Factor structure of the Sleep Disturbance Scale for Children (SDSC) in those with Attention Deficit and Hyperactivity Disorder (ADHD)

Vincent O. Mancini [a, b, c, *], Daniel Rudaizky [a, d], Benjamin T.D. Pearcy [a, e],
Angela Marriner [d], Carmela F. Pestell [d], Rapson Gomez [f], Romola S. Bucks [d], Wai Chen [a, g]

[a] Complex Attention and Hyperactivity Disorders Service (CAHDS), Child and Adolescent Health Service (CAHS),
Department of Health Western Australia, Australia
[b] Discipline of Psychological Science, Australian College of Applied Psychology, Sydney, NSW, Australia
[c] Curtin Medical School, Curtin University, Perth, Western Australia, Australia
[d] School of Psychological Science, University of Western Australia, Australia
[e] School of Psychology, Curtin University, Perth, Western Australia, Australia
[f] School of Health and Life Sciences, Federation University, Ballarat, Victoria, Australia
[g] Faculty of Health and Medical Sciences, Paediatrics, University of Western Australia, Australia

A R T I C L E   I N F O

A B S T R A C T

Objective: To examine the factor structure of the Sleep Disorder Scale for Children (SDSC) in children and adolescents with attention deficit and hyperactivity disorder (ADHD).
Method: The caregivers of 307 children with ADHD completed the SDSC. Standard and bifactor confirmatory factor analysis (CFA) evaluated the goodness-of-fit of competing factor structures.
Results: The original and unidimensional factor structure produced sub-optimal fit. Bifactor exploratory factor analysis (EFA) was performed to examine the underlying structure of the SDSC. A revised bifactor solution comprising six-specific factors and a general factor was identified. A nested version of this model was deemed to be the preferred model, which also demonstrated good psychometric properties.
Conclusion: There is evidence of a 'general sleep difficulties' factor in children with ADHD. Four of the six original factors were replicated in this study. However, the revised factor structure suggests that clinicians should be cautious of the utility of subscale scores pending further validation in ADHD samples.
Crown Copyright © 2019 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Caregivers of children with Attention Deficit Hyperactivity Disorder (ADHD) often report that sleep disturbance in this cohort is highly problematic and this impacts negatively on their child's wellbeing [1]. A meta-analysis by Cortese et al. [2], estimated up to 74% of ADHD children experienced comorbid sleep difficulties, which was significantly higher than estimates observed in typically developing children (between 5 and 40%; Romeo et al., [3]). Improving our understanding of the underlying nature and causes of sleep dysfunction in ADHD is important given that sleep disturbance may exacerbate existing cognitive and behavioural symptoms, social and academic impairments as well as potential negative impacts on treatment efficacy.

Additionally, poor sleep causes daytime somnolence, irritability, secondary inattention and oppositionality problems; the latter symptoms can frequently be misidentified as ADHD symptoms [4,5]. More recently, the associations between ADHD and disordered sleep have been reconceptualised as a bidirectional relationship of reciprocal causality, in which "sleep disturbances both may exacerbate core clinical symptoms and may be risk factors for increased psychopathology in children with ADHD" [1].

Notably, both pharmacological and behavioural interventions for daytime ADHD symptoms have been shown to improve sleep quality in children at night [6,7]. Behavioural interventions targeting sleep quality at night can also reduce the severity of daytime ADHD symptoms in the classroom [4,5]. Such findings underscore the importance of addressing sleep problems in the management of ADHD, regardless of causal direction, hence accurate and cost-efficient evaluation of sleep problems in ADHD forms a crucial step in ADHD care [8].

Polysomnography (PSG) is an objective measure of sleep quality and is regarded as the gold standard assessment of sleep difficulties [9]. However, PSG is an expensive and time-intensive procedure, therefore not suited to screening purposes. Informant-rated questionnaires, typically completed by parents, represent a more time and cost-efficient alternative. One of the most widely used questionnaires to assess sleep problems in children is the Sleep Disorder Scale for Children (SDSC) by Bruni et al. [10].

In a review of 21 paediatric sleep measures [11], identified only six measures that met well-established evidence-based assessment criteria. In another review [12], identified only 2 of 57 currently available paediatric sleep questionnaires that met operational principles of instrument development. The SDSC was the only questionnaire to be ranked in the highest category by both reviews. This 26-item, Likert-scale parent-rated questionnaire measures sleep disturbance across six dimensions: sleep breathing disorders (SBD); disorders of excessive somnolence (DOES); difficulty in initiating and maintaining sleep (DIMS); sleep−wake transition disorders (SWTD); disorders of arousal (DoA); and sleep hyperhidrosis (SH) [10]. The SDSC was developed and validated using a sample of typically developing children aged 6.5−15.3 years (n = 1157) and a smaller group of children diagnosed with 1 of 4 types of sleep disorders - insomnia, hypersomnia, respiratory disturbances, and parasomnias (n = 147), aged 5.8−15.2 years. Spruyt et al. [13], reported a first-order model for a modified version of the SDSC in a sample of typically developing children; but to our knowledge, no evidence of either unidimensionality or a general factor has been examined in either clinical or typically developing populations.

High rates of sleep problems in paediatric clinical populations [14], fuel the clinical demand for a cost-effective screening measure, despite SDSC being validated in predominantly typically-developing populations [10,15]. Notably, the SDSC has been used to measure sleep difficulties in children with disorders including epilepsy, autism-spectrum disorder (ASD), obsessive-compulsive disorder (OCD), and ADHD [16−18] − despite limited evidence regarding its validity and applicability in these groups [3,8].

Only one published study has attempted to replicate the validity of the SDSC in a clinical population. Marriner et al. [8], evaluated the factor structure of the SDSC in a sample of 416 children (aged 5−18 years) in a mixed sample with different neurodevelopmental disorders. The authors were unable to replicate the original six factor structure specified by Bruni et al. [10], using Confirmatory Factor Analysis (CFA). Modification indices were used to justify the removal of three items and the SH subscale to attain adequate fit. An ensuing five-factor revised version of the scale (SDSC-R) was proposed, with removal of the sleep hyperhidrosis factor. Moreover, their sample consisted of mixed neurodevelopmental disorders potentially confounding unmeasured variance attributable to the presence of unique and heterogeneous neurodevelopmental disorders, thereby highlighting a gap in the literature. Consequently, our study sought to address this gap and re-evaluate the factor structure of the SDSC for a single neurodevelopmental disorder, ADHD.

Furthermore, the SDSC subscale scores are also routinely summed to yield a 'total sleep difficulties' score [10]. Despite this practise, there is no study demonstrating unidimensionality of the SDSC to support the summation for a total score, given its reported factorial structure of six specific factors or a g (general) construct. The two broad objectives of the current study were: (i) to evaluate the factor structure of the SDSC for use in a paediatric ADHD setting; and (ii) to determine whether there is evidence for either unidimensionality or a g sleep construct that justifies summing all items to yield the 'total sleep difficulties' score. However, it is important to note that the study was not aimed either directly or indirectly at evaluating the tenability of an overarching general

sleep pathology construct, but on how the ratings for the SDSC should be interpreted and scored.

2. Method

2.1. Participants

This sample comprised 307 children and adolescents aged 4−17 years (262 males, 45 females; M = 10.07 years, SD = 2.68 years). All participants were recruited via the Complex Attention and Hyperactivity Disorders Service (CAHDS), in Perth, Western Australia. CAHDS is a referral-based, government-operated service, which provides comprehensive assessments, including: psychiatry, clinical psychology, speech pathology, social work, occupational therapy, and neuropsychology. Children accessing this service are diagnosed with ADHD by either a psychiatrist or paediatrician prior to referral, and are re-assessed by the allied health professional team at intake. This population predominantly comprises children with the combined (hyperactive and inattentive) presentation of ADHD (approximately 84%), followed by inattentive-only (approximately 14%) and hyperactive-only (approximately 2%). The SDSC was completed by parents or guardians, as part of a routine assessment battery. Ethics committee approval to use the de-identified client information was obtained from the North Metropolitan Health Service, and informed consent was provided by parents.

2.2. Measures

2.2.1. The sleep disturbance scale for children (SDSC; Bruni et al., [10])

The SDSC is a 26-item scale developed to assess the presence of sleep difficulties in children within the previous six months. The measure is completed by the parent of the child and takes approximately 5−10 min to complete. Item 1 measures the child's average hours of sleep, from 1 ('9 − 11 h') to 5 ('less than 5 h'). Item 2 measures the child's average time to fall asleep, from 1 ('less than 15 min') to 5 ('more than 60 min'). The remaining 24 items are rated on a 5-point Likert scale, from 1 ('Never') to 5 ('Always [daily]'); an example item is "The child has nightmares that he/she does not remember the next day". The SDSC has demonstrated acceptable internal reliability ($\alpha = 0.71$ to 0.79) for total sleep scores and good test-retest reliability ($r = 0.71$) in both typically-developing and children diagnosed with sleep disorders [10]. There is limited evidence on the reliability of the SDSC subscales, with previous research yielding mixed findings. Internal reliability for four subscales (SBD, DA, SWTD, DOES) has been previously identified as poor (Cronbach's $\alpha < 0.70$) [9]. Adequate sensitivity (0.89) and specificity (0.74) were found in distinguishing typically developing children from children with sleep disorders [10]. The SDSC also demonstrates suitable levels of convergent and discriminant validity in a typically developing sample [9]. These psychometric properties of the SDSC were most frequently assessed in predominantly typically developing samples. However, preliminary evidence has identified possible alternative factor structures of the SDSC when utilised in clinical populations [8].

2.3. Data analysis

Model testing was performed using Mplus (version 7.4). Model fit was assessed using chi-square adjusted for sample size, in addition to the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Akaike Information Criteria (AIC) and Bayesian Information Criteria adjusted for sample

size (A-BIC). In line with reporting conventions, the full array of fit indices were reported, including chi-square statistics. However, chi-square tests are highly vulnerable to type 1 error in samples exceeding 200 cases thus additional fit statistics were also reported in Table 1 ([19−21]). Weighted least-squares means and variance adjusted estimator was used to analyse the data to account for the ordinal nature of responses and any violations of the normality assumption [22].

Five models were assessed. The first model represented the six-factor correlated model as described by the original authors (Model 1 − Fig. 1). The second model assessed a unidimensional model of SDSC items (Model 2 − Fig. 1). Conventional factor models evaluate either unidimensionality or multidimensionality, but not both simultaneously. Bifactor models test for the 'g' general factor to represent the unidimensional latent construct while simultaneously allowing some multidimensionality within the model. Consequently, a follow-up bifactor CFA of this first model was also performed (Model 3 − Fig. 1). The sub-optimal fit statistics generated by the first three models prompted a data-driven exploratory factor analysis (EFA) to evaluate the underlying factor structure of the 26-items (Fig. 2). The EFA identified a bifactor solution, with one general factor and six specific factors, to provide the best fit. A bifactor confirmatory factor analysis (CFA) was then performed to evaluate the fit of this revised factor model and its structure. Only significant pathways with factor loadings ≥ 0.30 were retained in the final model, presented in Fig. 2b. To evaluate the psychometric properties of this final bifactor CFA model parameters, the percentage of uncontaminated correlations (PUC) as well as the factor parameters omega hierarchical (ω_h); omega subscales (ω_s); and Construct replicability (H) values were computed. In addition, Factor Determinacy (FD) were also calculated [23].

3. Results

3.1. Factor structure

3.1.1. Model 1: original six-factor structure

The CFA of the original six-factor model [10] - represented as Model 1 in Fig. 1 - revealed a sub-optimal fit to the data (Table 1). Although the adjusted chi-square estimate was adequate ($p < 0.05$), the CFI, TLI and RMSEA were beyond recommended cut-off values [21]. The original six-factor structure of the SDSC yielded sub-optimal fit when administered within an ADHD population. Fit indices and modification indices were examined to investigate whether previous rationale for modification to the SDSC in a paediatric clinical population [8] could be replicated. These were (a) exceedingly high standardised residuals for Item 9 loading (leading to the removal of the SH subscale and Item 9 and Item 16), and (b) item 10 failing to load strongly onto any single factor with multiple weak cross-loadings. These previous findings were partially-replicated in the current data; the modification indices provided indication of item 10 cross-loading onto multiple SDSC factors, though similar results were generated for several other SDSC items. These results provided further rationale to examine alternative factor structures.

This model structure was further evaluated through a bifactor modelling solution, whereby a general factor was added in addition to the six specific factors originally specified by Bruni et al., [10]. The fit statistics for this model gave slightly improved fit relative to the previous model, though sub-optimal fit statistics were still reported (see Table 1).

3.1.2. Model 2: unidimensional factor structure

A CFA of a unidimensional factor structure of the SDSC (Model 2 in Fig. 1) also revealed a poor fit to the data. These findings suggest that despite commonly being summed to yield a total score, the SDSC is not best understood as a simple unidimensional factor structure.

3.1.3. Model 3: bifactor CFA with the original six specific factors of the Bruni model

This model is represented by Model 3 in Fig. 1. This model yielded improved but suboptimal fit statistics. The modification indices indicated discrepancies between model and data in the original six specific factors specified according to the [10]. Importantly, this model provided support for the general factor in the bifactor model in addition to specific factors. For this reason, we retained the *general* factor in our bifactor specification but explored potential novel structures in the specific factors in the remaining exploratory analyses.

3.1.4. Model 4: bifactor exploratory factor structure

A bifactor EFA approach using bi-geomin rotation was taken based on the findings from the previous three CFA models. This data-driven approach allowed for the identification of underlying relationships between items not limited to those previously identified. The EFA evaluated several factor solutions with a seven-factor solution (including a general factor) (Model 4 in Fig. 2) identified as the most appropriate based on the seven factors with Eigenvalues exceeding a value of 1.00 and better fit statistics than competing EFA models (Table 1). Item loadings for the model are presented in Table 2. Results revealed that all 26-items had significant loadings onto a single factor (termed a general factor). Items loading onto the SH, SBD and DOES factors were consistent with those identified in the original SDSC [10]. The DoA subscale also retained all original items whilst also including item 18 (which originally loaded onto the SWTD subscale). Unlike the original SDSC, the current pattern of item loadings revealed a distinct

Table 1
Recommended fit indices and observed fit indices for 6-factor, unidimensional, exploratory factor analysis and bifactor CFA on the revised factor structure of the sleep disorder scale for children (SDSC).

	Recommended Fit Indices	Original Six-Factor CFA Model 1	Unidimensional CFA Model 2	Bifactor CFA-O Model 3	EFA Model 4	Bifactor CFA-F Model 5
Adjusted χ^2	$p < 0.05$	2.61 ($p < 0.001$)	6.14 ($p < 0.001$)	2.54 ($p < 0.001$)	1.74 ($p < 0.001$)	1.51 ($p < 0.001$)
CFI	>0.95	0.895	0.649	0.904	0.972	0.967
TLI	>0.95	0.880	0.618	0.885	0.945	0.962
RMSEA (90% CI)	≤0.05	0.073 (0.066, 0.079)	0.129 (0.124, 0.135)	0.071 (0.064, 0.077)	0.049 (0.039, 0.059)	0.041 (0.033, 0.049)
SRMR	<0.05	0.079	0.102	0.079	0.030	0.050
AIC	Smallest Preferred	22384.13	23215.51	22226.18	22091.31	22077.75
BIC-Adjusted	Smallest Preferred	22435.77	23258.83	22285.60	22209.59	22135.50

Note. CFI, TLI, and RMSEA statistics were generated using weighted least-squares means and variance adjusted (WLSMV) estimation. SRMR, AIC and BIC-Adjusted values are obtained using Maximum Likelihood (ML) estimation as these values are not provided when weighted least-squares means and variance adjusted (WLSMV) estimation is used. $N = 307$.
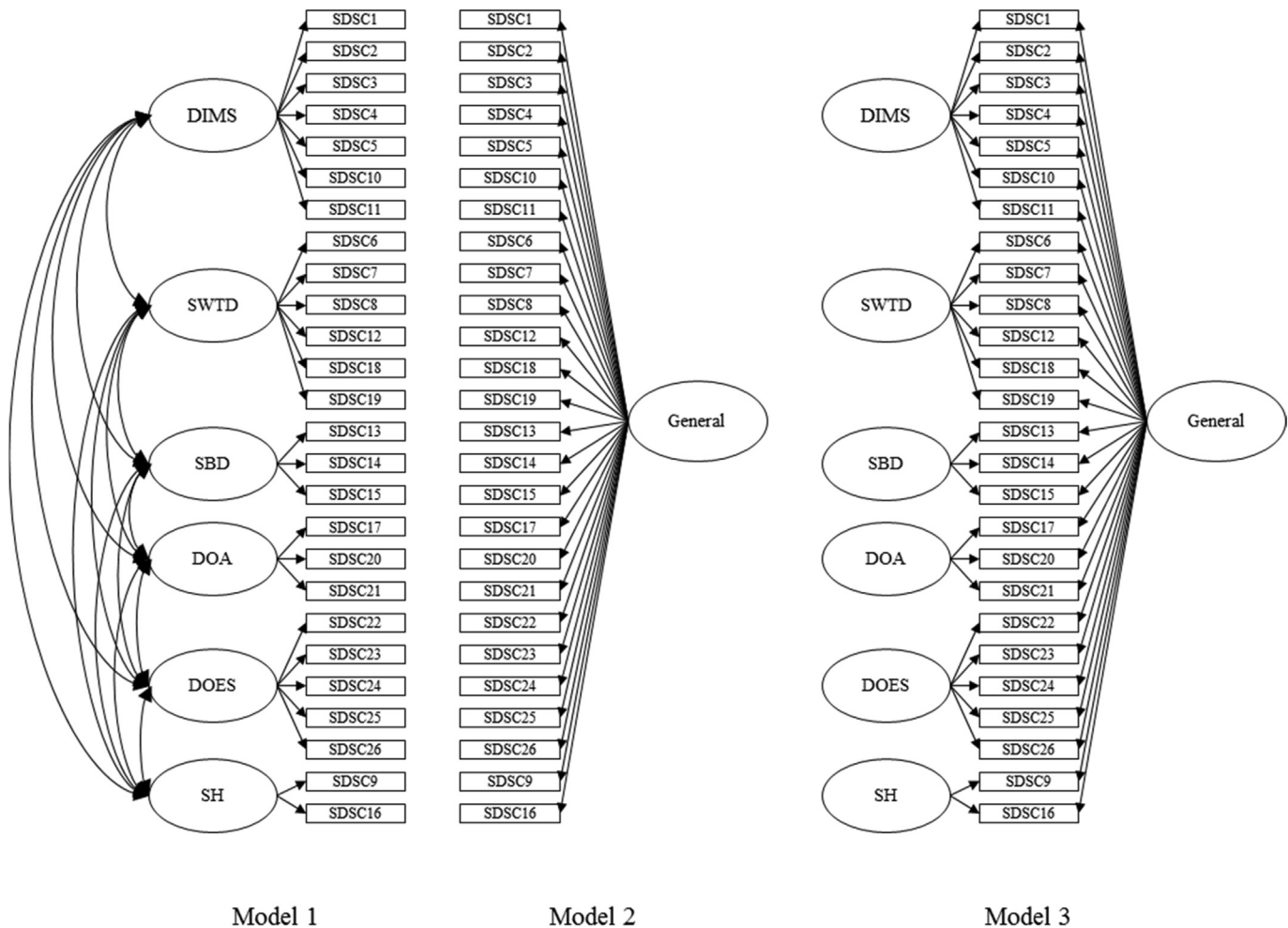
Fig. 1. Confirmatory Factor Analysis (CFA) models used to evaluate the underlying factor structure of the Sleep Disorder Scale for Children (SDSC) by Bruni et al. [10], in a sample of 327 children and adolescents with Attention Deficit and Hyperactivity Disorder (ADHD). Model 1 (left) (depicts a six-factor correlated factor structure. Model 2 (centre) depicts a unidimensional factor structure. Model 3 (right) depicts a bifactor CFA of the original six-factor structure (ie, Bifactor CFA-O). DIMS = Disorders Initiating and Maintaining Sleep; SWTD = Sleep Wake Transition Disorders; SBD = Sleep Breathing Disorders; DOA = Disorders of Arousal; DOES = Disorders of Excessive Somnolence; SH = Sleep Hyperhidrosis; G = General Factor.

division of the DIMS subscale whereby items concerning difficulties initiating sleep (eg, "The child has difficulty getting to sleep at night") loaded onto a separate factor from items concerning difficulties maintaining sleep (eg, "After waking up in the night, the child has difficulty to fall asleep again"). However, these factors remained significantly intercorrelated. The SWTD factor identified in the original SDSC was not replicated in the current EFA − five of the six items on this original scale had no significant specific factor loadings, though each contributed unique variance to the general factor. Item loadings onto the specific factor were typically distinct. However, cross-loadings for items 1, 22, 23, and 24 suggested that these statements may be indicators of multiple constructs. However, these items were retained for the subsequent bifactor CFA as no clear theoretical or data-driven rationale for the removal of these items could be justified.

3.1.5. Model 5: bifactor CFA

To test for a more parsimonious model comprised of clinically meaningful specific factors based on the face and content validity of the items, we conducted a bifactor CFA as a nested model by removing low cross-loadings deemed unlikely to embody substantial clinical significance (presented as Model 5 in Fig. 2). The emergence of our different six specific factors (four of which were largely consistent

with the original SDSC) and an additional *general* factor provided justification of evaluating the fit of a bifactor CFA model of the SDSC. Weak item-loadings (ie, ≤0.30) were not included (see Table 2). Only the Disorders Initiating Sleep (DI) factor correlated with the Disorders Maintaining Sleep (DMS) and SH subscales as per the results of the EFA (See Fig. 2b). Item 26 loading onto the DSM specific factor was non-significant, and so this pathway was removed. The bifactor CFA provided an excellent fit to the current data in comparison to previous models (see Table 1). Modification indices above 3.84 were inspected to assess whether model fit could be improved, however no theoretically meaningful modifications were identified. A chi-square difference test indicated a non-significant difference between the bifactor CFA model and the EFA model, χ^2 (2) = 4.22, p = 0.12), suggesting that the more parsimonious model is preferred. The standardised loading pattern and psychometric properties for the bifactor CFA model is presented in Table 3.

Conventional indications of the psychometric properties of a scale (eg, Cronbach's alpha) do not provide an accurate estimation of the psychometric properties of bifactor models (see Yang et al., [24]). The psychometric properties of the current bifactor CFA were therefore evaluated against several recommended criteria described by Refs. [23,25] using the Bifactor Indices Calculator [26]. These are presented as part of Table 3.
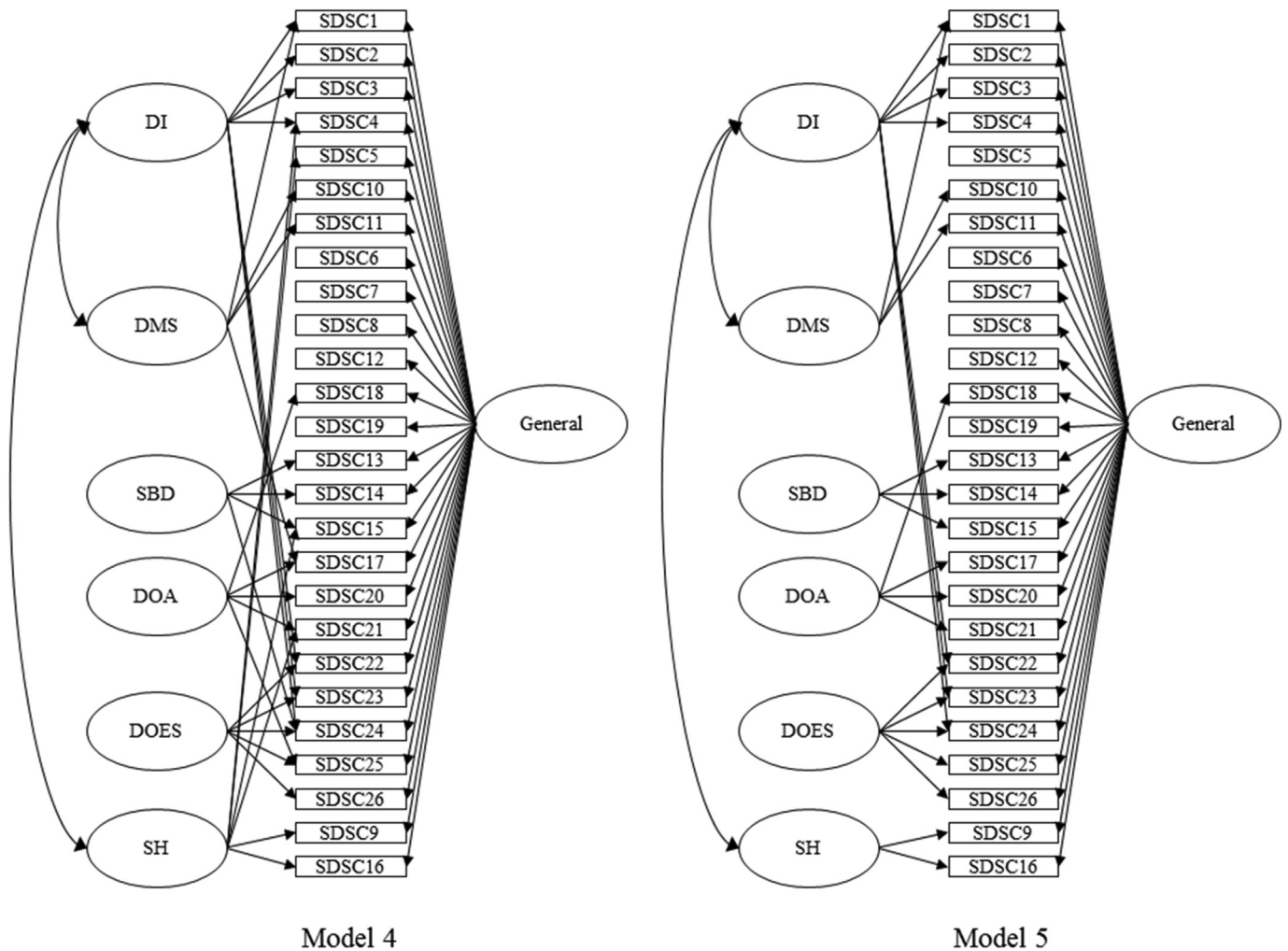
Fig. 2. Bifactor CFA model used to evaluate the underlying factor structure of the Sleep Disorder Scale for Children (SDSC) by Bruni et al. [10], in a sample of 327 children and adolescents with Attention Deficit and Hyperactivity Disorder (ADHD). Model 4 (left) depicts the structural model of the SDSC based on the results of a bifactor exploratory factor analysis (EFA) performed on the present data, with one general and six specific factors. Only significant pathways are depicted. Model 5 (right) depicts the final bifactor CFA model (ie, Bifactor CFA-F) that was tested, where non-significant or weak item cross-loadings ($\leq$0.30) were removed and correlations between specific factors were permitted based on a combination of theoretical grounds and via inspection of the model modification indices. Not all items had significant loadings onto a specific factors, though each item contributed significant variance to the general factor. DI = Disorders Initiating Sleep; DMS = Disorders Maintaining Sleep; SBD = Sleep Breathing Disorders; DOA = Disorders of Arousal; DOES = Disorders of Excessive Somnolence; SH = Sleep Hyperhidrosis; G = General Factor.

On the factor level, Explained Common Variance (ECV) indicated that 44.1% of all common variance was explained by the general factor. The ECV for items loading on each specific factor accounted for between 46.20% and 72.80%. The Omega statistic was 0.95 for the general factor and ranged from 0.80 to 0.90 for the six specific factors, demonstrating excellent internal reliability among scale items. Hierarchical Omega is an indicator of reliability expressed in terms of variance accounted for by a specific target construct. Hierarchical Omega for the general factor was 0.78, indicating that 77.60% of the variance in total scores can be attributed to variance on the general factor. For specific factors, this statistic reflects the proportion of reliable systematic variance of subscale scores after partitioning out variability attributed to the general factor [23,25] — this statistic ranged from 0.40 to 0.46. The H statistic provides a measure of construct replicability. H statistics $\geq$ 0.80 suggest a well-defined latent variable. H for the general factor was 0.92. There was some variability in the specific factor. The DMS and DOA factors reported less than desirable H statistics, suggesting that these factors may not be well-defined. The remaining specific factor

reported acceptable H statistics. The Factor Determinacy (FD) score is the correlation between factor scores and the factors. Strong FD values provide justification for calculating factor score estimates. The FD values for the DOA and DMS specific factor were still strong, but slightly under the recommended value of > 0.90 [27]. All other specific factor and general factor scores were >0.90.

On the model level, the Percent of Uncontaminated Variance (PUC) was 0.87. This value represents the percentage of covariance items which only reflect variance from the general factor. The PUC is interpreted in the context of the ECV. The ECV is this study was 0.44, highlighting a possible issue with relative bias. This was not determined to be problematic, as situations whereby the ECV < 0.70 and PUC > 0.70, relative bias is slight and common variance can be regarded as essentially unidimensional [23]. These statistics provide preliminary support for the psychometric properties of a revised bifactor structure of the SDSC in the current ADHD population.

Post-hoc analysis indicated that participant age were not correlated with the total SDSC scores ($r_s = 0.037$, $p = 0.596$). There

Table 2
Factor loadings for seven-factor solution of the Sleep Disorder Scale for Children (SDSC) identified using bifactor exploratory factor analysis (N = 302).

Item	Loadings						
	General	DI	SBD	DMS	SH	DOES	DoA
1. How many hours of sleep does your child get on most nights?	**0.303**	**0.509**		**0.458**			
2. How long after going to bed does your child usually fall asleep?	**0.255**	**0.779**					
3. The child goes to bed reluctantly	**0.419**	**0.497**					
4. The child has difficulty getting to sleep at night	**0.465**	**0.854**			−0.108		
5. The child feels anxious or afraid when falling asleep	**0.704**				−0.261		
6. The child startles or jerks parts of the body while falling asleep	**0.848**					−0.147	
7. The child shows repetitive actions such as rocking or head banging while falling asleep	**0.496**						
8. The child experiences vivid dream-like scenes while falling asleep	**0.684**						
9. The child sweats excessively while falling asleep	**0.480**				**0.610**		
10. The child wakes up more than twice per night	**0.586**			**0.588**			
11. After waking up in the night, the child has difficulty to fall asleep again	**0.573**			**0.536**			
12. The child has frequent twitching or jerking of legs while asleep or often changes position during the night or kicks the covers off the bed.	**0.598**						
13. The child has difficulty in breathing during the night	**0.459**		**0.724**				
14. The child gasps for breath or is unable to breathe during sleep	**0.454**		**0.862**				
15. The child snores	**0.441**		**0.393**	0.131			
16. The child sweats excessively during the night	**0.473**				**0.849**		
17. You have observed the child sleepwalking	**0.404**				0.210		**0.622**
18. You have observed the child talking in his/her sleep	**0.563**						**0.427**
19. The child grinds teeth during sleep	**0.458**						
20. The child wakes from sleep screaming or confused so that you cannot seem to get through to him/her, but has no memory of these events the next morning	**0.653**						**0.633**
21. The child has nightmares which he/she doesn't remember the next day	**0.645**				−0.192		**0.408**
22. The child is unusually difficult to wake up in the morning	**0.259**	**0.460**				**0.679**	
23. The child awakes in the morning feeling tired	**0.367**	**0.457**				**0.622**	
24. The child feels unable to move when waking up in the morning	**0.357**	**0.303**	−0.215			**0.649**	
25. The child experiences daytime somnolence	**0.465**					**0.558**	−0.229
26. The child falls asleep suddenly in inappropriate situations	**0.338**			**0.307**		**0.403**	

Note. Only significant factor loadings (p < 0.05) are depicted. Specific factor loadings ≤ 0.30 are excluded from inclusion in the follow-up bifactor CFA model (Fig. 2b). Item 26 loading onto the DMS factor were excluded from the final analysis due to identification as a non-significant pathway in the bifactor CFA. Significant pathways with factor loadings > .30 are depicted in bold. DI = Disorders Initiating Sleep; DMS = Disorders Maintaining Sleep; SBD = Sleep Breathing Disorders; DOA = Disorders of Arousal; DOES = Disorders of Excessive Somnolence; SH = Sleep Hyperhidrosis; G = general factor.

was no significant difference between males and females (Mann-Whitney U = 5168.50, p = 0.186). This suggests that SDSC scores may not differ as a function of age or gender.

4. Discussion

The overarching aims of the current study were (i) to evaluate the factor structure of the SDSC in a sample of children with ADHD and (ii) to establish evidence for unidimensionality. We first tested the original six-factor structure, and a univariate solution, and found each provided a poor fit to the data. An exploratory approach was accordingly undertaken, and a Bifactor EFA model provided a well-fitting model, comprising of a general factor and a novel pattern of six specific factors. This model retained several of the factors originally identified in the [10] SDSC. We then refined this model to remove significant cross-loadings of small effects (ie, factor loading <0.30) and deemed clinically irrelevant; and we specified a more parsimonious and clinically meaningful model for final testing. Finally, a bifactor CFA of this more parsimonious model yielded a similarly excellent fit to the data. This allowed for greater conceptual understanding of the SDSC factor structure in the current ADHD population without compromising model fit. To our knowledge, this is the first study that has evaluated the SDSC in an ADHD sample whilst simultaneously providing evidence of a general sleep difficulties factor and providing evidence for unidimensionality for applying the total SDSC score in an ADHD sample.

Our findings suggested that the parents of children with ADHD likely responded to scale items differently from those of typically developing children [10]; and also differently from those of children with mixed neurodevelopmental disorders [8]. ADHD may

disrupt sleep in a manner or pattern unique to this disorder. This disorder-specific disruption could be a combination of neurobiological (eg, cerebral hypoactivation), behavioural (eg, greater bedtime resistance behaviour) or environmental factors (eg, quality of parental attachment) specific to ADHD [28,29]. Such factors provide a plausible explanation of the different pattern of responses to SDSC items identified in this study.

The bifactor EFA results provided an explanation for the poor model fit identified in the original six-factor, its related bifactor CFA and unidimensional solutions. Our more data-driven approach highlighted that all 26-items in the SDSC had significant item loadings onto a general sleep factor. This general factor could be best conceptualised as 'total sleep difficulties' and explained 44% of the common variance in total SDSC scores. The six-specific factors differed from the original SDSC factors reported by Bruni et al., [10]. The pattern of item loadings for the SBD, DOA, SH and DOES factors in the current ADHD sample are largely consistent with the original respective factors. However, five of the six items originally identified as comprising the SWTD subscale failed to load onto any specific factor. These items (see Table 2) related to behaviours including grinding of teeth, repetitive or jerking motor movements, and experience of vivid dream-like scenes. Such symptoms appear distinctive on face validity; and may not group readily into a specific factor or cross-load onto another factor. Despite no significant specific factor loadings, all five SWTD items loaded onto the general factor with moderately sized factor loadings, indexing important contributions to the SDSC unidimensionality; therefore should not be removed. Item 18 ('you have observed the child talking in his/her sleep') was now shown to load onto the DOA factor, as parents may interpret 'sleep talking' as a possible sign of disordered arousal

Table 3
Standardized Loading Pattern for the final 6-factor Bifactor Structural Equation Model for the SDSC (N = 307).

Item	General factor Loading	S.E.	DI Loading	S.E.	DMS Loading	S.E.	SBD Loading	S.E.	DOA Loading	S.E.	DOES Loading	S.E.	SH Loading	S.E.	R²
Item 1	0.327	0.061	0.446	0.054	0.303	0.067									0.520
Item 2	0.276	0.061	0.848	0.031											0.796
Item 3	0.419	0.054	0.476	0.047											0.401
Item 4	0.447	0.053	0.794	0.033											0.830
Item 5	0.724	0.039													0.524
Item 10	0.575	0.044			0.539	0.06									0.621
Item 11	0.547	0.049			0.765	0.068									0.885
Item 13	0.418	0.072					0.785	0.118							0.791
Item 14	0.423	0.102					0.83	0.129							0.868
Item 15	0.468	0.058					0.369	0.074							0.356
Item 17	0.434	0.073							0.571	0.087					0.514
Item 20	0.670	0.058							0.655	0.077					0.877
Item 21	0.650	0.047							0.390	0.074					0.574
Item 6	0.769	0.034													0.592
Item 7	0.444	0.080													0.197
Item 8	0.693	0.044													0.480
Item 12	0.659	0.043													0.434
Item 18	0.577	0.044							0.358	0.064					0.461
Item 19	0.459	0.062													0.211
Item 22	0.248	0.067	0.388	0.061							0.709	0.044			0.714
Item 23	0.363	0.056	0.445	0.050							0.640	0.045			0.739
Item 24	0.308	0.068	0.312	0.067							0.677	0.046			0.651
Item 25	0.434	0.068									0.535	0.065			0.474
Item 26	0.345	0.093									0.325	0.108			0.226
Item 9	0.445	0.061											0.838	0.195	0.899
Item 16	0.460	0.058											0.669	0.155	0.660

Psychometric Properties	General factor	DI	DMS	SBD	DOA	DOES	SH
ω	0.949	0.901	0.804	0.856	0.860	0.848	0.870
ωH	0.776	0.646	0.433	0.583	0.396	0.616	0.610
H	0.920	0.847	0.545	0.807	0.633	0.741	0.760
FD	0.949	0.949	0.815	0.958	0.855	0.907	0.951
PUC	0.865	-	-	-	-	-	-
ECV	0.441	0.728	0.525	0.699	0.462	0.725	0.706

Note. All factor loadings included in the table are significant at $p < 0.05$. Shaded cells highlight the original items identified as indicators of each factor per the original SDSC [10]. DI = Disorders Initiating Sleep; DMS = Disorders Maintaining Sleep; SBD = Sleep Breathing Disorders; DOA = Disorders of Arousal; DOES = Disorders of Excessive Somnolence; SH = Sleep Hyperhidrosis; G = General factor. ω = omega coefficient for g factor, and omega subscale coefficient for SDSC subscales. ω_H = omega hierarchical coefficient for General factor, and omega hierarchical subscale coefficient for SDSC subscales. H = construct replicability. FD = factor determinacy. PUC = percent of un-contaminated variance. ECV = explained common variance.

during sleep rather than a sleep-wake transition issue. Alternatively, children with ADHD may 'sleep talk' more throughout the night, instead of only during sleep-wake transition.

The seven items originally identified as indicators of the DIMS factor were found to be parcelled into two independent, but strongly correlated, factors in the current ADHD sample. The first factor retained items primarily concerning items related to difficulties initiating sleep (DI) while the second factor retained items primarily concerning items related to maintaining sleep (DMS). The cross-loading for item 1 (How many hours of sleep does your child get on most nights?) was anticipated as both sleep initiation and maintenance difficulties are likely to impact sleep duration. Children with ADHD typically experience significant 'mental restlessness' when put to bed, leading to sleep initiation problem; but once asleep they do not typical experience sleep maintenance

problems.— thereby accounting for why these items were parcelled into two separate factors. This finding appears unique to our ADHD sample, contrasting with the original SDSC and the factor structure reported by Marriner et al., [8]; as both of which identified support for a unifying DIMS factor. Our finding needs to be replicated by other ADHD samples, despite the reported high prevalence of sleep initiation difficulties in ADHD children (Brown & McMullen [30]; Silvestri et al., [31]; Thunstrom, [32]). The distinction between initiating sleep and maintaining sleep may represent a uniquely salient feature of the ADHD population, contrasting with other non-ADHD samples. This finding has potentially important clinical implications for the assessment of sleep difficulties in children with ADHD. Difficulties initiating sleep should be considered independent of sleep maintenance issues, rather than in combination.

Whilst many of our model pathways were consistent with those of Bruni et al., [10] model, several unexpected item loadings were also identified. There is a tendency for data-driven models to report optimal model fit for their data therefore over-modelling clinically irrelevant paths. To improve both parsimony and clinical relevance of our final model, we removed significant but weak loadings. Item cross-loadings were only retained if they were clinically meaningful (eg, cross-loading of Item 1 was retained). The final bifactor CFA model comprised fewer pathways but improved conceptual structure and parsimony, without significant deterioration of fit statistics. We propose that future studies on SDSC validation should consider including this model for evaluation.

ADHD affects 5−10% of all children, making it one of the most common childhood neurodevelopmental disorders [33]. Up to 74% of children with ADHD experience additional sleep difficulties [2], leading to the suggestion that approximately 3.7−7.4% of all children experience ADHD in conjunction with comorbid sleep-related difficulties. The potential magnitude of this issue highlights the relevance and significance of our findings and further research investigating the unique expression of sleep-related difficulties in children with ADHD. Our findings provide a novel contribution to this area of research, highlighting the importance of further investigation on whether the SDSC may be adapted to improve the validity for use with children with ADHD.

In the absence of any other well-validated and clinically-relevant screening instruments for clinical populations, clinicians currently may still use the SDSC to evaluate sleep disturbance in children with ADHD, as our findings provide strong support for the factorial validity of the summed total score. However, there could be limitations in the validity of subscale scores, and these should be interpreted with more caution. Notably, our findings suggest it is best to score 'sleep initiation' separately (see Table 2) from those of sleep maintenance for more accurate information. When summed, good 'sleep maintenance' could potentially dilute the higher score of 'poor sleep initiation' leading to misclassification. However, our findings are preliminary, awaiting replication; and this suggested approach should be adopted with caution and corroborated with other clinical information.

4.1. Limitations and directions for future research

Our sample size limited the scope of further post-hoc analyses, for instance, applying the findings to a validation sample and proceeding to measurement invariance analysis. Given the constraints of sample size and characteristics, it was not methodologically feasible to evaluate measurement invariance across subgroups within our sample, for example, 89% were male. Post-hoc analyses in the present study showed that neither age nor sex were associated with SDSC total scores. This was consistent with [8]; who evaluated the measurement invariance of the SDSC-R across sex and found no significant differences in their clinical sample. Future research on sleep difficulties in children with ADHD could further address such issues.

We tested five competing models, and did not apply adjustments for multiple testing, as the exploratory components of our analyses should be regarded as hypothesis-generating explorations. Finally, our study and previous validation of the SDSC (eg, Marriner et al., [8]) were limited by the absence of an objective or 'gold-standard' measure of sleep disorder (eg, PSG). As PSG is an expensive and time-consuming procedure, further studies could embed concurrent laboratory validation in a subset of the research samples.

Neither the current study or previous validation study by Marriner et al., [8] could replicate the SDSC factor structure in a clinical population of Australian children. One plausible explanation is the clinical characteristics of these samples being different to the mostly typically-developing sample used by Bruni et al., [10]. However, cross-cultural differences in parental experiences of their children's sleep offer an alternative explanation that should also be considered. Family and cultural influences on children's sleep behaviour are well-established empirically [34]. Thus, screening measures for sleep difficulties should present items in a manner that accommodates the unique cultural characteristics of the sample. Bruni et al., [10] created the SDSC to evaluate sleep in Italian children with their own language and a certain way of talking about sleep. The sleep behaviour of Australian children is different compared to children from other cultures, including Italian children [34,35]. The English-translation of the SDSC has not yet been culturally adapted to account for the unique way in which Australian parents understand their child's sleep. This could influence the pattern in which parents rated their children's sleep difficulties in the current study. Thus we recommend that a cultural adaptation of the SDSC be piloted in future studies seeking to validate this measure for use in Australia.

4.2. Conclusion

This study addresses the literature gap to evaluate the factorial validity of SDSC in children with ADHD, amongst whom sleep difficulties are common. The results of this study provide preliminary evidence (i) to support unidimensionality of SDSC and the items can be summed to yield a total score: (ii) to suggest that the original six-factor structure of the SDSC could only be partially replicated in the current ADHD population; and (iii) to indicate a novel pattern in the parcellation of SDSC items amongst children with ADHD, notably, sleep initiation and sleep maintenance are partitioned into two separate factors in our ADHD sample, consistent with clinical experience of children with ADHD, who have more difficulties of falling asleep due to 'mental restlessness'.

The parents of children with ADHD appear to respond to scale items differently to those of typically developing children based on our inability to replicate the original SDSC factor structure. Our findings suggest that the scale previously known as Disorders of Initiating and Maintaining Sleep was instead conceptualised as two separate, but correlated factors (ie, Disorders Initiating Sleep, and Disorders Maintaining Sleep) in the current sample. The scale previously known as Sleep-wake Transition Disorders was not identified in the current analysis − these items were only weakly correlated with any other SDSC scale items but did account for variance in a general sleep difficulties factor.

Our study is the first to apply a bifactor evaluation of the SDSC items. The present findings suggested that all items load onto the general factor regardless of the strength or significance related to other specific factors. As such, there is sufficient preliminary evidence for the continued use of a total sleep difficulties score on the SDSC for an ADHD sample. Calculation of sleep disorder subtypes (namely DIMS and SWTD) using the SDSC in children with ADHD should be interpreted with caution, as these two specific factors were not replicated in the current study. Disorders initiating sleep should also be considered independent of disorders maintaining sleep in ADHD children. However, our findings are preliminary; and need to be replicated and, preferably, validated against gold-standard measures of sleep disturbance (ie, PSG) in future studies, before a definitive revision of the scoring procedure for SDSC should be considered.

Funding

Acknowledgements

Conflict of interest

None.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleepx.2019.100006.

References

[1] Thomas S, Lycett K, Papadopoulos N, et al. Exploring behavioral sleep problems in children with ADHD and comorbid autism spectrum disorder. J Atten Disord 2018;22:947–58. https://doi.org/10.1177/1087054715613439.

[2] Cortese S, Faraone SV, Konofal E, et al. Sleep in children with attention-deficit/hyperactivity disorder: meta-analysis of subjective and objective studies. J Am Acad Child Adolesc Psychiatry 2009;48:894–908. https://doi.org/10.1097/chi.0b013e3181ac09c9.

[3] Romeo DM, Brogna C, Quintiliani M, et al. Sleep disorders in children with cerebral palsy: neurodevelopmental and behavioral correlates. Sleep Med 2014;15:213–8. https://doi.org/10.1016/j.sleep.2013.08.793.

[4] Hiscock H, Sciberras E, Mensah F, et al. Impact of a behavioural sleep intervention on symptoms and sleep in children with attention deficit hyperactivity disorder, and parental mental health: randomised controlled trial. BMJ 2015;350:h68. https://doi.org/10.1136/bmj.h68.

[5] Sciberras E, Fulton M, Efron D, et al. Managing sleep problems in school aged children with ADHD: a pilot randomised controlled trial. Sleep Med 2011;12:932–5. https://doi.org/10.1016/j.sleep.2011.02.006.

[6] Bériault M, Turgeon L, Labrosse M, et al. Comorbidity of ADHD and anxiety disorders in school-age children: impact on sleep and response to a cognitive-behavioral treatment. J Atten Disord 2018;22(5):414–24. https://doi.org/10.1177/1087054715605914.

[7] Cassoff J, Wiebe ST, Gruber R. Sleep patterns and the risk for ADHD: a review. Nat Sci Sleep 2012;4:73–80. https://doi.org/10.2147/NSS.S31269.

[8] Marriner AM, Pestell C, Bayliss DM, et al. Confirmatory factor analysis of the Sleep Disturbance Scale for Children (SDSC) in a clinical sample of children and adolescents. J Sleep Res 2017;26:587–94. https://doi.org/10.1111/jsr.12526.

[9] Ferreira VR, Carvalho LB, Ruotolo F, et al. Sleep disturbance scale for children: translation, cultural adaptation, and validation. Sleep Med 2009;10(4):457–63. https://doi.org/10.1016/j.sleep.2008.03.018.

[10] Bruni O, Ottaviano S, Guidetti V, et al. The Sleep Disturbance Scale for Children (SDSC) - construction and validation of an instrument to evaluate sleep disturbances in childhood and adolescence. J Sleep Res 1996;5:251–61. https://doi.org/10.1111/j.1365-2869.1996.00251.x.

[11] Lewandowski AS, Toliver-Sokol M, Palermo TM. Evidence-based review of subjective pediatric sleep measures. J Pediatr Psychol 2011;36:780–93. https://doi.org/10.1093/jpepsy/jsq119.

[12] Spruyt K, Gozal D. Pediatric sleep questionnaires as diagnostic or epidemiological tools: a review of currently available instruments. Sleep Med Rev 2011;15:19–32. https://doi.org/10.1016/j.smrv.2010.07.005.

[13] Spruyt K, Cluydts R, Verleye GB. Pediatric sleep disorders: exploratory modulation of their relationships. Sleep 2004;27:495–501. https://doi.org/10.1093/sleep/27.3.495.

[14] Matsuoka M, Nagamitsu S, Iwasaki M, et al. High incidence of sleep problems in children with developmental disorders: results of a questionnaire survey in a Japanese elementary school. Brain Dev 2014;36(1):35–44. https://doi.org/10.1016/j.braindev.2012.12.004.

[15] Huang M-M, Qian Z, Wang J, et al. Validation of the Sleep Disturbance Scale for Children and prevalence of parent-reported sleep disorder symptoms in Chinese children. Sleep Med 2014;15(8):923–8. https://doi.org/10.1016/j.sleep.2014.03.023.

[16] Jaspers-Fayer F, Lin SY, Belschner L, et al. A case-control study of sleep disturbances in pediatric obsessive-compulsive disorder. J Anxiety Disord 2018;55:1–7. https://doi.org/10.1016/j.janxdis.2018.02.001.

[17] Neto FK, Nunes MLJSM. In: Evaluation of sleep organization in patients with attention deficit hyperactivity disorder (ADHD) and ADHD as a comorbidity of epilepsy, vol. 33; 2017. p. 91–6. https://doi.org/10.1016/j.sleep.2016.08.013.

[18] Precenzano F, Ruberto M, Parisi L, et al. Sleep habits in children affected by autism spectrum disorders: a preliminary case-control study. Acta Med Mediterr 2017;33:405–9. https://doi.org/10.19193/0393-6384_2017_3_059.

[19] Barrett P. Structural equation modelling: adjudging model fit. Personal Individ Differ 2007;42:815–24. https://doi.org/10.1016/j.paid.2006.09.018.

[20] Geiser C. Data analysis with Mplus. New York, NY: Guilford Press; 2012.

[21] Hu LT, Bentler PM. Cut-off criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model: Multidiscip J 1999;6(1):1–55. https://doi.org/10.1080/10705519909540118.

[22] Cunningham E. A practical guide to structural equation modelling using Mplus. Melbourne: Statsline; 2010.

[23] Rodriguez A, Reise SP, Haviland MG. Applying bifactor statistical indices in the evaluation of psychological measures. J Personal Assess 2016;98(3):223–37. https://doi.org/10.1080/00223891.2015.1089249.

[24] Yang Y, Green SB. Evaluation of structural equation modeling estimates of reliability for scales with ordered categorical items. Methodology 2015;11:23–34. https://doi.org/10.1027/1614-2241/a000087.

[25] Rodriguez A, Reise SP, Haviland MG. Evaluating bifactor models: calculating and interpreting statistical indices. Psychol Methods 2016;21(2):137. https://doi.org/10.1037/met0000045.

[26] Dueber DM. Bifactor Indices Calculator: a Microsoft Excel-based tool to calculate various indices relevant to bifactor CFA models. 2016. Available at, http://sites.education.uky.edu/apslab/resources.

[27] Gorsuch RL. Factor analysis. 2nd ed. Hillsdale, NJ: Erlbaum; 1983.

[28] Prihodova I, Paclt I, Kemlink D, et al. Sleep disorders and daytime sleepiness in children with attention-deficit/hyperactivity disorder: a two-night polysomnographic study with a multiple sleep latency test. Sleep Med 2010;11:922–8. https://doi.org/10.1016/j.sleep.2010.03.017.

[29] Sloan EP, Maunder RG, Hunter JJ, et al. Insecure attachment is associated with the α-EEG anomaly during sleep. Biopsychosoc Med 2007;1(1):20–6. https://doi.org/10.1186/1751-0759-1-20.

[30] Brown TE, McMullen WJ. Attention deficit disorders and sleep/arousal disturbance. Ann N Y Acad Sci 2001;931(1):271–86. https://doi.org/10.1111/j.1749-6632.2001.tb05784.x.

[31] Silvestri R, Gagliano A, Aricò I, et al. Sleep disorders in children with Attention-Deficit/Hyperactivity Disorder (ADHD) recorded overnight by video-polysomnography. Sleep 2009;10:1132–8. https://doi.org/10.1016/j.sleep.2009.04.003.

[32] Thunström M. Severe sleep problems in infancy associated with subsequent development of attention-deficit/hyperactivity disorder at 5.5 years of age. Acta Paediatr 2002;91:584–92. https://doi.org/10.1111/j.1651-2227.2002.tb03281.x.

[33] Polanczyk G, De Lima MS, Horta BL, et al. The worldwide prevalence of ADHD: a systematic review and metaregression analysis. Am J Psychiatry 2007;164:942–8. https://doi.org/10.1176/appi.ajp.164.6.942.

[34] Giannotti F, Cortesi F. Family and cultural influences on sleep development. Child Adolesc Psychiatr Clin N Am 2009;18:849–61. https://doi.org/10.1016/j.chc.2009.04.003.

[35] Mindell JA, Sadeh A, Wiegand B, et al. Cross-cultural differences in infant and toddler sleep. Sleep Med 2010;11:274–80. https://doi.org/10.1016/j.sleep.2009.04.012.