Document Type: Original Article
https://dorl.net/dor/20.1001.1.26455447.2022.5.19.4.3

Iranian Journal of Learning and Memory, 2022, 5(19), 51-62

Investigation of the Relationship among Sleep Disorders, Executive Dysfunction, and Sluggish Cognitive Tempo in Adolescents: A Network Analysis

Asgar Alimohamadi, Ph.D.
Department of Psychology and Education of Exceptional Children, Allameh Tabataba'i University, Tehran, Iran.
Mahdieh Bayati, Ph.D.
Department of Statistics, Allameh Tabataba'i University, Tehran, Iran.
Karim Abdolmohamadi, Ph.D.
Department of Psychology, Azarbaijan Shahid Madani University, Tabriz, Iran.

Abstract

The objective of the present study was to examine the relationship among sleep disorders, executive dysfunction, and sluggish cognitive tempo in adolescents utilizing a network approach. The study was performed based on descriptive-correlation method. The population of study contained all the adolescents (aged 12-18 years) in Tehran, Ardebil, Southern Azerbaijan and Western Azerbaijan provinces during the academic year 2021-2022. Data were collected from Two thousand six hundred and fifty-nine adolescents who were recruited through convenience sampling method. Participants completed the Adult Concentration Inventory (Becker et al. 2015), Sleep Disorders Symptom Checklist (Klingman et al. 2017), and Executive Skills Questionnaire-Revised (Strait et al. 2019). The bootnet package in R software was used for data analysis. Results showed Sluggish Cognitive Tempo (SCT) was positively and more closely related to Sleep Disorders (insomnia) than Executive Dysfunction. The results showed that the most robust relative bridge connections were Sluggish Cognitive Tempo (SCT) and Plan Management (PM), edge weight = 0.33; Sluggish Cognitive Tempo (SCT) and Insomnia edge weight = 0.26; in addition to the positive bridge connections, a negative robust connection was also recognized between Obstructive Sleep Apnea (OSA) and Emotional Regulation (ER), edge weight = - 0.07. In the current research, the analysis indicated Sluggish Cognitive Tempo (SCT) symptoms as a significant node with high centrality in the network whereas emotional regulation demonstrated high expected influence in the network with the consideration of the negative edges. In conclusion, Sluggish Cognitive Tempo (SCT) was positively associated with sleep disorders and executive dysfunction. Future interventions can emphasize the bridge connections of sleep disorders, executive dysfunction, and sluggish cognitive tempo in adolescents.

Keywords: Adolescents, Executive Dysfunction, Sleep Disorders, Sluggish Cognitive Tempo

Receive Date: 12 August 2022
Revise Date: 06 September 2022
Accept Date: 12 September 2022
Publish Date: 01 October 2022

Corresponding Author: Karim Abdolmohamadi
Email: karim.abdolmohamadi@yahoo.com

How to Site: Alimohamadi, A., Bayati, M., & Abdolmohamadi, K. (2022). Investigation of the Relationship among Sleep Disorders, Executive Dysfunction, and Sluggish Cognitive Tempo in Adolescents: A Network Analysis. *Iranian Journal of Learning & Memory*, *5*(19), 51-62. https://dorl.net/dor/20.1001.1.26455447.2022.5.19.4.3

Introduction

One of the most critical public health problems is sleep disorder which influences individuals from different age groups, including adolescents and young adults, and they may have severe consequences at both individual and societal levels. As Kansagra (2020) reported, sleep disorders are widespread among adolescents. Adolescents often find disturbances in their sleep/wake cycles, and as a result, they often complain about their poor quality of sleep. An example of adolescents sleep disorders is a study conducted by Short et al. (2013). In the study, the researchers estimated that up to 66 % of adolescents would face a particular type of sleep disorder.

Adolescents' sleep problems are generally of certain types, some of which include insomnia (Hebbar et al. , 2017), daytime sleepiness, staying up late and waking up early, frequent nightmares, and elevated risk of sleep problems (Liu et al., 2008; Owens et al., 2014; Roberts et al., 2001; Roberts et al., 2008). However, previous studies have found that insomnia is the most prevalent sleep disorder among adolescents (Amaral et al., 2013; Johnson et al., 2006; Kaneita et al., 2006; Roberts et al., 2008). In fact, researchers cite a range of symptoms closely related to insomnia for adolescents' sleep disorders. For instance, Yang et al. (2003) mentioned absence of sleep, trouble falling asleep, or remaining asleep as common among adolescents with sleep disorders. Sleep disorders are linked to some other issues. More specifically, researchers view inadequate and poor sleep among adolescents as a public health problem and indicate a connection between this variable and academic performance (Stormark et al., 2019). Among other factors related to poor sleep, depression (Zhang et al. 2022), anxiety (Lindsay et al. 2022), academic performance (Henriquez-Beltran et al. 2022), social isolation, and attention deficit hyperactivity disorders (Lecendreux & Cortese, 2007; Lima et al., 2020; Richardson et al., 2019; Van Dyk, Becker, & Byars, 2019) are mentioned in adolescents.

Research indicates that despite the relatively rich literature on sleep disorders, the link between sleep disorders and other significant processes like executive functions has been neglected (Araújo & Almondes, 2014). This under-investigation, as well as the significance of sleep and executive functions for social-emotional competence and successful life, might require further attention from researchers. Along the same line, researchers state that behavioral concepts such as sluggish cognitive tempo (SCT) might be connected with sleep problems and daytime drowsiness, which points toward a slower mental processing rate (Becker et al. , 2016). Thus, the current study sought to fill this gap by trying to discover the potential link among the three concepts of sleep disorders, executive dysfunction, and sluggish cognitive tempo in adolescents via offering a network model.

Executive functions are an array of high-order complex cognitive skills. These cognitive skills are supported by neural networks in the brain and are essential for independent goal-oriented behavior (Lyons Usher et al., 2016). Executive functions are related to cognitive and behavioral inhibition, organization and planning, working memory, cognitive flexibility, and self-regulation (Aghdar et al., 2020). This is particularly true when adapting to changing, new, or complex situations (Diamond, 2013).

The link between sleep and cognitive functions among adolescents has been scrutinized by a host of researchers (Tomaso et al., 2020). These researchers have considered both the advantages of sufficient sleep as well as the disadvantages of lack of adequate sleep. Adequate sleep is essential for the accomplishment of cognitive behaviors. Similarly, as Zhang et al. (2022) pointed out, inadequate or poor sleep may influence numerous cognitive functions negatively. In fact, researchers have found a positive correlation between the severity of sleep disorders and the severity of executive functions (EF) (Wennberg et al., 2019). Moreover, a reciprocal link has been found between sleep disturbance and executive function. Some researchers believe that disorders related to sleep might partly account for the poor executive function performance in an individual's everyday activities (Stabouli et al., 2019).

Along the same line, Caruso et al. (2014) reported that sleep quality can mediate deficits in behavior and executive functioning. Among the common examples of sleep disorders impacting executive functions is insomnia. Research indicates that sleep disorders such as insomnia can affect executive functions like cognitive speed, attention, reaction time, working memory, vigilance, as well as higher executive functions (Durmer & Dinges, 2005). As Ballesio et al, (2019) and Cellini (2017) argued, individuals suffering from sleep disorders, like insomnia, generally have difficulties in various cognitive functions including, executive control such as attention, memory, as well as concentration.

Previous studies on infants, toddlers, and children (Holley et al., 2014; Stabouli et al., 2019) have found some links between sleep disorders and executive dysfunctions. However, as Holley et al. (2014) claimed, there is an under-investigation of the connection between sleep disorders and executive functioning in more extensive community-based samples of adolescents, or the impact of moderators like low socioeconomic status (SES).

Another concept that has attracted researchers' attention is Sluggish Cognitive Tempo (SCT) (Fredrick & Becker, 2022). According to some researchers (e.g. Barkley, 2014; Becker et al., 2014), individuals with SCT often experience too much daydreaming and mental confusion, generally appear to be “in a fog,”, and suffer from slowed behavior or thought processes. Along the same line, Becker et al. (2016) defined SCT as a collection of behavioral symptoms, mainly including mental confusion and fogginess, slow behavior and thought processes, lack of energy and sleepiness, and extreme daydreaming.

Previous studies on sleep disorders (Becker et al., 2016b; Becker et al., 2016c) have mainly found an association between sleep disorders and SCT. These studies have been conducted primarily on samples of children, and their outcomes have emphasized the relationship between sleep disorders and SCT. For instance, carrying out research on school children with sleep disorders, Becker et al. (2016a) found out that SCT, as reported by parents, was distinctively related to various measures of sleep disorders and daytime drowsiness. Similarly, SCT had a weak to moderate correlation with most sleep measures, as well as a mild to strong correlation with daytime sleepiness measures. In two other studies with experimental sleep restriction/extension protocol, researchers sought the potential links between sleep duration and SCT symptoms whereas Becker et al. (2019) reported a causal link between shortened sleep duration and increased SCT symptoms in adolescents with ADHD, Garner et al. (2017) reported the same link in adolescents without ADHD. In another similar study, Smith et al. (2019) found that self-reported SCT was distinct and yet had a strong correlation with daytime drowsiness in adolescents with ADHD.

Overall, findings show strong evidence for the link between SCT and low-quality sleep, high levels of daytime sleepiness, and a later evening daily preference (Fredrick et al. , 2022). Nevertheless, there have also been exceptions among the studies focusing on the correlation between SCT and sleep disorders. These studies have failed to present a strong or steady link between parent- or teacher-reported SCT and children’s sleep disorders (Becker et al., 2016c; Koriakin et al. , 2015), particularly in studies with strong SCT measures. Besides, most studies have focused on children’s sleep disorders and SCT, hence there is a need for a survey on adolescents.

As stated earlier, SCT refers to a constellation of symptoms involving slowed behavior/thinking, less alertness, excessive daydreaming, and a lack of control over one’s thoughts (Becker et al., 2016a; McBurnett et al., 2014). Among SCT symptoms, one may refer to being slow, underactive, indifferent, forgetful, susceptible to daydreaming, unenthusiastic, lost in thoughts, and confused. Individuals with SCT have poor performance in some neuropsychological tests. They demonstrate normal intelligence; however, their attention is usually reduced (Milich et al., 2001). SCT symptoms might also be connected with executive dysfunction, such as excessively slow working memory systems as well as excessively fast inhibition systems. Kofler et al. (2019) claimed that from a behavioral perspective, the need for more time to re-arrange the active contents of working memory leads to a delay in responding while an excessively active inhibition system probably ends thoughts too abruptly.

Although the majority of studies support the potential link between SCT and executive functions Barkley et al. 2022; Camprodon-Rosanas et al. 2020), the findings in this regard have been rather inconsistent. For instance, in a meta-analysis, Becker, et al. (2016b) reported only a poor link between increased evidence of SCT symptoms and lower general intelligence test scores, working memory, response inhibition, sustained attention, and processing speed. Considering the limited and inconsistent results about the link between SCT and executive functions among adolescents, there is a need for the present study.

In the present study, the researchers utilized the network framework to scrutinize the potential interaction of the three variables of sleep disorders, executive dysfunctions, and SCT among adolescents. Some researchers (e.g. Burns, et al., 2022; Goh et al. , 2020) have recently commenced the use of network analyses on psychopathological symptomatology for the study of psychological issues such as SCT. As Cramer et al. (2010) argued, in a network model, symptoms as well as their interactions, are assumed to be the actual disorders instead of being considered echoes of the underlying reasons for mental disorders. In this new approach, psychological variables are regarded nodes in a network while the interactions between nodes are viewed as edges of the network. A unique characteristic of the network analysis lies in its capability to make the study of independent relationships between pairs of nodes possible while at the same time monitoring the effects of the rest of the nodes in the network. Epskamp et al. (2018) believed that the edges of an estimated network indicate partial correlation coefficients of two nodes while controlling for the rest of the nodes in the network.

In the current research, network analysis is employed to address two essential issues: First, although many existing studies have investigated the relationship among sleep disorders, executive dysfunctions, and SCT, they have failed to pay sufficient attention to adolescent populations especially in Iranian student society. Second, whereas previous research has held opposing views on the relations among sleep disorders, executive functions, and SCT, no investigation has examined such underlying associations in terms of symptoms. Therefore, the current study investigating the association among sleep disorders, executive functions, and SCT will fill the gap and can be regarded as the first studies to investigate the relationship among the mentioned variables.

Method

Design

The current study was a correlational study utilizing a network approach and was performed based on descriptive-correlation method.

Participants

The population of study contained all the adolescents (aged 12-18 years) in Tehran, Ardebil, Southern Azerbaijan and Western Azerbaijan provinces during the academic year 2021-2022. Data were collected from Two thousand six hundred and fifty-nine adolescents who were recruited through convenience sampling method. The Klein formula (2010) was used to determine the sample size, and finally, 2900 participants took part in the survey. However, after excluding respondents who submitted incomplete questionnaires, data from 2,659 participants were finally considered for the data analysis (See Table 1 for sample demographic information). The inclusion criteria consisted of being in the age range of 12-18 years, having no serious mental problems based on school health profile and consent to participate in this study. Participant excluded from study if failing to answer all the questions completely.

Instruments

SCT symptoms: For the current research, the Adult Concentration Inventory (ACI) (Becker et al., 2015) was selected. The scale is a novel self-report measure of SCT and consists of the 13 SCT items determined by Becker et al. (2016b) as ideal for differentiating between SCT and ADHD-IN symptoms. However, three mental confusion items have also been added to the original 13-items scale owing to the significance of these items in the assessment of SCT (McBurnett et al., 2014), resulting in a 16-item scale. Regarding the scoring system, the items on the scale are rated on four points (0= not at all, 1= sometimes, 2 = often, 3 = very often) according to the past six months. Additionally, the ACI comprises eight items that evaluate the present impairment because of the existence of any SCT behaviors (0= no difficulty, 4 = severe difficulty). Cronbach's α was reported to be 0.89 for the 10-item ACI scale identified below in the exploratory CFAs (McBurnett et al., 2014). In the current study, the Cronbach's alpha of the SCT symptoms items was .91.

Sleep Disorders Symptom Checklist: The checklist was prepared by Klingman et al. (2017). The checklist is utilized to assess sleep disorders dimensions like insomnia, restless legs syndrome, obstructive sleep apnea, narcolepsy, circadian rhythm, and parasomnias. It compromises 17 items, and its scores range from 0 (never) to 3 (frequently). The sum of the scores ranges from 0 to 51. The content validity of the checklist was established by the researchers, and the Cronbach alpha for the dimensions of insomnia, obstructive sleep apnea, circadian rhythm, restless legs syndrome, narcolepsy, and parasomnias were 0.76, 0.69, 0.93, 0.80, 0.93 and 0.83 respectively. As for the current study, the Cronbach's alpha on the items of the Sleep Disorders Symptom Checklist was .84.

Executive Skills Questionnaire-Revised (ESQ-R): The ESQ-R comprises 25 items for the measurement of executive deficiency on a 4-point scale ranging from never or rarely (0) to very often (3). The ESQ-R consists of five factors including, plan management (with 11 items), time management (with 4 items), materials organization (with 3 items), emotional regulation (with 3 items), and behavior regulation (with 4 items). Based on the scoring system, the average score of each one of the five factors can be utilized for identifying areas of executive deficiency whereas the sum of the scores from the five factors can be employed for determining general executive dysfunction. Excellent internal consistency has been reported for the scale (Nasir et al. , 2021). As for the current study, Cronbach's alpha for ESQ-R items was .88.

Procedure

Data analysis was carried out with the use of R Studio. The researchers utilized the *bootnet* package in R for the evaluation of the network structure with the help of the Graphical Gaussian Model (GGM) (Epskamp et al., 2012). The model is generally used with continuous data that are multivariate and have normal distribution to evaluate pairwise association parameters. As part of the data analysis, the researchers viewed each symptom as a node in the structure. As for edges, in the current model they are assumed as partial correlation coefficients and range from - 1 to 1. Following Epskamp et al. (2018), thicker edges are viewed as reflections of more robust associations between two nodes. Regarding the layout of the network, *Fruchterman-Reingold* algorithm with a gamma hyperparameter of 0.3 was used by the researchers. within the algorithm, nodes with more robust associations were put next to each other (Fruchterman

& Reingold, 1991). Following Armour et al. (2020), two different styles were utilized for the illustration of correlations: solid lines indicated positive associations (Figure 1) while dashed lines displayed negative relations. Additionally, following Friedman et al. (2008), the graphical LASSO was used for the regularization of the network as well as the avoidance of spurious correlations

Findings

The purpose of the present study was to pinpoint edges linking symptoms from the symptoms communities of sleep disorders, executive functions and, SCT. Jones et al. (2018) defined communities as symptoms within the network that are conceptually linked to each other. The researchers utilized the R package *networktools* for the identification of bridge strength. Jones et al. (2018) defined bridge strength as the total of absolute edge weight values belonging to all inter-community edges.

For the evaluation of the accurateness and stability of the network, the R package *bootnet* was used in order to bootstrap (1000 iterations) the edge weights (Epskamp & Fried, 2018). The package was used so that the researchers could test for significant variations between edge weights, estimated at a 95% confidence interval. Costenbader and Valente (2003) evaluated the strength centrality index, and thus utilized the correlation stability (CS)-coefficient. Costenbader and Valente (Epskamp & Fried, 2018) contended that a CS-coefficient ≥ 0.50 is required for the interpretation of variations in centrality. Finally, following Wang et al. (2021), the researchers employed goldbricker in the R package *networktools* for the identification of nodes that may most probably gauge the same construct. In the current study, pairs with less than 25% of different correlations in a significant manner were assumed as "bad pairs".

Table 1
Participant Characteristics

Row	Characteristics	Level	Number (Percent)
1.	Gender	Male	803 (30.2)
		Female	1856 (69.8)
2.	Age	12 years' old	54 (2)
		13 years' old	161 (6.1)
		14 years' old	253 (9.5)
		15 years' old	432 (16.2)
		16 years' old	443 (16.7)
		17 years' old	510 (19.2)
		18 years' old	806 (30.3)
3.	Parents' marital status	Married	2347 (88.26)
		Divorced	275 (10.34)
		Widow	37 (1.39)
4.	Parent education	Below high school	476 (17.9)
		High school diploma, GED	894 (33.62)
		Associates degree, vocational training	237 (8.91)
		Bachelor's degree	719 (27.04)
		Master's degree	271 (10.19)
		Advanced graduate degree (Ph.D.)	62 (2.33)

In this study, a regularized network was estimated, which involved sleep disorders, executive dysfunctions, and SCT symptoms, as displayed in Figure 1. Based on the findings, the internal connections in each scale were strong, and indicated groups of nodes .The means and standard deviation for each symptom from the ESQ-R, SDS-CL, and SCT scales are given in Table 2.

Table 2

Coding, Item Content, Mean, and Standard Deviation for Each Item in ESQ-R, SDS-CL, and SCT Scales

Item	Item content	Mean	Standard Deviation
PM	Plan Management	10.88	0.94
ER	Emotional Regulation	3.87	1.00
TM	Time Management	3.78	0.92
MO	Material Organization	2.71	0.94
BR	Behavioral Regulation	5.25	1.02
In	Insomnia	4.00	1.01
CR	Circadian Rhythm	2.16	1.07
Na	Narcolepsy	1.25	0.87
OSA	Obstructive Sleep Apnea	2.84	0.95
RLS	Restless Legs Syndrome	2.50	0.97
Pa	Parasomnias	2.15	0.92
SCT	Sluggish Cognitive Tempo	15.79	0.98

Table 3

The Results of Correlations Test between Variables of ESQ, SDS, and SCT

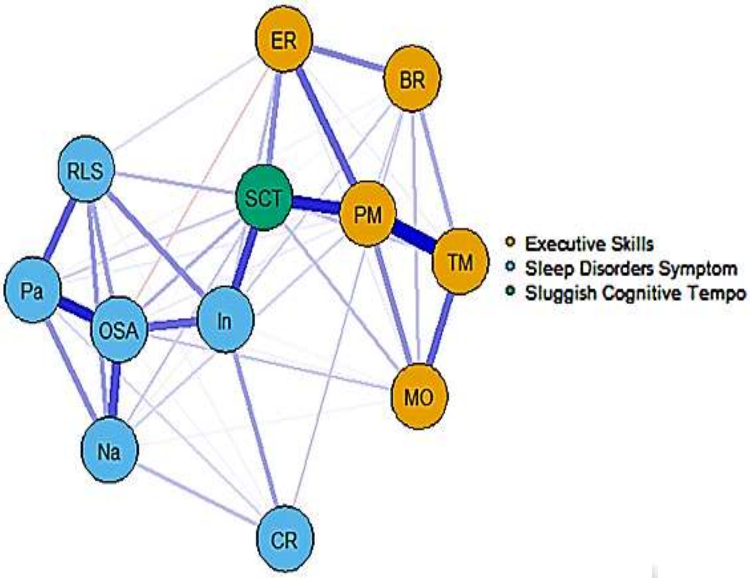
Variable		PM	ER	TM	MO	BR	In	CR	Na	OSA	RLS	Pa	SCT
Executive Functions Disorders	Plan Management	-											
	Emotional Regulation	0.57**	-										
	Time Management	0.70**	0.46**	-									
	Material Organization	0.57**	0.39**	0.55**	-								
	Behavioral Regulation	0.39**	0.37**	0.37**	0.32**	-							
Sleep Disorders	Insomnia	0.48**	0.41**	0.39**	0.33**	0.29**	-						
	Circadian Rhythm	0.20**	0.16*	0.16*	0.15*	0.17*	0.30**	-					
	Narcolepsy	0.43**	0.25**	0.33**	0.33**	0.15*	0.41**	0.25**	-				
	Obstructive Sleep Apnea	0.49**	0.29**	0.37**	0.40**	0.21**	0.57**	0.26**	0.60**	-			
	Restless Legs Syndrome	0.43**	0.33**	0.32**	0.30**	0.21**	0.51**	0.24**	0.50**	0.57**	-		
	Parasomnias	0.44**	0.28**	0.35**	0.35**	0.16*	0.46**	0.25**	0.54**	0.65**	0.57**	-	
sluggish cognitive tempo	Sluggish Cognitive Tempo	0.72**	0.54**	0.58**	0.51**	0.35**	0.62**	0.25**	0.48**	0.57**	0.51**	0.51**	-

** Significant correlation 0.01, * Significant correlation 0.05

The complete network is given in Figure 1. Symptoms with topological overlap were not seen in the network.

Figure 1

The Estimated Regularized Network Structure of SDS, ES, and SCT in the Sample



The strength stability with bootstrap 95% confidence intervals was good, CS = 0.75 (CS-coefficient for strength is higher than 0.5, suggesting the centrality indices were stable). In both networks, the most robust edges were seen within each sleep disorder, executive functions, and SCT symptoms cluster. As for the most robust edges, in the Sleep Disorders community, OSA (Obstructive Sleep Apnea) and Pa (Parasomnias) appeared as the strongest, with PM (Plan Management) and TM (Time Management) being the strongest in the executive functions cluster. With respect to centrality (see Figure 3), the highest strength belonged to SCT, and next came PM (Plan Management), In (Insomnia), and ER (Emotional Regulation) in descending order. Based on Figure 3, PM, SCT, and OSA varied from half of the other nodes in terms of strength, while the remaining did not differ from the majority of the other nodes in a significant manner.

Figure 2

Centrality Index of the Network Structure of SDS, ES, and SCT symptoms

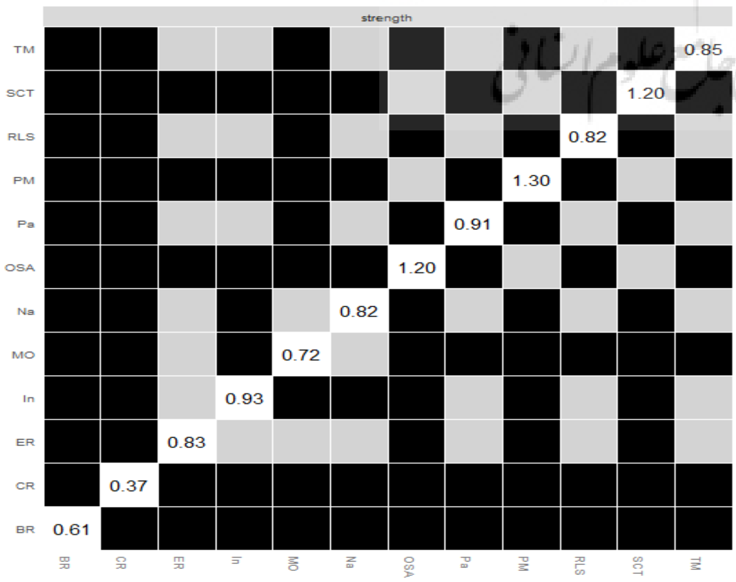
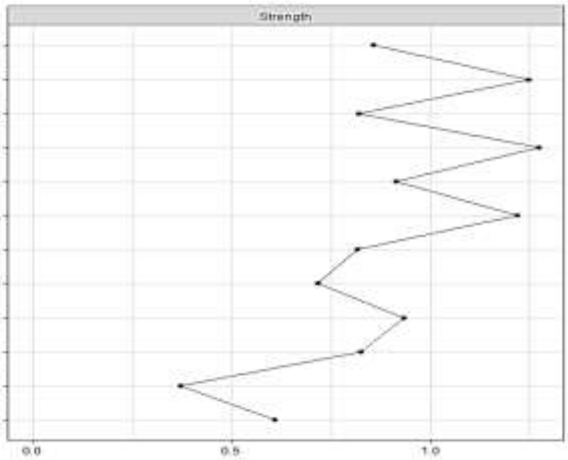


Figure 3

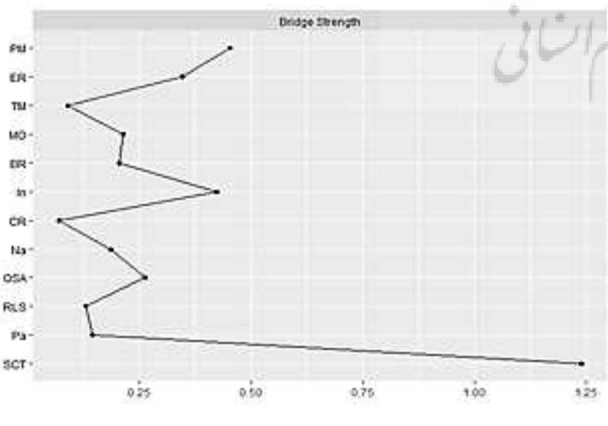
Bootstrapped Difference Test of Node strength in the network structure



In the network, different bridge connections were recognized (see Fig. 2). The most robust relative bridge connections were SCT and PM, edge weight = 0.33; SCT and in (insomnia), edge weight = 0.26; in addition to the positive bridge connections, a negative robust relationship was also recognized between OSA, and ER, edge weight = - 0.07. The findings of the bootstrapped difference test indicated other bridge connections.
Figure 4 demonstrates the adjusted bridge strength for each node. The nodes with almost high levels of bridge strength in descending order included SCT= 1.25; PM= 0.48 and in (insomnia) = 0.43.

Figure 4

Adjusted Bridge Strength (Standardized Scores)



Discussion

In this research, we examined the association among sleep disorders, executive dysfunction and sluggish cognitive tempo in adolescents. The present study is the first network analytic research aiming at examining the link between these constructs. Outcomes implied that clustering within symptoms, and cluster communities were the most robust. Different key bridge symptoms were also pinpointed among sleep disorders, executive dysfunction, and sluggish cognitive tempo, which implied potential pathways for intervention.

The most robust edge in the executive dysfunction, which was also the strongest edge in the whole network, was discovered between "Plan Management" and "Time Management". This connection might indicate the significance of the provision of training based on plan management to boost executive function efficacy.

In the present study, bridge connections of the whole network were discovered among sluggish cognitive tempo, insomnia, and plan management. This outcome matches previous findings suggesting the potential relationship between sleep dysfunctions like insomnia and higher rates of SCT symptoms (Becker et al., 2016a). Additionally, previous research indicates a modest independent correlation between SCT, and certain (not all) domains of executive functions. The studies suggest that SCT might be, in fact linked with executive function deficits in adult populations, especially with regard to deficits in metacognition and self-organization. The findings of this study were in line with those of Araújo and Almondes (2014), Zhang et al. (2022), Wennberg et al. (2019), Becker, et al. (2016) and Fredrick et al. (2022).

In explaining the results of this study, it can be declared that among students, persistent lack of sleep was related to poor executive functioning. Poor sleep quality may lead to inhibitory processes problems associated with poor executive functioning. Sleep problems including insomnia and sleep deprivation, could change cognitive performance and negatively impact on selective and sustained attention, alertness and cognitive inhibition (García et al. 2021). In addition, deterioration in executive function has been indicated in students with insomnia. In other words, functional changes in the subcortical regions, prefrontal cortex, and cingulate gyrus that are related to executive functioning, have been shown in students with sleep disorders (Grau-Rivera et al. 2020). Also, a meta-analysis conducted recently showed that sleep problems have an undeniable impact on a broad range of cognitive components such as perceptual functions, working memory, and problem-solving (Wardle-Pinkston et al. 2019). The Biopsychosocial Model revealed that sleep quality was related to high levels of perceived stress that could decrease emotion regulation in students (Venus, 2019).

In the current research, centrality analysis indicated SCT symptoms as a significant node with high centrality in the network whereas emotional regulation demonstrated high expected influence in the network with the consideration of the negative edges. Indeed, the relationship between sleep disorders and executive dysfunction was mediated by the severity of SCT, and previous research confirms this finding (Sevincok et al., 2020). Such a relationship lends support to previous findings indicating that sleep disturbance following a trauma exposure might result in impaired emotion regulation and aggravate other symptoms.

In general, studies have found significant bivariate associations between SCT symptoms, and various neurocognitive performance domains including, behavioral inhibition, working memory, processing speed, sustained attention, reaction time variability, and vigilance (Becker et al., 2016b). Some studies show that the metacognitive aspect of EF has been most consistently associated with SCT in studies with older children (Becker & Langberg, 2014). Becker et al. (2019) reported a causal link between shortened sleep duration and increased SCT symptoms in adolescents which was supported in the study done by Garner et al. (2017). In a similar study, Smith et al. (2019) found that self-reported SCT was distinct and yet had a strong correlation with daytime drowsiness in adolescents. Thus, SCT symptoms may negatively impact metacognitive EF functions as children develop.

Conclusion

The results of the study showed that there were strong connections among sluggish cognitive tempo, plan management and insomnia. In addition, there was negative connection between obstructive sleep apnea and emotional regulation. Also, in the current research, centrality analysis indicated sluggish cognitive tempo symptoms had a significant role in the network of variables. Thus, it can be concluded that sluggish cognitive tempo was positively associated with sleep disorders and executive dysfunction. Future interventions are needed to emphasize the connections of sleep disorders, executive dysfunction, and sluggish cognitive tempo in adolescents.

The study suffered from certain limitations that call for further research. First, sleep disorders, executive dysfunction, and sluggish cognitive tempo were measured with self-reported scales; thus, our results may have been biased by social desirability and recall bias. Second, the proportion of males and females in the study was not equal; female students formed a relatively larger proportion. It is suggested that future researchers control for the gender proportion in their studies. Third, as Bringmann et al. (2019) have cautioned against causal interpretations on the basis of the connectedness of elements within networks, especially with cross-sectional data, the nature of the study makes any causal or directional conclusions hard. Finally, to evaluate the generalizability of the findings in this study, further research might be required to confirm outcomes in clinical and more diverse samples. In so doing, it might become easier to determine if any of the results were sample-specific.

The outcomes of this study confirm the presence of an association among sleep disorders, executive dysfunction, and sluggish cognitive tempo, and may have implications for early intervention as well as clinical practice. Nonetheless, further research should be conducted on sleep disorders, particularly among adolescents.

Conflicts of interest

The authors declared no conflicts of interest.

References

Aghdar, A., Allipour, S., & Shehni Yeilagh, M. (2020). The Relationship between executive functions and self-regulated academic learning regarding the mediating role of metacognition and working memory among university students. *Iranian Journal of Learning & Memory*, *2*(8), 73-82.

Amaral, M. O. P., de Figueiredo Pereira, C. M., Martins, D. I. S., de Serpa, C. d. R. D. N., & Sakellarides, C. T. (2013). Prevalence and risk factors for insomnia among Portuguese adolescents. *European Journal of Pediatrics*, *172*(10), 1305-1311.

Araújo, D. d. F., & Almondes, K. M. d. (2014). Sleep and cognitive performance in children and pre-adolescents: a review. *Biological Rhythm Research*, *45*(2), 193-207.

Ballesio, A., Aquino, M. R. J. V., Kyle, S. D., Ferlazzo, F., & Lombardo, C. (2019). Executive functions in insomnia disorder: a systematic review and exploratory meta-analysis. *Frontiers in Psychology*, *10*, 101.

Barkley, R. A. (2014). Sluggish cognitive tempo (concentration deficit disorder?): Current status, future directions, and a plea to change the name. *Journal of Abnormal Child Psychology*, *42*(1), 117-125.

Becker, S. P., Epstein, J. N., Tamm, L., Tilford, A. A., Tischner, C. M., Isaacson, P. A., . . . Beebe, D. W. (2019). Shortened sleep duration causes sleepiness, inattention, and oppositionality in adolescents with attention-deficit/hyperactivity disorder: Findings from a crossover sleep restriction/extension study. *Journal of the American Academy of Child and Adolescent Psychiatry*, *58*(4), 433-442.

Becker, S. P., Garner, A. A., & Byars, K. C. (2016a). Sluggish cognitive tempo in children referred to a pediatric sleep disorders center: Examining possible overlap with sleep problems and associations with impairment. *Journal of Psychiatric Research, 77*, 116-124.

Becker, S. P., Leopold, D. R., Burns, G. L., Jarrett, M. A., Langberg, J. M., Marshall, S. A., . . . Willcutt, E. G. (2016b). The internal, external, and diagnostic validity of sluggish cognitive tempo: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry, 55*(3), 163-178.

Becker, S. P., Marshall, S. A., & McBurnett, K. (2014). Sluggish cognitive tempo in abnormal child psychology: an historical overview and introduction to the special section. *Journal of Abnormal Child Psychology, 42*(1), 1-6.

Becker, S. P., Pfiffner, L. J., Stein, M. A., Burns, G. L., & McBurnett, K. (2016c). Sleep habits in children with attention-deficit/hyperactivity disorder predominantly inattentive type and associations with comorbid psychopathology symptoms. *Sleep Medicine*, *21*, 151-159.

Burns, G. L., Preszler, J., Ahnach, A., Servera, M., & Becker, S. P. (2022). Multisource network and latent variable models of sluggish cognitive tempo, ADHD-inattentive, and depressive symptoms with Spanish children: Equivalent findings and recommendations. *Research on Child and Adolescent Psychopathology*, 1-14.

Camprodon-Rosanas, E., Ribas-Fitó, N., Batlle, S., Persavento, C., Alvarez-Pedrerol, M., Sunyer, J., & Forns, J. (2020). Association between sluggish cognitive tempo symptoms and attentional network and working memory in primary schoolchildren. *Journal of Attention Disorders, 24*(13), 1787-1795.

Caruso, N. C., Radovanovic, B., Kennedy, J. D., Couper, J., Kohler, M., Kavanagh, P. S., . . . Lushington, K. (2014). Sleep, executive functioning and behaviour in children and adolescents with type 1 diabetes. *Sleep Medicine, 15*(12), 1490-1499.

Cellini, N. (2017). Memory consolidation in sleep disorders. *Sleep Medicine Reviews, 35*, 101-112.

Cramer, A. O., Waldorp, L. J., Van Der Maas, H. L., & Borsboom, D. (2010). Comorbidity: A network perspective. *Behavioral and Brain Sciences, 33*(2-3), 137-150.

de Bruin, E. J., Dewald-Kaufmann, J. F., Oort, F. J., Bögels, S. M., & Meijer, A. M. (2015). Differential effects of online insomnia treatment on executive functions in adolescents. *Sleep Medicine, 16*(4), 510-520.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135.

Durmer, J. S., & Dinges, D. F. (2005). *Neurocognitive Consequences of Sleep Deprivation.* Paper presented at the Seminars in neurology.

Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: A tutorial paper. *Behavior Research Methods, 50*(1), 195-212.

Feiz, P., Emamipour, S., Hassani-Abharian, P., & Kooshki, S. (2020). Comparing cup stacking and transcranial direct current stimulation on working memory and processing speed. *Iranian Journal of Learning & Memory, 3*(11), 61-68.

Zhang, M. M., Ma, Y., Du, L. T., Wang, K., Li, Z., Zhu, W. L., ... & Li, S. X. (2022). Sleep disorders and non-sleep circadian disorders predict depression: A systematic review and meta-analysis of longitudinal studies. *Neuroscience & Biobehavioral Reviews*, 104532.

Zhang, L. G., Cheng, L. F., Wang, T. T., Wang, L. L., Zhou, S. J., Luo, Y. H., & Chen, J. X. (2023). Chain mediating effect of insomnia, depression, and anxiety on the relationship between nightmares and cognitive deficits in adolescents. *Journal of Affective Disorders*, *322*, 2-8.

Lindsay, J. A., McGowan, N. M., King, N., Rivera, D., Li, M., Byun, J., ... & Duffy, A. (2022). Psychological predictors of insomnia, anxiety and depression in university students: potential prevention targets. *BJPsych Open*, *8*(3), e86.

Barkley, R. A., Willcutt, E., & Jacobson, L. A. (2022). What is the cognitive deficit in sluggish cognitive tempo (SCT)? A review of neuropsychological research. *The ADHD Report*, *30*(2), 1-10.

Henríquez-Beltrán, M., Zapata-Lamana, R., Ibarra-Mora, J., Sepúlveda-Martin, S., Martinez, L., & Cigarroa, I. (2022). Association between sleep disorders and academic performance: Finding of health survey and academic performance in the Bio-Bio province 2018. *Andes Pediatrica: Revista Chilena de Pediatria*, *93*(2), 235-246.

Fredrick, J. W., & Becker, S. P. (2022). Sluggish Cognitive Tempo (Cognitive Disengagement Syndrome) and academic functioning: A systematic review and agenda for future research. *Clinical Child and Family Psychology Review*, 1-39.

Fredrick, J. W., Yeaman, K. M., Yu, X., Langberg, J. M., & Becker, S. P. (2022). A multi‐method examination of sluggish cognitive tempo in relation to adolescent sleep, daytime sleepiness, and circadian preference. *Journal of Child Psychology and Psychiatry*.

Garner, A. A., Hansen, A., Baxley, C., Becker, S. P., Sidol, C. A., & Beebe, D. W. (2017). Effect of sleep extension on sluggish cognitive tempo symptoms and driving behavior in adolescents with chronic short sleep. *Sleep Medicine, 30*, 93-96.

Goh, P. K., Martel, M. M., & Barkley, R. A. (2020). Clarifying ADHD and sluggish cognitive tempo item relations with impairment: A network analysis. *Journal of Abnormal Child Psychology, 48*(8), 1047-1061.

Hebbar, S., Jose, T. T., & Nayak, S. (2017). Prevalence and the contributing factors of insomnia among adolescents in selected secondary schools of Udupi district Karnataka. *Manipal Journal of Nursing and Health Sciences (MJNHS), 3*(1), 23-28.

Holley, S., Whitney, A., Kirkham, F., Freeman, A., Nelson, L., Whitlingum, G., & Hill, C. (2014). Executive function and sleep problems in childhood epilepsy. *Epilepsy & Behavior*, *37*, 20-25.

Johnson, E. O., Roth, T., Schultz, L., & Breslau, N. (2006). Epidemiology of DSM-IV insomnia in adolescence: lifetime prevalence, chronicity, and an emergent gender difference. *Pediatrics, 117*(2), e247-e256.

Kaneita, Y., Ohida, T., Osaki, Y., Tanihata, T., Minowa, M., Suzuki, K., . . . Hayashi, K. (2006). Insomnia among Japanese adolescents: a nationwide representative survey. *Sleep, 29*(12), 1543-1550.

Kansagra, S. (2020). Sleep disorders in adolescents. *Pediatrics, 145*(Supplement_2), S204-S209.

Kofler, M. J., Irwin, L. N., Sarver, D. E., Fosco, W. D., Miller, C. E., Spiegel, J. A., & Becker, S. P. (2019). What cognitive processes are “sluggish” in sluggish cognitive tempo? *Journal of Consulting and Clinical Psychology, 87*(11), 1030.

Koriakin, T. A., Mahone, E. M., & Jacobson, L. A. (2015). Sleep difficulties are associated with parent report of sluggish cognitive tempo. *Journal of Developmental and Behavioral Pediatrics: JDBP, 36*(9), 717.

Lecendreux, M., & Cortese, S. (2007). Sleep problems associated with ADHD: a review of current therapeutic options and recommendations for the future. *Expert Review of Neurotherapeutics, 7*(12), 1799-1806.

Lima, R. A., de Barros, M. V. G., Dos Santos, M. A. M., Machado, L., Bezerra, J., & Soares, F. C. (2020). The synergic relationship between social anxiety, depressive symptoms, poor sleep quality and body fatness in adolescents. *Journal of Affective Disorders, 260*, 200-205.

Liu, X., Zhao, Z., Jia, C., & Buysse, D. J. (2008). Sleep patterns and problems among Chinese adolescents. *Pediatrics, 121*(6), 1165-1173.

Lyons Usher, A. M., Leon, S. C., Stanford, L. D., Holmbeck, G. N., & Bryant, F. B. (2016). Confirmatory factor analysis of the Behavior Rating Inventory of Executive Functioning (BRIEF) in children and adolescents with ADHD. *Child Neuropsychology, 22*(8), 907-918.

McBurnett, K., Villodas, M., Burns, G. L., Hinshaw, S. P., Beaulieu, A., & Pfiffner, L. J. (2014). Structure and validity of sluggish cognitive tempo using an expanded item pool in children with attention-deficit/hyperactivity disorder. *Journal of Abnormal Child Psychology, 42*(1), 37-48.

Milich, R., Balentine, A. C., & Lynam, D. R. (2001). ADHD combined type and ADHD predominantly inattentive type are distinct and unrelated disorders. *Clinical Psychology: Science and Practice, 8*(4), 463.

Owens, J., Group, A. S. W., Adolescence, C. o., Au, R., Carskadon, M., Millman, R., . . . Breuner, C. C. (2014). Insufficient sleep in adolescents and young adults: an update on causes and consequences. *Pediatrics, 134*(3), e921-e932.

Richardson, C., Oar, E., Fardouly, J., Magson, N., Johnco, C., Forbes, M., & Rapee, R. (2019). The moderating role of sleep in the relationship between social isolation and internalising problems in early adolescence. *Child Psychiatry and Human Development, 50*(6), 1011-1020.

Roberts, R. E., Roberts, C. R., & Chen, I. G. (2001). Functioning of adolescents with symptoms of disturbed sleep. *Journal of Youth and Adolescence, 30*(1), 1-18.

Roberts, R. E., Roberts, C. R., & Duong, H. T. (2008). Chronic insomnia and its negative consequences for health and functioning of adolescents: a 12-month prospective study. *Journal of Adolescent Health, 42*(3), 294-302.

Short, M. A., Gradisar, M., Gill, J., & Camfferman, D. (2013). Identifying adolescent sleep problems. *PLoS One, 8*(9), e75301.

Smith, Z. R., Eadeh, H.-M., Breaux, R. P., & Langberg, J. M. (2019). Sleepy, sluggish, worried, or down? The distinction between self-reported sluggish cognitive tempo, daytime sleepiness, and internalizing symptoms in youth with attention-deficit/hyperactivity disorder. *Psychological Assessment, 31*(3), 365.

Stabouli, S., Gidaris, D., Printza, N., Dotis, J., Papadimitriou, E., Chrysaidou, K., . . . Zafeiriou, D. (2019). Sleep disorders and executive function in children and adolescents with chronic kidney disease. *Sleep Medicine, 55*, 33-39.

Stormark, K. M., Fosse, H. E., Pallesen, S., & Hysing, M. (2019). The association between sleep problems and academic performance in primary school-aged children: Findings from a Norwegian longitudinal population-based study. *PLoS One, 14*(11), e0224139.

Strait, J. E., Dawson, P., Walther, C. A., Strait, G. G., Barton, A. K., & Brunson McClain, M. (2020). Refinement and psychometric evaluation of the executive skills questionnaire-revised. *Contemporary School Psychology, 24*, 378-388.

Tomaso, C. C., Nelson, J. M., Espy, K. A., & Nelson, T. D. (2020). Associations between different components of executive control in childhood and sleep problems in early adolescence: A longitudinal study. *Journal of Health Psychology, 25*(13-14), 2440-2452.

Van Dyk, T. R., Becker, S. P., & Byars, K. C. (2019). Rates of mental health symptoms and associations with self-reported sleep quality and sleep hygiene in adolescents presenting for insomnia treatment. *Journal of Clinical Sleep Medicine, 15*(10), 1433-1442.

Wennberg, A., Lorusso, R., Dassie, F., Benavides-Varela, S., Parolin, M., De Carlo, E., . . . Semenza, C. (2019). Sleep disorders and cognitive dysfunction in acromegaly. *Endocrine, 66*(3), 634-641.

Yang, C.-M., Wu, C.-H., Hsieh, M.-H., Liu, M.-H., & Lu, F.-H. (2003). Coping with sleep disturbances among young adults: a survey of first-year college students in Taiwan. *Behavioral Medicine, 29*(3), 133-138.

Grau-Rivera, O., Operto, G., Falcón, C., Sánchez-Benavides, G., Cacciaglia, R., Brugulat-Serrat, A., ... &

Molinuevo, J. L. (2020). Association between insomnia and cognitive performance, gray matter volume, and white matter microstructure in cognitively unimpaired adults. *Alzheimer's Research & Therapy*, *12*, 1-14.

Wardle-Pinkston, S., Slavish, D. C., & Taylor, D. J. (2019). Insomnia and cognitive performance: A systematic review and meta-analysis. *Sleep Medicine Reviews*, *48*, 101205.

Venus, K. (2019). *Sleep quality and executive function: Does emotion regulation and stress mediate this relationship in college students?* Doctoral dissertation, California State University Dominguez Hills.