

Data were taken from two samples of adolescents from public and private schools in four urban and rural municipalities in southern Sweden. After approval from the school administrations, written information about the study and its voluntary nature was distributed to students and their parents or legal guardians. The study was approved by the Regional Ethical Review Board in Lund, Sweden (EPN 2015/113 and EPN 2017/600). All procedures were conducted in accordance with the Declaration of Helsinki (World Medical Association Declaration 2018).

Sample 1 consisted of students in grades 7 and 8 (13–15 years, median 14 years). In sample 1, the questionnaire was distributed by the respective school nurses in connection with the regular health visit conducted during school hours between 2015 and 2017. The questionnaire was completed using paper and pencil, and the school nurse was present to answer any questions related to the questionnaire. Sample 1 comprised 1518 students (72.7% response rate) of which 50.7% were females.

Sample 2 consisted of students in the first year of upper secondary school (15–17 years, median 16 years). In sample 2, the questionnaire was distributed via a web survey by the teachers during school hours between 2017 and 2019. Sample 2 comprised 1504 students (72% response rate) of which 56.6% were females.

Instrument

The MISS is an insomnia-screening tool that includes three items: difficulty falling asleep (item 1); night awakenings (item 2); and not being rested by sleep (item 3) (Broman et al. 2008). There are five response categories (no, minor, moderate, severe, and very severe problems) scored from 0 to 4. This yields a total score ranging from 0 to 12 with higher scores indicating more severe insomnia symptoms. In this study we include an additional item about daytime disturbance (item 4), using the same response categories as for the original three items. This item was formulated as "To what extent do sleep difficulties disturb your everyday life (e.g., fatigue, schoolwork, leisure, concentration, memory and mood)?" (non-validated English translation). Here we explored whether adding item 4 to the original MISS items can improve measurement properties, hereafter labeled the four-item MISS. We also explored whether item 4 can replace item 3 since "daytime disturbance" possibly better captures the impact on daytime functioning than "not being rested by sleep". We hereafter label this the MISS-Revised (MISS-R).

The Rasch measurement model

The Rasch measurement model is named after the Danish mathematician George Rasch (Andrich and Marais 2019) and was developed for dichotomous items. Later on, the Rasch model was further developed for polytomous items (Andrich and Marais 2019). The observed data are tested regarding how well they fit the expectations of the measurement model (Andrich and Marais 2019). The Rasch model estimates item locations (item difficulty), and respondent locations (person ability) independently of each other on an interval level logit (log-odd units) scale, with the mean item location set at 0 (Rasch 1960; Andrich 1988; Mari and Wilson 2014). If data accord with the model, linear measurement and invariant comparisons are possible, regardless of which group is being investigated within a relevant frame of reference (Hobart 2009).

Analyses

Analyses according to the Rasch model (Andrich and Marais 2019; Hobart 2009) followed the same procedures as described in Westergren et al. (Westergren et al. 2015), using the RUMM2030 software (Andrich and Sheridan 2012). Two-tailed p-values <0.05, following Bonferroni adjustment (Armstrong 2014) (i.e. p-values <0.017 for three items, and <0.012 for four items), were judged to be significant. Because calculation of a total MISS score and application of cut-offs for identification of cases with possible insomnia require complete item responses, analyses were based on respondents without any missing item responses. The analyses were performed stepwise, as described below.

Targeting, precision and reliability

Good targeting between the relative locations of the persons and items is elemental for good measurement and means that the scale characterizes the different levels of insomnia described by the sample, and vice versa

(Hudgrens et al. 2004). Mean person locations within ±0.5 logits of the mean item location (i.e., 0 logits) have been suggested as an indicator of acceptable targeting (Edelsbrunner PaD 2019). However, the greatest concern with screening instruments is to maximize precision and information around the cut-off point, i.e., to separate those with insomnia from those without. To assess this, the information function (IF) can be used. This is the inverse of the measurement error and should therefore peak around the cut-off point. The ability of a scale to separate a sample into distinct groups is reflected through score reliability as assessed by the Person Separation Index (PSI), which is similar to coefficient alpha. PSI can be used to derive the number of statistically distinct groups (separated by ≥3 standard errors) that can be distinguished by the scale (Wright and Masters 1982). Two strata (i.e., those with and without, e.g., possible insomnia) can be considered as the minimum requirement for a screening tool.

Response category functioning

The locations where there is an equal probability of responding with either of two adjacent response categories are called response category thresholds, and the average of these is taken as the item location (Hobart and Cano 2009). Disordered thresholds signal that response categories do not work as intended and can for instance occur when respondents are not able to distinguish between two response categories (Hobart and Cano 2009).

Model fit

Fit of data to the model is crucial in the examination of the measurement properties (Hobart 2009). Fit means the extent to which observed item responses accord with what is expected from the Rasch model. Data that accord with expectations support model fit. Model fit was investigated both statistically and graphically (by means of item characteristic curves (ICCs)).

People are grouped into class intervals depending on their location on the measured continuum. Standardized item fit residuals represent the differences between observed and expected responses for the respective class intervals and should range between −2.5 and 2.5, with the ideal being 0, for items as well as persons (Hobart 2009). Low negative values (<−2.5) suggest local dependency, while high positive values (>2.5) indicate multidimensionality (Hobart 2009). Thus, sufficient fit to the Rasch model suggests that the basic assumptions of local independency and unidimensionality are supported. To further explore local dependency, item residual correlations were checked relative to the average observed residual correlation. Residual correlations that are high, relative to the overall set of correlations, indicate violation of the local independence assumption (Christensen et al. 2017). The critical value for relative residual correlations was identified following the procedures described by Christensen et al. (Christensen et al. 2017).

The differences between expected and observed item responses are tested by the Chi-squared statistics for individual items as well as for the overall scale, which should not be significant to support the model fit (Andrich and Marais 2019). However, the Chi-square is sensitive for type I error, since it increases with increasing sample size. One way to deal with this with large data sets is to algebraically adjust the sample size in the analysis, which does not affect other aspects of data (e.g., locations, fit residuals) (Hobart 2009; Andrich and Hagquist 2015). Therefore, the sample size in the present study was adjusted to $n = 500$ (Andrich 1988; Hobart 2009; Hagell and Westergren 2016).

Differential item functioning (DIF)

DIF occurs when an item does not function in the same way for different groups of persons (e.g., age and gender groups) (Andrich and Marais 2019). There are two forms of DIF: uniform (systematic difference in response probabilities between subgroups across the measurement continuum) and non-uniform (interaction between subgroup and location) DIF (Andrich 1988).

A two-way ANOVA of residuals was used to test for DIF by age (13–15 vs. 16–17 years old) and gender across the respective class intervals (Hagquist and Andrich 2017). In case of a uniform DIF, this was resolved by splitting the item into two subgroup-specific items. This is possible because the Rasch model can accommodate missing responses (Hagquist and Andrich 2017).

The clinical significance of DIF was explored by testing whether the same total scores reflected the same levels of insomnia among younger and older adolescents. This was done by rearrangement and reanalysis of data (Westergren et al. 2015; Wright 1996), by horizontally creating three item blocks: 1) the total sample; 2) the younger sample; and 3) the older sample. These blocks were arranged next to each other, with missing values for those cases not in that age group. Thus, the younger sample had missing values in the "older sample block" and vice versa. The first block, i.e., for the total sample, served as a linkage in the data set. The three item blocks were treated as multiple tests and the logit values of the same summed raw scores were compared across the samples (Westergren et al. 2015; Lundgren-Nilsson et al. 2006; Wann-Hansson et al. 2008).

Results

The vast majority of the total sample ($n = 3022$) had completed all MISS items and a total score could be computed for 2968 (98.2%) for the MISS, for 2955 (97.8%) for the four-item MISS, and for 2980 (98.6%) for the MISS-R. Thus, a total score could not be calculated for 1.8% (95% confidence interval (CI),1.34–2.33%) for the MISS scale, and 2.2 (95% CI, 1.72–2.81%) for the four-item scale, and 1.4 (95% CI, 1.0–1.87%) for the MISS-R scale. Table 1 presents the raw score characteristics for the three MISS versions considered here. Out of the total sample ($n = 3022$), 50.2% ($n = 1518$) were younger (13–15 years), and 49.8% ($n = 1504$) were older (16–17 years) adolescents. In the younger sample, 48.9% were females, compared with 52.0% in the older sample. All response categories were used by the sample, but endorsement rates were relatively low for the categories "severe" and "very severe" (Table 2).

Targeting, precision and reliability

Figure 1 shows the relationship between person locations (top histograms) and MISS item response category threshold locations (bottom histograms) on the common latent insomnia variable. The MISS, the four-item MISS, and the MISS-R scales represent a quantitative continuum from less to more, with about the same range from approximately − 2.6 to 1.8 logits. There are gaps between − 1 and − 2 logits, and items do not represent people at the lowest and (to a lesser extent) highest levels of insomnia. The mean person location relative to the items are for the MISS scale − 1.195 (SD, 1.219), for the four-item scale − 1.267 (SD, 1.399), and for the MISS-R scale

Table 1 Raw score distribution and floor—/ceiling effects for the MISS; the four-item MISS; and the MISS-R scale

	MISS [a]	4-item MISS [b]	MISS- R [a]
Total sample			
N (missing %) [c]	2968 (1.8)	2955 (2.2)	2980 (1.4)
Mean (SD) score	3.19 (2.3)	4.49 (3.1)	3.10 (2.3)
Median (q1-q3) score	3 (1–5)	4 (2–6)	3 (1–4)
Floor/ceiling, %	10.1/0.4	8.6/0.3	11.6/0.4
Younger [d]			
n (missing, %) [c]	1491 (1.8)	1491 (1.8)	1507 (0.7)
Mean (SD) score	2.55 (2.1)	3.53 (2.8)	2.48 (2.1)
Median (q1-q3) score	2 (1–4)	3 (1–5)	2 (1–3)
Floor/ceiling %	15.7/0.3	13.5/0.2	17.4/0.3
Older [e]			
n (missing %) [c]	1477 (1.8)	1464 (2.7)	1473 (2.1)
Mean (SD) score	3.83 (2.3)	5.47 (3.1)	3.72 (2.3)
Median (q1-q3) score	4 (2–5)	5 (3–7)	3 (2–5)
Floor/ceiling %	4.5/0.5	3.5/0.4	5.7/0.4
Females			
n (missing, %) [c]	1566 (0.1)	1560 (0.2)	1570 (0.1)
Mean (SD) score	3.31 (2.2)	4.67 (3.0)	3.20 (2.2)
Median (q1-q3) score	3 (2–5)	4 (3–6)	3 (2–4)
Floor/ceiling %	7.3/0.3	6.1/0.3	9.1/0.4
Males			
n (missing %) [c]	1364 (0.2)	1357 (0.2)	1372 (0.1)
Mean (SD) score	3.05 (2.4)	4.28 (3.2)	2.98 (2.3)
Median (q1-q3)	3 (1–4)	4 (2–6)	3 (1–4)
Floor/ceiling %	13.3/0.4	11.3/0.3	14.4/0.3

MISS Minimal Insomnia Symptom Scale, *SD* Standard Deviation

[a] Possible total score range, 0–12

[b] Possible total score range, 0–16

[c] Number of respondents with complete responses (percentage of responders with ≥1 missing item response)

[d] Younger: 13–15 years old

[e] Older: 16–17 years old

Table 2 Item response rates for the Minimal Insomnia Symptom Scale (items 1–3) and the new item "daytime disturbance" (item 4)

	Response category endorsement n (%)				
	No	**Minor**	**Moderate**	**Severe**	**Very severe**
Total sample (*n* = 2955)					
Problems with… (item#)					
…difficulties falling asleep (1)	802 (27.1)	1286 (43.5)	615 (20.8)	187 (6.3)	65 (2.2)
…night awakening (2)	1594 (53.9)	940 (31.8)	290 (9.8)	88 (3.0)	43 (1.5)
…not being rested by sleep (3)	714 (24.2)	984 (33.3)	765 (25.9)	363 (12.3)	129 (4.4)
…daytime disturbance (4)	726 (24.6)	1106 (37.4)	728 (24.6)	281 (9.5)	114 (3.9)
Younger (*n* = 1491) [a]					
Problems with… (item#)					
…difficulties falling asleep (1)	487 (32.7)	676 (45.3)	243 (16.3)	59 (4.0)	26 (1.8)
…night awakening (2)	889 (59.6)	461 (30.9)	94 (6.3)	33 (2.2)	14 (0.9)
…not being rested by sleep (3)	546 (36.6)	530 (35.5)	254 (17.0)	120 (8.0)	41 (2.7)
… daytime disturbance (4)	558 (36.8)	592 (39.7)	229 (15.4)	84 (5.6)	38 (2.5)
Older (*n* = 1464) [b]					
Problems with… (item#)					
…difficulties falling asleep (1)	315 (21.5)	610 (41.7)	372 (25.4)	128 (8.7)	39 (2.7)
…night awakening (2)	705 (48.2)	479 (32.7)	196 (13.4)	55 (3.8)	29 (2.0)
…not being rested by sleep (3)	168 (11.5)	454 (31.0)	511 (34.9)	243 (16.6)	88 (6.0)
… daytime disturbance (4)	178 (12.2)	514 (35.1)	499 (34.1)	197 (13.5)	76 (5.2)
Females (*n* = 1560)					
Problems with… (item#)					
…difficulties falling asleep (1)	391 (25.1)	706 (45.3)	330 (21.2)	101 (6.5)	32 (2.1)
…night awakening (2)	805 (51.6)	522 (33.5)	167 (10.7)	42 (2.7)	24 (1.5)
…not being rested by sleep (3)	301 (19.3)	544 (34.9)	461 (29.6)	190 (12.2)	64 (4.1)
… daytime disturbance (4)	331 (21.2)	609 (39.0)	411 (26.3)	146 (9.3)	63 (4.0)
Males (*n* = 1357)					
Problems with… (item#)					
…difficulties falling asleep (1)	399 (29.4)	570 (42.0)	272 (20.0)	84 (6.2)	32 (2.4)
…night awakening (2)	764 (56.3)	409 (30.1)	120 (8.8)	46 (3.4)	18 (1.3)
…not being rested by sleep (3)	403 (29.7)	431 (31.8)	293 (21.6)	166 (12.2)	64 (4.7)
… daytime disturbance (4)	388 (28.6)	480 (35.4)	310 (22.8)	130 (9.6)	49 (3.6)

Only those with no missing item responses included. [a] Younger: 13–15 years old

[b] Older: 16–17 years old

− 1.291 (SD, 1.316). This means, that items tend to represent more severe levels of insomnia than that reported by the sample. However, this can be considered acceptable from the perspective of screening.

Reliability (PSI) for the MISS scale was 0.497 (95% CI, 0.47–0.52), 0.683 (95% CI, 0.66–0.70) for the four-item scale, and 0.551 (95% CI, 0.52–0.57) for the MISS-R scale. These reliabilities suggest that items can separate approximately two distinct groups of people (1.7, 2.3 and 1.8 strata for the MISS, the four-item MISS, and the MISS-R, respectively).

The highest IFs (least measurement error) were found at locations of 0.53 logit for the MISS, 0.77 logit for the four-item scale, and 0.57 logit for the MISS-R (Fig. 1).

(See figure on next page.)

Fig. 1 Distribution of the locations of persons (upper panels) and response category thresholds (lower panels) on the common logit metric from less (lower/negative logit locations) to more (higher/positive logit locations) insomnia (x-axis) for the Minimal Insomnia Symptom Scale (MISS; **A**), the four-item MISS (**B**), and the MISS-Revised (**C**). Superimposed green curves represent the information function (IF; higher values = less error and more information, i.e., better measurement precision). Maximum IFs (vertical green lines) correspond to logit locations 0.53 (corresponding raw score, 7; Panel **A**), 0.77 logit (corresponding raw score, 10; Panel **B**), and 0.57 (corresponding raw score, 7; Panel **C**)

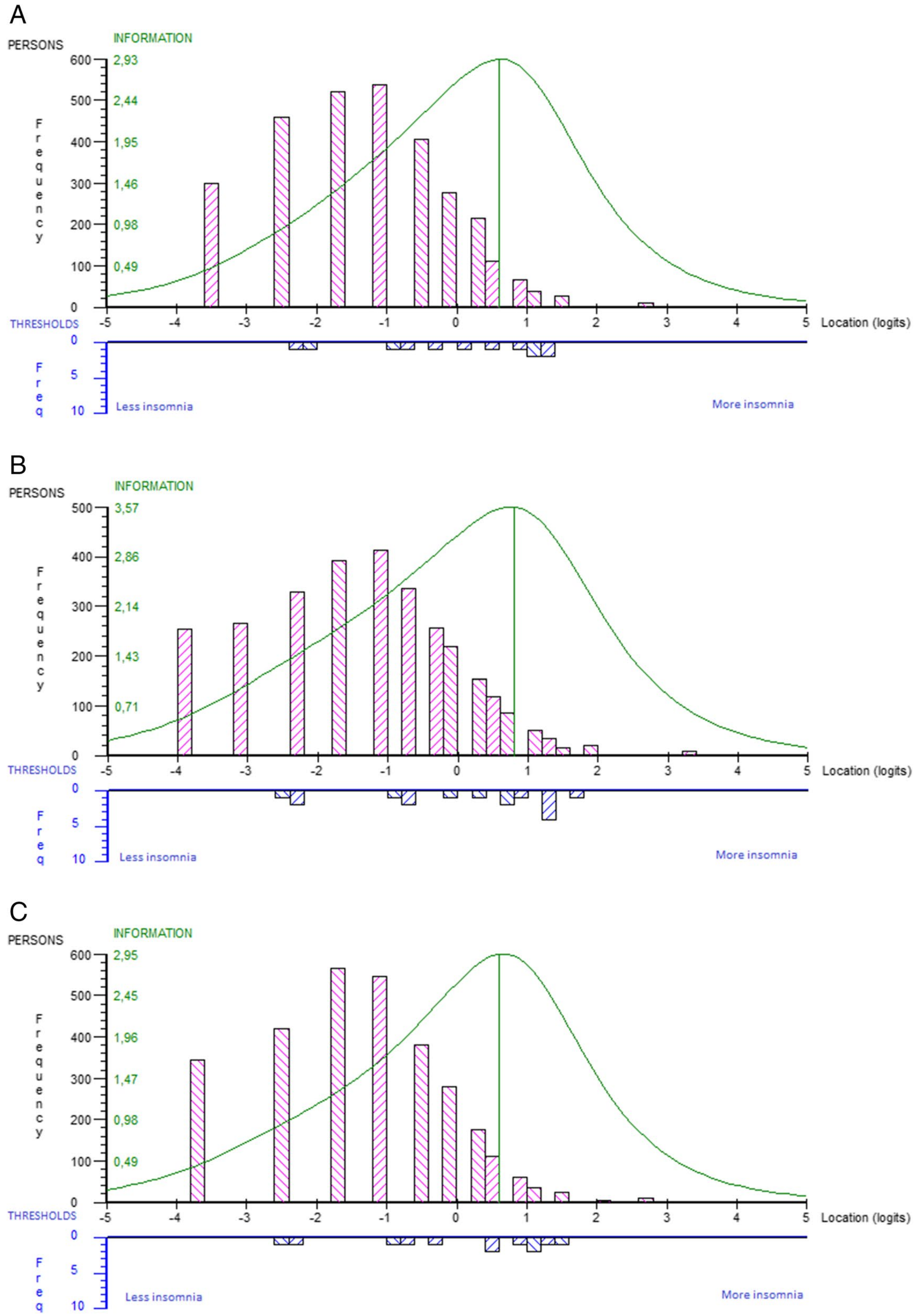

Fig. 1 (See legend on previous page.)

Taken together, targeting, precision and reliability are considered acceptable from a screening perspective. The reliability differed significantly between the three tools (non-overlapping 95% CIs) and was highest for the four-item MISS, followed by the MISS-R and the MISS.

Response category functioning

The response categories functioned as expected without any disordered thresholds, reflecting successively increasing levels of the measured variable (Fig. 2).

Model fit

Overall model fit was acceptable for all three scales, with non-significant item-trait interaction (MISS: $X^2 = 19.90$, $p = 0.339$; four-item MISS: $X^2 = 45.53$, $p = 0.101$; MISS-R: $X^2 = 24.31$, $p = 0.145$).

At the item level, the MISS and MISS-R exhibited acceptable model fit (fit residuals, −2.043 to 2.133) but the four-item MISS was associated with some misfit (Table 3). Similarly, there was acceptable person fit (fit residual values between −2.5 and 2.5) for all respondents with the MISS and MISS-R scales, whereas 75 respondents had fit residuals below −2.5 and one had a fit residual above 2.5 with the four-item MISS.

Inspection of the respective ICCs suggested reasonable item fit for both the MISS (not illustrated) and the MISS-R (Fig. 3). Since the Q3* values for the MISS (0.1) and MISS-R (0.0) were equal to or below the critical value for the 95th Q3* percentile (0.1) there was no local dependency in the MISS and MISS-R. However, there was local dependency in the four-item MISS (Q3*, 0.3), which involved items 3 and 4.

Taken together, the MISS and MISS-R showed acceptable fit to the Rasch model. Due to questionable model fit for the four-item MISS we hereafter only proceed with the MISS and MISS-R scales.

Differential item functioning

There was no DIF by gender but uniform DIF by age for item 3 in the MISS and item 4 in the MISS-R (Table 4), where older adolescents were more likely to score higher (i.e., reporting more problems) than younger adolescents. Resolving the age DIF for the MISS and the MISS-R resulted in improved overall fit by means of the

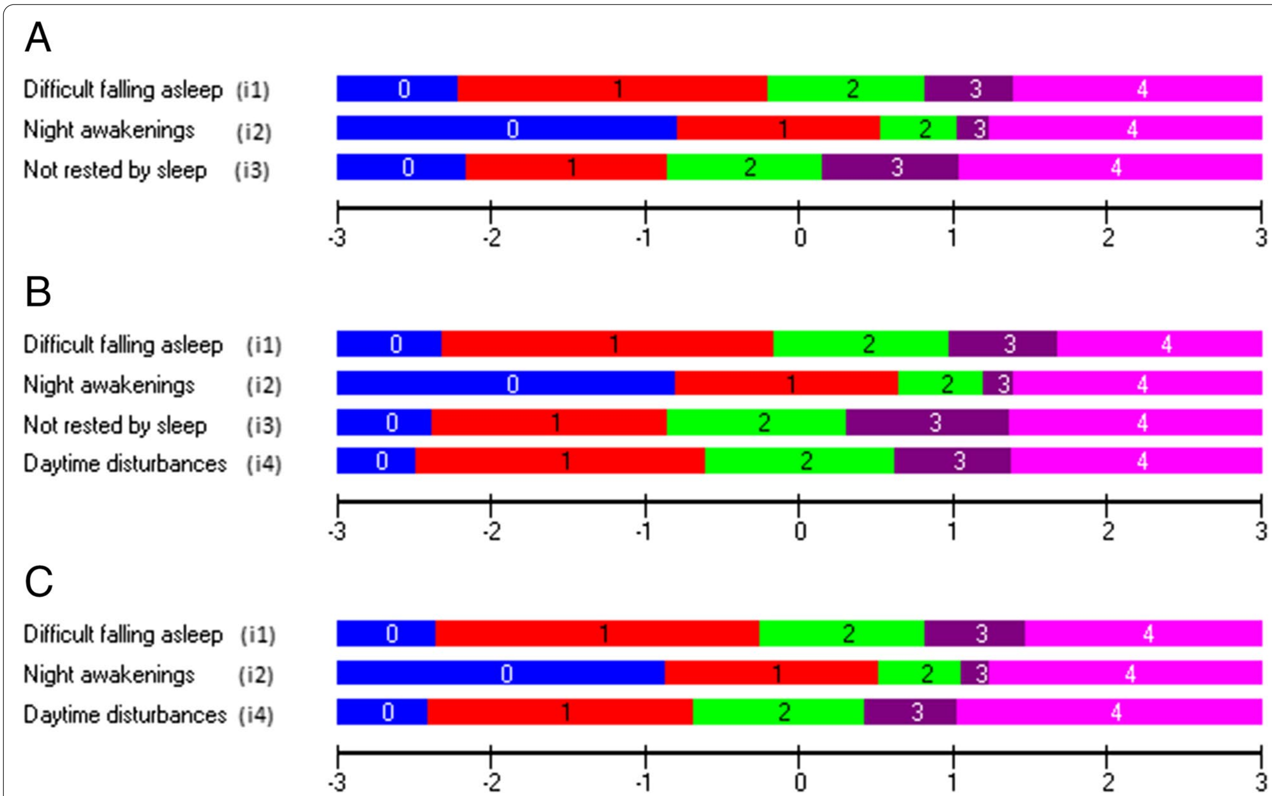

Fig. 2 Response category functioning for the Minimal Insomnia Symptom Scale (MISS; **A**), the four-item MISS (**B**), and the MISS-Revised (**C**). Areas 0–4 correspond to the five response categories (0 = no problems, 1 = minor problems, 2 = moderate problems, 3 = severe problems, 4 = very severe problems), and the borders between the respective areas are the logit threshold location on the insomnia continuum (x-axis; positive values = more insomnia) where there are equal probabilities of responding in either of the adjacent response categories

Table 3 Item level Rasch model location and fit statistics for the MISS scale, the four-item MISS and the MISS-R [a]

	Location (SE) [b]	Fit Residual [c]	p [d]
MISS (*n* = 2968)			
Problems with… (item#)			
…difficulties falling asleep (1)	−0.049 (0.025)	− 0.576	0.381
…night awakening (2)	0.504 (0.026)	1.503	0.233
…not being rested by sleep (3)	−0.454 (0.023)	−1.579	0.490
Four-item MISS (n = 2955)			
Problems with… (item#)			
…difficulties falling asleep (1)	0.050 (0.026)	1.898	0.947
…night awakening (2)	0.610 (0.027)	5.839	0.111
…not being rested by sleep (3)	−0.386 (0.024)	−4.103	0.470
… daytime disturbance (4)	−0.274 (0.025)	−6.571	0.014 [e]
MISS-R (*n* = 2980)			
Problems with… (item#)			
…difficulties falling asleep (1)	−0.077 (0.026)	−1.395	0.422
…night awakening (2)	0.486 (0.026)	2.133	0.153
… daytime disturbance (4)	−0.409 (0.024)	−2.043	0.179

MISS Minimal Insomnia Symptom Scale, *MISS-R* MISS Revised, *SE* standard error

[a] Based on data from respondents with no missing item responses (within each scale)

[b] Item locations are expressed in logit values and represent the mean of each item's response category threshold locations. Negative locations represent less insomnia and positive locations represent more insomnia

[c] Standardized fit residuals represent discrepancies between observed and model expected responses; should range between ±2.5

[d] Based on an amended sample size (*n* = 500)

[e] Not significant after Bonferroni adjustment

item-trait interaction (MISS, $X^2 = 21.56$, $p = 0.896$; MISS-R, $X^2 = 26.78$, $p = 0.635$) with no additional gender DIF or response category threshold disordering and a PSI reliability for the MISS scale of 0.51 (i.e., 1.7 strata) and for the MISS-R scale of 0.55 (i.e., 1.8 strata).

To assess the clinical significance of DIF, we tested whether the same total scores reflected the same levels of insomnia across the younger and older samples by examining the equivalence of raw score-to-location estimates between the samples. This revealed a small difference at the higher end of the scale for both the MISS and the MISS-R (illustrated for the MISS-R only, Fig. 4).

Cut-off scores

Previous studies have estimated the optimal cut-off score among adults to be ≥6 (Westergren et al. 2015) and among older ≥7 (Hellström et al. 2010), and Rasch based analyses found a ≥ 6 cut-off to allow for valid comparisons between adults and older people regarding the potential presence of insomnia (Westergren et al. 2015). Similarly, we also found that the two adolescent age groups were comparable regarding the raw score-to-location estimates of insomnia at a raw score of 6 (Table 5). That is, a raw score cut-off of 6 appears to be adequate also for adolescents, as it is associated with the smallest difference in logits between the age groups.

Taken together, two items (item 3 and item 4) did not work in the same way for younger and older adolescents. However, when considering the identified cut-off score (not the total score) the importance of this issue diminishes.

Discussion

The findings show that both the original MISS as well as the new MISS-R have good fit to the Rasch model, whereas adding the item about daytime disturbance to the original three MISS items compromised model fit. However, there are indicators that the MISS-R works slightly better with adolescents than the original MISS.

"Daytime disturbance" (item 4) is important in screening for insomnia since the DSM-5 (Association AP 2013) has a stronger emphasis on daytime functioning than when the original MISS was developed (Broman et al. 2008). However, when adding the item on daytime functioning to the original three MISS items, local dependence with item 3 (not being rested by sleep) was introduced, which also compromised the model fit of item 2. Replacing item 3 with item 4 (i.e., the MISS-R) did not compromise model fit notably, but improved reliability. Furthermore, given measurement uncertainty (±1.96SE) the locations of items 3 and 4 are indistinguishable in the original MISS and MISS-R, meaning that they are equivalent from a measurement perspective. Although our observations provide support for the usefulness of the original MISS among adolescents, we encourage the use of the MISS-R when screening for insomnia among adolescents due to three main reasons. First, based on clinical reasoning and the DSM-5 criteria (Association AP 2013), item 4 is better suited to assess insomnia compared to item 3. Second, there was a non-significant tendency (overlapping 95% CI) for fewer missing responses to item 4 than item 3. Third, the MISS-R scale had significantly better reliability (PSI) than the original MISS. Further studies are needed to address whether these advantages are specific for adolescents, or if they apply also to other age groups.

When comparing the results in this study with the findings from the study among adults/older people (Westergren et al. 2015) the hierarchical item order (from less to more insomnia) differs. For adolescents "not being rested by sleep" indicates less insomnia while for adults/older people "night awakening" indicates less insomnia while "night awakening" indicates more severe insomnia among adolescents and "difficulties falling asleep" does so among adults/older people. To the best of our knowledge,

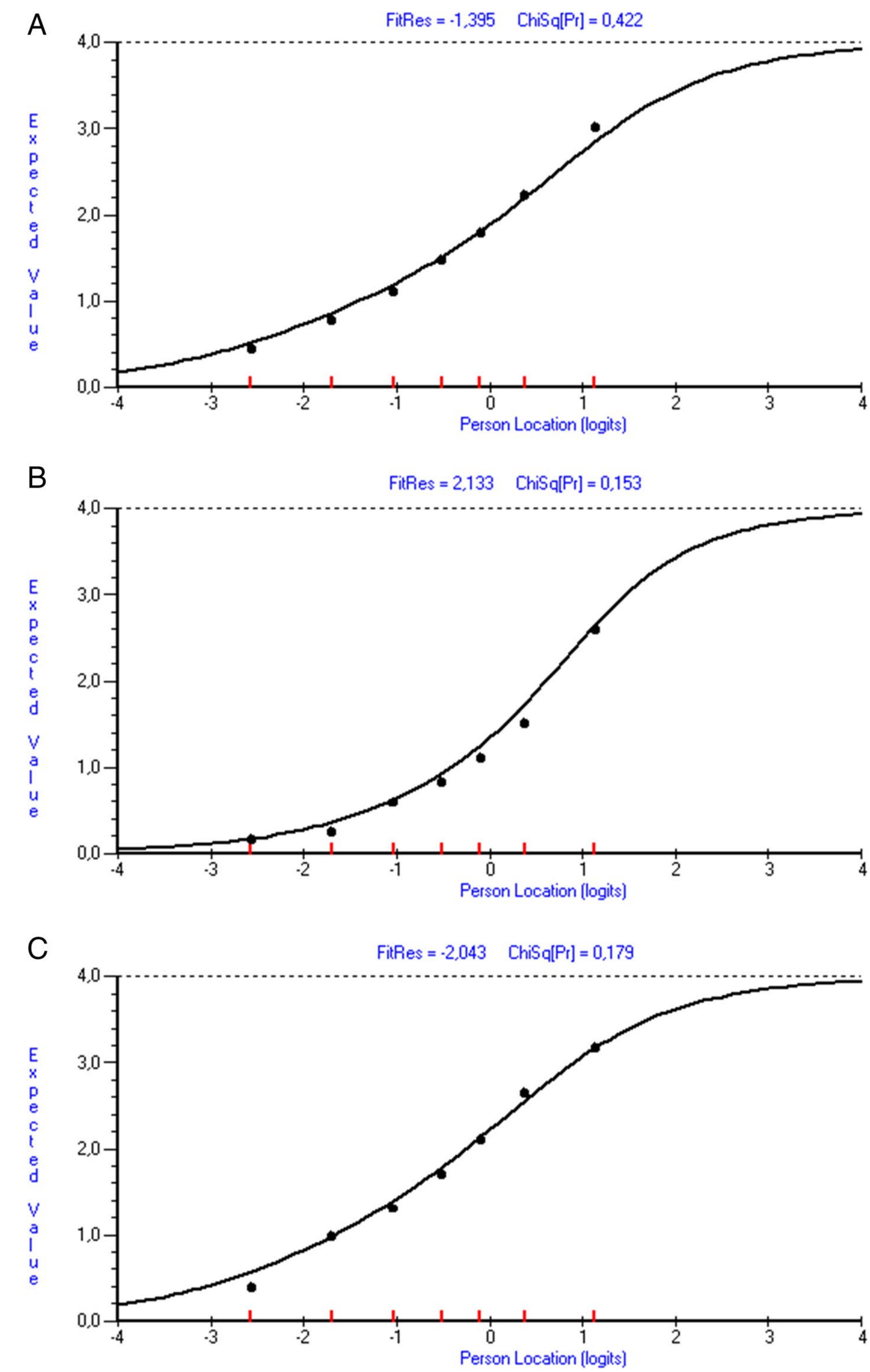

Fig. 3 ICCs representing the Minimal Insomnia Symptom Scale-Revised item 1 ('difficulties falling asleep'; Panel **A**), item 2 ('night awakenings'; Panel **B**), item 4 ('daytime disturbance'; Panel **C**). ICCs represent expected item responses (y-axis) for each person location (x-axis) on the measured continuum. Black dots represent observed responses from groups of persons (class intervals) at similar locations on the measured continuum (x-axis)

Table 4 Differential item functioning by age [a] of the MISS and MISS-R

	Age group		Age group by class interval	
	F-ratio	p [b]	F-ratio	p [b]
MISS				
Problems with … (item#)				
…difficulties falling asleep (1)	2.958	0.0861	0.738	0.619
…night awakening (2)	3.325	0.0689	0.271	0.950
…not being rested by sleep (3)	15.703	< 0.001 [c]	−0.132	0.999
Following split of item 3 by age				
…difficulties falling asleep (1)	0.495	0.482	0.798	0.450
…night awakening (2)	0.293	0.588	1.756	0.173
…not being rested by sleep (3, younger)	–	–	–	–
…not being rested by sleep (3, older)	–	–	–	–
MISS-R				
Problems with … (item#)				
…difficulties falling asleep (1)	3.640	0.0570	0.926	0.476
…night awakening (2)	3.516	0.0614	0.482	0.822
…daytime disturbance (4)	18.731	< 0.001 [c]	0.380	0.892
Following split of item 4 by age				
…difficulties falling asleep (1)	0.072	0.789	−0.023	0.999
…night awakening (2)	0.031	0.860	0.031	0.970
…daytime disturbance (4, younger)	–	–	–	–
…daytime disturbance (4, older)	–	–	–	–

MISS Minimal Insomnia Symptom Scale, *MISS-R* MISS Revised

[a] Younger (13–15 years old) vs. older (16–17 years old)

[b] Based on an amended sample size ($n = 500$)

[c] Significant following Bonferroni correction

these different pattens have not been described before. These patterns suggest that insomnia as a phenomenon differs among adolescents and adults/older people. This implies that it is unlikely that a common insomnia outcome measure would provide invariant measures across adolescents and adults/older people since insomnia seems to change character through life. However, from a screening perspective, such as with the MISS and the MISS-R, this aspect is arguably of less importance since the focus is on the cut-off point for identifying those with possible insomnia that need further assessment.

Older adolescents were more likely to report worse problems regarding daytime disturbance (item 4) as well as not being rested by sleep (item 3) than younger adolescents, introducing a DIF for these items. The identified DIF limits the validity of the MISS and MISS-R for invariant comparisons between younger and older adolescents. As for the MISS among adults and the elderly (Westergren et al. 2015), this uniform DIF by age can be reduced by avoiding a total score comparison and only using the insomnia cut-off. A raw score cut-off ≥6 according to the smallest difference in logits between the age groups appears to be preferable. To capture more adolescents with possible insomnia risk and in need of further assessment, we propose a raw score cut-off of ≥6. While there is psychometric support for this cut-off, determination of the optimal cut-score for identifying clinical insomnia must ultimately be done in relation to gold standard diagnostic criteria (Westergren et al. 2015; Hellström et al. 2010).

It is important to emphasize that the MISS and MISS-R are screening tools. This means that if insomnia is

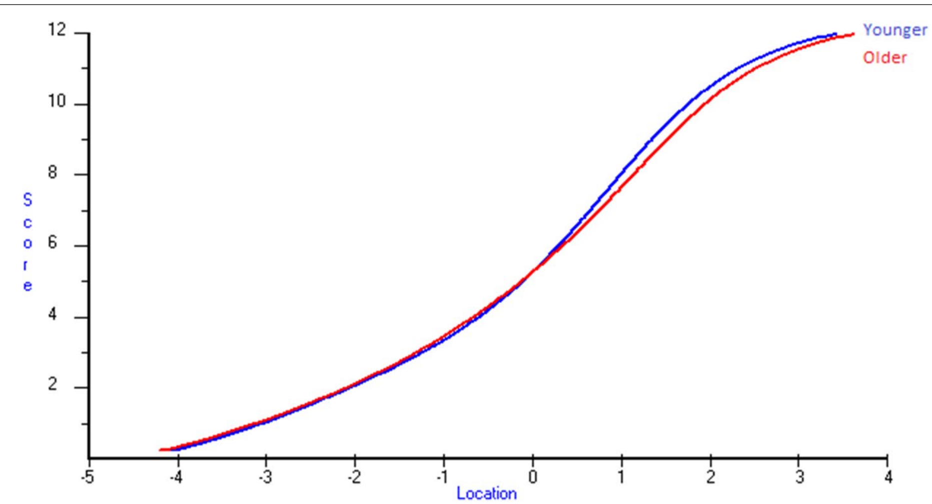

Fig. 4 The Minimal Insomnia Symptom Scale–Revised raw scores (y-axis, higher scores = more insomnia) and their corresponding linear logit values on the insomnia continuum (x-axis, positive values = more insomnia) for younger ($n = 1226$) and older ($n = 1375$) adolescents

Table 5 Raw scores and linear logit values for the MISS and for MISS-R for the full sample ($n=2657$ and $n=2601$, respectively), younger sample ($n=1253$ and $n=1226$, respectively), and older sample ($n=1404$ and $n=1375$, respectively)

Raw score	Full sample		Younger		Older		Difference in logit locations (younger – older)
	Location (logit)	SE (logit)	Location (logit)	SE (logit)	Location (logit)	SE (logit)	
MISS							
0	-3.450	1.354	-3.465	1.411	-3.724	1.386	0.259
1	-2.419	1.016	-2.283	1.034	-2.632	1.050	0.349
2	-1.636	0.834	-1.453	0.824	-1.788	0.868	0.335
3	-1.040	0.736	-0.870	0.707	-1.135	0.769	0.265
4	-0.556	0.671	-0.434	0.632	-0.604	0.701	0.170
5	-0.147	0.627	-0.083	0.585	-0.158	0.654	0.075
6	0.208	0.598	0.217	0.558	0.230	0.623	-0.013
7	0.528	0.585	0.488	0.547	0.582	0.609	-0.094
8	0.834	0.590	0.752	0.555	0.918	0.611	-0.166
9	1.149	0.618	1.028	0.584	1.260	0.637	-0.232
10	1.512	0.683	1.352	0.652	1.644	0.702	-0.292
11	2.007	0.835	1.808	0.799	2.161	0.852	-0.353
12	2.680	1.192	2.451	1.125	2.853	1.200	-0.402
MISS-R							
0	-3.680	1.357	-3.672	1.348	-3.901	1.395	-0.229
1	-2.565	1.055	-2.483	1.070	-2.715	1.083	-0.232
2	-1.703	0.873	-1.580	0.879	-1.804	0.895	-0.224
3	-1.037	0.762	-0.895	0.746	-1.103	0.783	-0.208
4	-0.517	0.683	-0.404	0.654	-0.554	0.705	-0.150
5	-0.098	0.631	-0.034	0.597	-0.107	0.651	-0.073
6	0.255	0.598	0.272	0.565	0.274	0.617	0.002
7	0.571	0.583	0.546	0.552	0.614	0.600	0.068
8	0.873	0.587	0.813	0.559	0.936	0.603	0.123
9	1.186	0.615	1.094	0.589	1.266	0.629	0.172
10	1.546	0.681	1.424	0.655	1.641	0.694	0.217
11	2.039	0.833	1.884	0.803	2.148	0.845	0.264
12	2.712	1.184	2.525	1.132	2.836	1.193	0.311

SE standard error

Gray areas show optimal cut-offs with the lowest differences in logit locations between younger (13–15 years) and older (16–17 years) persons

indicated it should be followed up with more comprehensive questionnaires, interviews and/or examinations (Westergren et al. 2015). It also means that they are very brief, which is both a strength and a limitation. A strength is that they are quick and easy to use. A limitation is that screening tools are too short to represent the full range of insomnia problems, and provide less precision compared to longer instruments. However, they can be valuable for initial screening. Future work should compare the MISS/MISS-R with other more extensive tools. However, this implies that also these tools need to be tested for use among adolescents, preferably using the Rasch measurement model. In addition, more recently a new screening tool, the Adolescent Insomnia Questionnaire (AIQ), was developed. It is a 13-item brief screening tool for insomnia in adolescents developed using CTT (Bromberg et al. 2020). It would be worthwhile to compare the MISS-R and AIQ in future studies. Finally, there is a need to test the MISS and the MISS-R against golden standard, i.e. formally and actually diagnosed adolescents with insomnia.

There are both strengths and limitations to this study. One strength of the study is its large sample size, which is likely to be representative for 13–17-year-old adolescents in Sweden. There is a need for studies exploring the MISS and MISS-R measurement properties in the age group between 18 and 19 years old, since we here only included those being 13–17 years old, and in a previous study only those being 20 years and older were included (Westergren et al. 2015). We also acknowledge that cultural differences may affect the international generalizability of the results, pointing to the potential need to confirm findings in other countries. The relatively large sample may also cause problems in the analysis of model fit. To avoid this, a recommended down-sizing of the sample to $n = 500$ was carried out (Andrich 1988; Hobart 2009; Hagell and Westergren 2016) and Bonferroni adjustments were applied (Armstrong 2014). Finally, using the Rasch model is more appropriate than using traditional CTT methods, and provides insights that are not achievable by such methods. For instance, CTT methods are generally based on correlations, typically Pearson product-moment correlations, that assume quantitative normally distributed data rather than ordered categorical data (Hobart 2009). In addition, the Rasch model is based on measurement principles similar to those employed in the physical sciences, and provides similar detailed information, e.g., regarding measurement uncertainty at the individual person and item levels.

Conclusions

Both the MISS and the MISS-R showed good measurement properties by meeting the rigorous criteria of the Rasch measurement model, although the MISS-R showed slight advantages over the original MISS. In this study the optimal cut-off for indicating insomnia among adolescents was identified (≥6), but this needs to be confirmed by using other clinical insomnia criteria. Caution should be exercised when comparing total MISS/MISS-R raw scores between age groups, but as screening tools for identifying potential insomnia they appear to work invariantly across both age and gender groups. At this stage, neither the MISS nor the MISS-R can be advocated over the other for use among adolescents, although MISS-R had slightly better reliability than the MISS.

Abbreviations

CI: Confidence Interval; CTT: Classical Test Theory; DIF: Differential item functioning; DSM-5: Diagnostic and Statistical Manual of Mental Disorders; ICCs: Item Characteristic Curves; ISI: The Insomnia Severity Index; MISS: Minimal Insomnia Symptom Scale; MISS-R: Minimal Insomnia Symptom Scale-Revised; PSI: Person Separation Index; PSQI: Pittsburgh Sleep Quality Index; SCI: Sleep Condition Indicator; SD: Standard Deviation.

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Authors' contributions

All author has participated sufficiently in the work to take public responsibility for appropriate portions of the content: GH, PG, PH, ANC, AW, HT. Analyzed data: GH and AW. Wrote the first draft of the manuscript: GH. Revised the manuscript and approved the final version: GH, PG, PH, ANC, AW, HT.

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Availability of data and materials

The datasets during and/or analyzed during the current study are available. from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Regional Ethical Review Board in Lund, Sweden (EPN 2015/113 and EPN 2017/600). All the study participants consented to participate All procedures were conducted in accordance with the Declaration of Helsinki (World Medical Association Declaration 2018).

Consent of publication

All listed authors have approved of the submission of the manuscript to the journal.

Competing interests

The authors declare that they have no conflict of interest.

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