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REVIEW

Efficacy of Mindfulness-Based Interventions for Attention and Executive Function in Children and Adolescents—a Systematic Review

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Abstract The purpose of this study was to evaluate the efficacy of mindfulness-based interventions including mindful movements such as yoga on attention and executive function in children and adolescents. Systematic searches were conducted on five databases (PubMed, PsycINFO, CINAHL, Web of Science, and Scopus). Included studies consisting of randomized or quasi-randomized controlled trials with a mindfulness-based intervention were assessed for quality, and relevant data was extracted and collated. Thirteen randomized control trials were identified as meeting inclusion criteria, including mindfulness-based psychological interventions (n = 7), yoga (n = 3), and traditional meditation techniques (n = 2). Studies recruited adolescents or children that were typically developing, diagnosed with attention-deficit hyperactivity disorder, orphans, or had reading difficulties, or in correctional schools/institutions. The quality of the 13 studies ranged from low to high based on the PEDro (Physiotherapy Evidence Database) scale with the average score of 6.62 out of the highest possible score of 11 (the higher the score, the higher the quality). Five of the 13 studies found a statistically significant intervention effect for at least one outcome measure of attention or executive function with medium to large effect sizes (0.3–32.03). Mindfulness-based interventions are a promising approach to targeting attention and executive function in children and adolescence, especially with the use of computerized measures as outcome measures. All identified studies included interventions with multiple treatment components, so the effects attributable to mindfulness-based training still remain undetermined. Further quality trials are needed to assess the effectiveness of mindfulness-based interventions in enhancing attention and executive function in children and adolescents.

Keywords Mindfulness · Yoga · Meditation · Attention · Executive function · Children · Adolescence

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Introduction

Mindfulness is the deliberate awareness of the present moment without judgment (Kabat-Zinn 2003). Mindfulness meditations involve selecting a point of focus, such as the breath, or a physical action such as raising and lowering arms, and regulating and directing attention to that point with sustained focused attention (Bishop et al. 2004). If the mind wanders from the point of focus, then mindfulness involves acknowledging the thought or feeling that arises, inhibiting rumination, and switching attention back to the point of focus (Bishop et al. 2004). When mindfulness is the foundation of a movement-based practice, such as Hatha Yoga, and emphasis is placed on interoceptive, proprioceptive, and kinesthetic aspects of the experience in addition to the mindfulness aspects, this kind of mindful movement practices encourages an embodied experience of the self as well (Schmalzl et al. 2014).

Several investigators have proposed theoretical accounts of how the practice of mindfulness can enhance and develop

attention regulation (Bishop et al. 2004; Lutz et al. 2008). They proposed four types of attention regulation involved in mindfulness: sustained attention on the present moment (i.e., by focusing on a target object), monitoring the present moment (i.e., detect mind wandering), executive function abilities such as attentional switching (i.e., disengage from a distracting object/thought without further involvement), and selective attention (i.e., ability to redirect focus promptly back to the target object).

Attention and executive function (EF) underlies most behavior from childhood onward (Douglas 1972; Tannock and Schachar 1996). Attention is a cognitive ability that regulates the amount of information we take in and acts as a "spotlight" (Cohen 2014). It is related to most cognitive and neuropsychological functions in our everyday life (Cohen 2014), such as EF processes. EF is an umbrella term for cognitive processes such as self-control (inhibition), decision-making, goal setting, planning, problem solving, emotional responses, and behavior (Lezak 2012).

Attention and EF is required to perform everyday activities. Deficits in attention or EF are likely to influence a child's behavior, self-regulation, and academic abilities (Carver and Scheier 2012). Such disruption in attention is often associated with behavioral characteristics of childhood neurodevelopmental disorders including cerebral palsy (Bax et al. 2005), attention-deficit hyperactivity disorder (ADHD) (Brocki and Bohlin 2006), autism spectrum disorders (Joseph et al. 2005), and behavioral problems such as bullying and delinquency (Hughes et al. 2000). The growing body of research demonstrating concurrent and longitudinal associations between deficits in attention, socio-emotional development, and academic performance is indicative of the importance of attention and its impact across different areas of development (Blair and Razza 2007; Hughes et al. 2001; Riggs et al. 2004).

Chiesa et al. (2011) conducted a systematic review of the efficacy of mindfulness training on cognitive abilities in adults. The review identified 23 studies, including 15 RCTs or controlled trials (CT) and 8 case-control studies. Their results provide preliminary evidence that mindfulness-based practices can enhance attention and working memory capacity, although limitations in the quality of the existing research are noted. Systematic literature reviews with the pediatric literature have noted that yoga is a promising intervention for physical rehabilitation (Galantino et al. 2008); physical fitness; cardiorespiratory effects; motor skills/strength; mental health and psychological disorders, behaviors, and development; and irritable bowel syndrome (Birdee et al. 2009). Yet, a systematic literature review focusing on attention has not been conducted in the pediatric population.

The first aim is to review the current literature on mindfulness-based interventions for attention and EF in children and adolescents. The second aim is to examine mindfulness outcomes within the included studies.

Method

Search Strategy

The following databases were searched: PubMed, PsycINFO, CINAHL, Web of Science, and Scopus from 1972 to 2016 were comprehensively searched. The search strategy comprised the following MeSH headings or Keywords: Yoga OR mindfulness OR "mindful awareness" OR meditation AND; Child OR children OR adolescence OR adolescent OR paediatric OR pediatric AND; Cognition OR attention OR cognitive function OR executive function. Studies were downloaded into Endnote 15, and duplicates were deleted. Studies were identified by title and abstract and screened by the authors to assess whether they met the selection criteria set out below. The reference lists of relevant systematic reviews were screened for additional references, with snowballing used to ensure that all relevant papers were identified.

Inclusion Criteria

Studies were included in this systematic review if they were randomized controlled trials and quasi-randomized controlled trials (e.g., randomization by group); interventions with a focus on yoga, meditation, and/or mindfulness-based techniques; yoga interventions which incorporated asana (yoga postures) or pranayama (yogic breathing) or yoga nidra (yogic relaxation) and/or meditation for the children or adolescents; mindfulness-based interventions which included mindfulness meditations and/or other mindfulness exercises, such as mindful eating, mindful walking, or Tai Chi; and if study participants were children/adolescents aged between 5 and 18 years old. Studies were required to have attention or executive function as an outcome measure; yoga and/or mindfulness interventions that incorporated other modalities, such as interactive discourse and non-specified relaxation techniques, were included; and dissertations were included.

Consequently, studies were excluded if they did not provide at least one adequate measure of child attention or executive function outcome, such as if study only measured overall child ADHD symptoms without examining attention specifically. Papers outside the peer-reviewed literature that were not dissertations were also excluded.

The full search yield was initially reviewed for inclusion by two independent reviewers (first and second author) on the basis of title and abstract. We contacted the first authors of two non-English papers (Bueno and Delgado 2015; Haffner et al. 2006) to ask if they have an available English translation. One author (Haffner et al. 2006) sent an English-translated version of their paper, and the other author (Bueno and Delgado 2015) offered to translate their Spanish paper into English; however, after a brief discussion, it became clear that the paper did not fit our inclusion criteria. Both reviewers then

assessed the full text of the remaining articles for adherence to the inclusion criteria, and discrepancies were resolved by discussion. We also contacted the first authors of four of the included studies for additional data and details of their studies. One author replied with the additional information required (Semple et al. 2010), while three authors unfortunately could not be contacted (Kratter 1983; Leonard et al. 2013; Verma et al. 1982).

Methodological Quality Assessment

Methodological quality of included studies was assessed using the Physiotherapy Evidence Database (PEDro) Scale. The studies were assessed by first and second authors independently. Discrepancies were resolved through discussion.

Assessment of Risk of Bias

The risk of bias of the included studies was assessed using the Cochrane Collaboration's tool (Higgins and Green 2008). The tool looks at the six domains of bias. These domains include selection bias (whether sequence adequately generated and allocation adequately concealed prior to assignment), performance bias (was there blinding of participants and personnel or was the knowledge of group/intervention allocation by participants and personnel during the study adequately prevented?), detection bias (was there blinding of outcome assessors or was the knowledge of group/intervention allocation by outcome assessors adequately prevented?), attrition bias (were amount and nature of handling of incomplete outcome data adequately addressed?), reporting bias (was report of the study free of suggestion of selective outcome reporting?), and other bias (was the study free of other problems not covered above that could put it at a high risk of bias?).

First and second authors independently made judgments for each of the domains but selecting "low risk," "high risk," or "unclear risk" of bias. Unclear risk of bias was selected when insufficient detail was reported or the risk of bias was unknown. Discrepancies were resolved through discussion. The risk of bias of the included studies is presented in the risk of bias graph (Fig. 1) and risk of bias table (Fig. 2).

Data Extraction

Data extracted from each study included study design, participant characteristics, intervention characteristics, and the attention and/or executive outcome measures and mindfulness measures. The first author extracted and tabulated the relevant data from the studies, and any queries were clarified with the second author.

Data Synthesis

Relevant quantitative outcome data from each study were analyzed to determine a measure of intervention effect size. The reported means, standard deviations, and sample size for control and treatment groups at post-intervention time point were used to calculate a *t* test value using Hedges' g, as illustrated in the equation below (mean difference/pooled standard deviation), and to determine if there was a significant difference between the groups after the intervention. Based on the guidelines suggested by Cohen (1992), effect sizes were classified as small (0.2), medium (0.5), or large (0.8).

$$\frac{M_{postT} - M_{postC}}{\sqrt{\left(\mathrm{SD}_{postT^2}(n_T - 1) + \mathrm{SD}_{postC^2}(n_C - 1)\right) \Big/ (n_T + n_C - 2)}}$$

The authors intended to conduct a meta-analysis on the collated outcome data using RevMan 5.0. Due to the substantial variation in the population, the measures used, and the outcomes assessed in the included studies, however, only a small meta-analysis with two studies were conducted.

Results

Descriptions of Studies

A total of 1034 articles were identified from the databases (see Fig. 3) using the search strategy described above. Two additional references found from the identified systematic reviews were included. Three hundred sixty-one duplicated articles

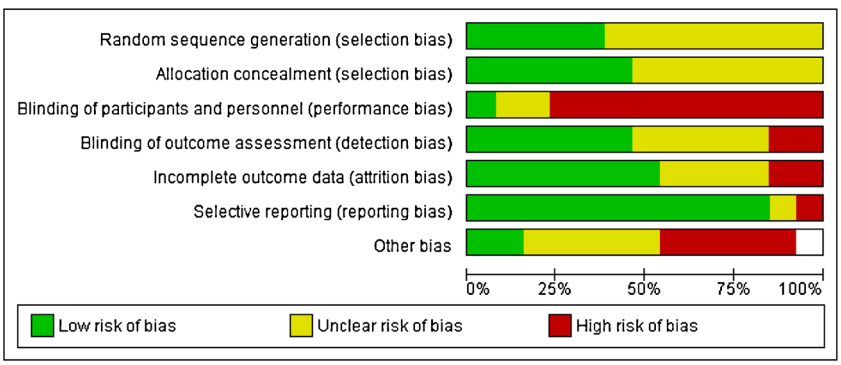

Fig. 1 Risk of bias graph across included studies

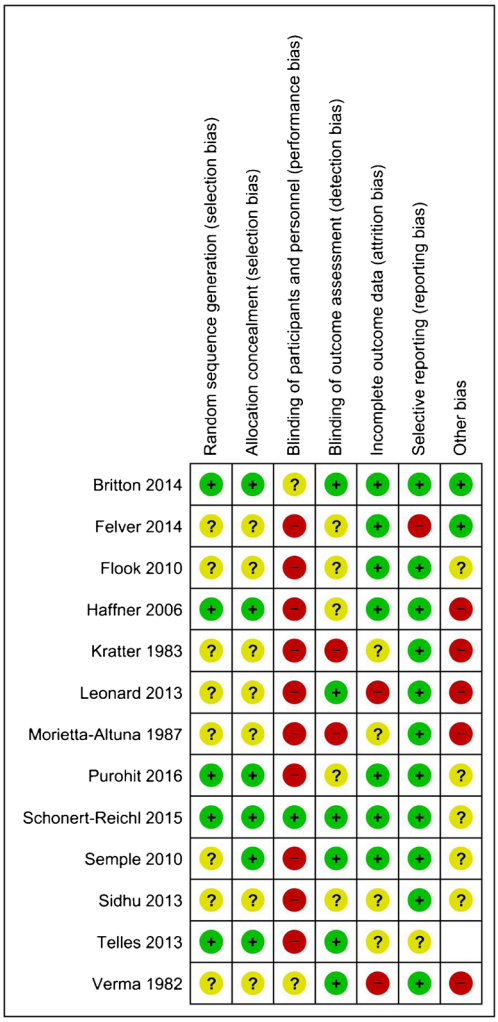

Fig. 2 Risk of bias summary for all included studies

were excluded, and 673 articles were screened by title and abstract. Of these, 651 articles were excluded, as they clearly did not meet the inclusion criteria. A total of 22 papers were retrieved to consider in further detail, of which 13 met inclusion criteria.

Settings

Eight of the 13 studies included in this review were carried out in the USA (Britton et al. 2014; Felver et al. 2014; Flook et al. 2010; Kratter 1983; Leonard et al. 2013; Moretti-Altuna 1987; Semple et al. 2010; Sidhu 2013). Five of these studies were part of a dissertation (Felver et al. 2014; Kratter 1983; Moretti-Altuna 1987; Semple et al. 2010; Sidhu 2013). Two studies were carried out in India (Telles et al. 2013; Verma et al. 1982), one in Germany (Haffner et al. 2006), and one in Canada (Schonert-Reichl et al. 2015).

Nine of the 13 included studies were published between 2010 and 2016 (Britton et al. 2014; Felver et al. 2014; Flook et al. 2010; Leonard et al. 2013; Purohit and Pradhan 2016; Schonert-Reichl et al. 2015; Semple et al. 2010; Sidhu 2013; Telles et al. 2013), while one study was published in 2006 (Haffner et al. 2006), and three studies were published between 1982 and 1987 (Kratter 1983; Moretti-Altuna 1987; Verma et al. 1982).

Participants

As detailed in Table 1, the age and population varied across the studies. For the purpose of this review, only the data for the non-treatment control group and the treatment mindfulness-based intervention group of the included studies were included. The data for other available comparison groups such as medication (Moretti-Altuna 1987) or relaxation (Kratter 1983) comparison groups were not included.

Ten studies consisted of children (ranged between 7 and 12 years). Five of these studies recruited typically developing children (Britton et al. 2014; Felver et al. 2014; Flook et al. 2010; Schonert-Reichl et al. 2015; Telles et al. 2013), while four of the studies recruited children with ADHD (Haffner et al. 2006; Kratter 1983; Moretti-Altuna 1987; Sidhu 2013) and one recruited children with reading difficulties (Semple et al. 2010). Three studies recruited adolescents (ranged between 11 and 18 years), and of these three studies, one recruited adolescents in correctional schools (Verma et al. 1982), another study recruited incarcerated adolescents (Leonard et al. 2013), and the third study recruited adolescent orphans (Purohit and Pradhan 2016).

The first author for one of the included studies could not be contacted when more information on their study was requested (Kratter 1983). As a consequence, the missing information, number of participants per group, was listed as unknown.

Types of Intervention

Three categories of mindfulness-based interventions were identified: yoga intervention (Haffner et al. 2006; Purohit and Pradhan 2016; Telles et al. 2013), mindfulness-based psychological interventions (Britton et al. 2014; Felver et al. 2014; Flook et al. 2010; Leonard et al. 2013; Schonert-Reichl et al. 2015; Semple et al. 2010; Sidhu 2013), and traditional meditation training (Kratter 1983; Moretti-Altuna 1987; Verma et al. 1982) (see Table 1).

All interventions included a component of body-awareness training (i.e., observing the breath), although in some interventions, this was not the primary focus. Interventions were delivered in a variety of ways across the studies, but not all the studies reported how the interventions were delivered or who delivered them. Of those that reported this information, two studies reported that the intervention was delivered by people trained specifically in the study's intervention techniques (Felver et al. 2014; Telles et al. 2013), one delivered by clinicians trained in mindfulness training and cognitive behavior

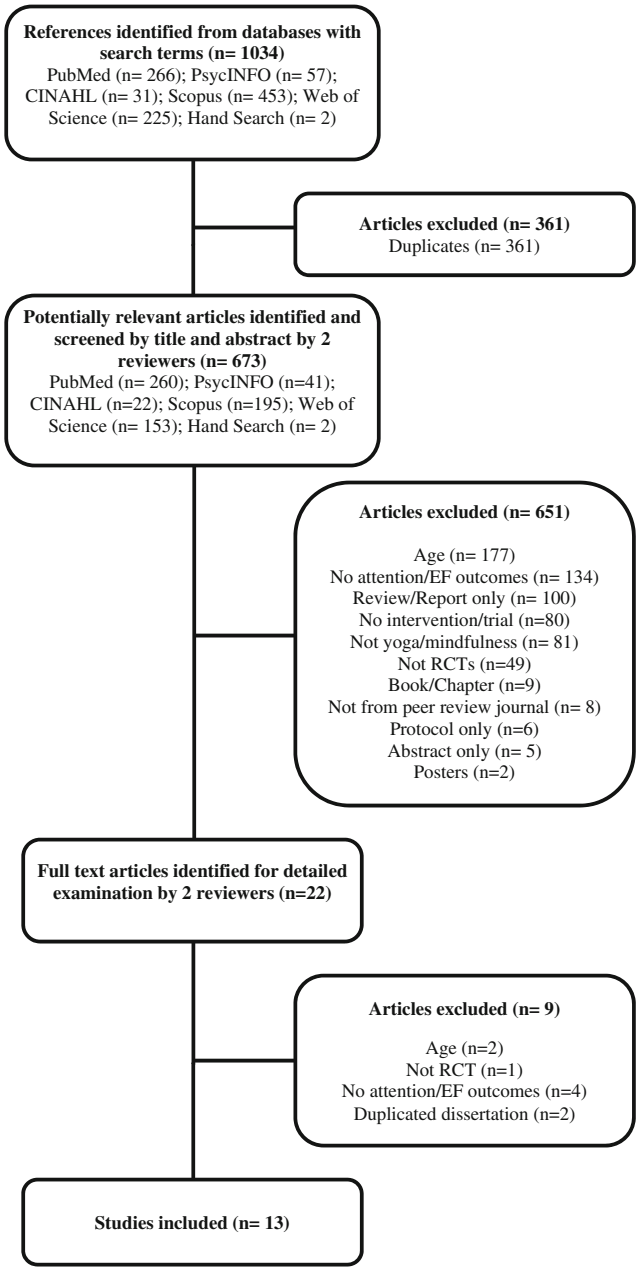

Fig. 3 Flow chart of article screening—included and excluded studies

therapy (Leonard et al. 2013), and another by researchers (Sidhu 2013), while one reported that the superintendent of the correctional centers delivered the intervention (Verma et al. 1982), and two studies reported that school teachers delivered the intervention (Britton et al. 2014; Schonert-Reichl et al. 2015). Two of the 13 studies invited parents to participate in the mindfulness intervention with their children; one of these studies allowed the parent to join their children after two parent-only sessions (Semple et al. 2010) and the other study invited the parents to attend the sessions with the children straight away, but each session consisted of a period of time where parents and children participated separately (Felver et al. 2014).

The duration, intensity, and dosage of the interventions varied across the 13 studies. Duration of interventions ranged widely from 3 to 24 weeks, while the dosage also ranged widely from 135 to 4320 min. It should be noted that the dosage of one of the studies could not be calculated because the duration of each session was unknown (Verma et al. 1982).

Measures

A range of measures were used across the studies to measure attention and EF as detailed in Table 2. Some of the measures were self-report questionnaires from the perspective of the child/adolescent, parent, or teacher, while other measures

Table 1 Sample characteristics and experimental design of included studies

Study	Methods	Intervention	Control	Criteria	Age Range (years)	Male n (% of total n)	Duration/Intensity	Dosage (minutes)	Attention/EF Measure	Treatment n	Control/ Waitlist n
Britton et al. 2014	Quasi RCT – Groups	MBPI	Ancient African History Class		11-12	55 (54)	2 x 60 min session per week for 8 weeks	960	YSR	52	48
Felver et al. 2014	RCT	MBPI	Waitlist Control	Parent-child dyad	9-12	20 (43)	90min per week; 15-20mins daily home practice for 8 weeks	1440-1640	ANT*	22	19
Flook et al. 2010	Quasi RCT - Groups	MBPI	Silent Reading		7–9	29 (45)	2 x 30 min per week for 8 weeks	480	BRIEF	32	32
Haffner et al. 2006	RCT	Yoga	Motor training exercises	ADHD	8-11	13 (65)	2 x 60 min session per week for 8 weeks	960	1) FBB-HKS* 2) DAT*	8	11
Kratter 1983	RCT – Stratified	Traditional Meditation	Waitlist Control	ADHD	7-11	24 (100)	2x/week; sessions increased from 2min to 8min by the end of 4-week; Practiced 3x/week at home for 4 weeks	100 (approx)	FDT	unknown	unknown
Leonard et al. 2013	Quasi RCT - Groups	MBPI	Cognitive-perception intervention	Incarcerated	16-18	201 (100)	75 mins x 2-3/week for 3-5 weeks	750 (approx)	ANT*	114	87
Moretti-Altuna 1987	RCT	Meditation	Standard Therapy	ADHD	6-10	23 (100)	30min x 2/week; Meditation duration gradually increased from 1min to 8min by the end of 4-week; Practiced at least 3x/week at home for 4 weeks.	240 (approx)	FDT	9	8
Purohit 2016	RCT	Yoga	Waitlist Control	Orphans	11-16	45 (63)	90min x 4/week for 12 weeks	4320	1) Stroop 2) DSST 3) TMT*	40	32
Schonert-Reichl 2015	Quasi RCT – Groups	MBPI	Social responsibility program		9-11	55 (56)	40-50min/week + 3mins Mindfulness practice 5 days/week for 12 weeks	660-780	1) Flanker Task 2) Heart and Flowers Task	48	51
Semple et al. 2010	RCT	MBPI	Waitlist Control	Parent-child dyad; Children with difficulties reading	9-13	10 (40)	90 min session per week for 12 weeks	1080	CBCL	13	12
Sidhu 2013	RCT	MBPI	Puzzle, Lego or Block stacking games	ADHD	7-12	13 (45)	45 mins x 2/week for 4 weeks	360	1) CPRS 2) BASC-2 3) TOVA*	15	14
Telles et al. 2013	RCT	Yoga	Physical exercise		8-13	60 (61)	45mins x 5 days/week for 12 weeks	2700	1) Stroop 2) Teacher's Rating on Attention	43	43
Verma et al. 1982	RCT - Stratified	Traditional Meditation	Control	Correctional School	12-18	50 (100)	2 sessions per day for 24 weeks = 336 session in total	NA	Cancellation of number 9	23	15
Total included										419	372

n: Number of participants, EF: Executive Function, RCT: Randomized Controlled Trial, MBPI: Mindfulness-based Psychological Intervention, ADHD: Attention deficit hyperactivity disorder, YSR: Youth Self Report Scale, ANT: Attention Network Task, BRIEF: Behavior Rating Inventory of Executive Function, FBB-HKS: Fremdbeurteilungsbogen für hyperkinetische Störungen, DAT: Dortmund Attention Test, FDT: Fruit Distraction Test, DSST: Digit Symbol Substitution Test, TMT: Trail Making Test, CBCL: Child Behavior Checklist, CPRS-R:L: Conners' Parent Rating Scale –Revised: Long, BASC-2: Behavior Assessment System for Children, TOVA: Test of Variables of Attention; * at least one measure variable found significant intervention effect

Table 2 Attention and executive function measures used in the studies reviewed

Studies	Computerised Measures				Pen-Paper Assessment Measures						Parent Report					Teacher Report		Self-Report
	Attention		EF		Attention		EF				Attention/Inattention subscales				EF	Attention/Inattention subscales	EF	Attention
	ANT	TOVA	Flanker	HFT	DAT	C9	Stroop Test	FDT	TMT	DSST	CBCL	CPRS-R:L	BASC-2	FBB-HKS	BRIEF	Teachers' Analogue rating	BRIEF	YSR
Britton et al. 2014																		✓
Felver et al. 2014	✓*																	
Flook et al. 2010															✓		✓	
Haffner et al. 2006					✓*									✓*				
Kratter 1983								✓										
Leonard et al. 2013	✓*																	
Morietta-Altuna 1987								✓										
Purohit 2016							✓		✓*	✓								
Schonert-Reichl et al. 2015			✓	✓														
Semple et al. 2010											✓							
Sidhu 2013		✓*										✓	✓					
Telles et al. 2013							✓									✓		
Verma et al. 1982						✓												

EF: Executive Function; ANT: Attention Network Task, TOVA: Test of Variables of Attention, HFT: Hearts and Flowers Test; C9: Cancellation of number 9; FDT: Fruit Distraction Test, TMT: Trail Making Test, DSST: Digit Symbol Substitution Test, DAT: Dortmund Attention Test, YSR: Youth Self Report Scale, CBCL: Child Behavior Checklist, CPRS-R:L: Conners' Parent Rating Scale –Revised: Long, BASC-2: Behavior Assessment System for Children, FBB-HKS: Fremdbeurteilungsbogen für hyperkinetische Störungen, BRIEF: Behavior Rating Inventory of Executive Function; * at least one measure variable found significant intervention effect.

were objective neuropsychological assessments such as computer-orientated tasks or pen-paper task that assess particular aspects of attention or EF. Within the 13 studies, 21 different measures of attention and EF were used (see Appendix for a description of the measures by the included studies). The Attention Network Task (ANT), the Stroop Test, and the Fruit Distraction Test (FDT) were the only attention and EF measures used more than once across the 13 studies. The ANT is a computer task used to measure attention, and it was used in two studies (Felver et al. 2014; Leonard et al. 2013); however, a meta-analysis could not be conducted on the data from these two studies because the data could not be pooled together. This is because one of the studies reported a mean and standard deviation for each of the ANT subsystems (Felver et al. 2014), while the other study reported an overall mean and standard error across the three subsystems (Leonard et al. 2013). In addition, the population of the two studies were too diverse; one population consisted of healthy children between 9 and 12 years (Felver et al. 2014), and the other population consisted of incarcerated youths between 16 and 18 years old (Leonard et al. 2013). The Stroop Test, a color-word naming task used to measure EF, was also used in two studies (Purohit and Pradhan 2016; Telles et al. 2013), and a small meta-analysis was conducted using the pooled Stroop Test data from these two studies. The findings of the meta-analyses are reported under the "Findings of Studies" section of this paper. Finally, the FDT was another EF test that was used in two studies (Kratter 1983; Moretti-Altuna 1987). A meta-analysis could not be conducted, however, because the number of participants in each group in the analysis was not reported in one of the studies (Kratter 1983).

Computerized Measures

Apart from the ANT mentioned above, there were three other different computer tasks used by two studies to measure attention and EF in children and adolescents. One study (Sidhu 2013) used the Test of Variables of Attention (TOVA), a continuous performance task used to measure attention, while another study (Schonert-Reichl et al. 2015) used the computerized Flanker task and the Hearts and Flowers task to measure EF.

Pen-Paper Assessment Measures

As mentioned before, two studies used the Stroop test and two other studies used the Fruit Distraction Test to measure EF. Four other paper-and-pencil assessment tasks were used to measure attention and EF. These tasks were the Dortmund Attention Test (Haffner et al. 2006), Cancellation of number 9 (Verma et al. 1982), the Trail Making Test (Purohit and Pradhan 2016), and the Digit Symbol Substitution Test (Purohit and Pradhan 2016).

Self-Report or Parent/Teacher Report Questionnaires

Six of the 13 included studies used questionnaires to measured attention or EF outcomes. They were either measured directly by the questionnaires or the questionnaires consisted of an attention or EF subscale. One of these six studies used the Youth Self-Report Scale with an attention problem subscale (Britton et al. 2014); another study used the Teacher and Parent report versions of the Behavior Rating Inventory of Executive Function (BRIEF) (Flook et al. 2010). Parent versions of the Child Behavior Checklist—Attention Problem Subscale (CBCL) (Semple et al. 2010) and the FBB-HKS (Fremdbeurteilungsbogen für Hyperkinetische Störungen; Brühl et al. 2000), a rating scale for ADHD symptoms (Haffner et al. 2006), were used to measure attention problems or deficits in children. One study used an analog scale of the teachers' rating of children's attention (Telles et al. 2013). Finally, one study used both the Cognitive Problems/Inattention subscale of the Conners' Parent Rating Scale-Revised: Long (CPRS-R:L) and the Attention Problem Scale of the Behavior Assessment System for Children (BASC-2) to measure outcome of attention (Sidhu 2013).

Although some studies reported additional variables such as clinical symptom conditions such as depression, anxiety, conduct disorder, and oppositional defiant disorder (Britton et al. 2014; Semple et al. 2010), emotional and child behavior (Britton et al. 2014; Semple et al. 2010; Sidhu 2013), self-esteem (Telles et al. 2013), child's impulsivity and hyperactivity (Kratter 1983; Moretti-Altuna 1987), overall ADHD symptoms (Kratter 1983; Moretti-Altuna 1987; Sidhu 2013), physical activity levels (Kratter 1983; Moretti-Altuna 1987; Telles et al. 2013), other cognitive function (Moretti-Altuna 1987; Verma et al. 1982), academic performance (Schonert-Reichl et al. 2015; Telles et al. 2013), physiological measurements (Schonert-Reichl et al. 2015), and general well-being (Schonert-Reichl et al. 2015), these were considered beyond the scope of this review and therefore were not reported.

Quality Assessment

Thirteen studies scored between 4 and 9 points out of a total of 11 points on the PEDro Scale (Table 3), with an average score of 6.62. This suggests that the included studies consisted of moderate methodological quality. There were two of the 11 potential points for methodological strengths that were impractical to obtain in an RCT of a mindfulness-based intervention, where only one study reported the masking of participants to treatment (Schonert-Reichl et al. 2015) and only one study reported masking of therapists to treatment allocation (Purohit and Pradhan 2016).

Table 3 Methodological quality assessment of included studies—PEDro Scale

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Britton et al. 2014	1	1	1	1	0	0	1	1	1	1	1	9
Felver et al. 2014	1	1	0	1	0	0	0	1	1	1	1	7
Flook et al. 2010	0	1	0	1	0	0	0	1	1	1	1	6
Haffner et al. 2006	1	1	0	1	0	0	0	0	0	1	1	5
Kratter 1983	1	1	0	1	0	0	0	0	0	1	1	5
Leonard et al. 2013	1	1	0	1	0	0	1	0	0	1	1	6
Morietta-Altuna 1987	1	1	0	1	0	0	0	0	0	1	1	5
Purohit 2016	1	1	1	1	0	1	1	1	0	1	1	9
Schonert-Reichl 2015	0	1	1	1	1	0	1	1	0	1	1	8
Semple et al. 2010	1	1	0	1	0	0	1	1	1	1	1	8
Sidhu 2013	1	1	0	1	0	0	0	1	0	1	1	6
Telles et al. 2013	1	1	1	1	0	0	0	1	1	1	1	8
Verma et al. 1982	0	0	0	1	0	0	1	0	0	1	1	4

Scale of item score 0 = absent/unclear, 1 = present. The PEDro scale criteria are: (1) specification of eligibility criteria; (2) random allocation; (3) concealed allocation; (4) prognostic similarity at baseline; (5) subject blinding; (6) therapist blinding; (7) assessor blinding; (8) greater than 85% follow-up of at least one key outcome; (9) intention to treat analysis; (10) between group statistical comparison for at least one key outcome; (11) point estimates and measures of variability provided for at least one key outcome.

Findings of Studies

Data for child and adolescent attention or EF outcomes for each study were tabulated in Table 4. The effect sizes reported in Table 4 are those calculated specifically for this review. Based on this review's effect size calculations, five of the 13 studies found at least one significant intervention effect for attention or EF with medium to large effect sizes (0.3–32.03) (Felver et al. 2014; Haffner et al. 2006; Leonard et al. 2013; Purohit and Pradhan 2016; Sidhu 2013). Eight studies did not find significant intervention effects (Bogels et al. 2008; Britton et al. 2014; Flook et al. 2010; Jensen and Kenny 2004; Kratter 1983; Moretti-Altuna 1987; Schonert-Reichl et al. 2015; Semple et al. 2010; Telles et al. 2013; Verma et al. 1982, Verma et al. 1982) based on our effect size analysis.

The five studies that found an intervention effect provided data for a total of 28 outcome variables of attention or EF, of which 11 showed significant intervention effects. To determine if these significant intervention effects were clinically significant, the mean differences between groups were inspected and if the mean differences between groups were larger than the pooled standard deviation for that measure, then it was considered as clinically significant (Kendall and Sheldrick 2000).

Seven of these 11 significant outcome variables were from computerized measures, namely, the Attention Network Test (ANT; Felver et al. 2014) and the Test of Variable of Attention (TOVA; Sidhu 2013). The significant ANT variables were specifically conflict monitoring (Felver et al. 2014) as well as the overall accuracy and intra-individual coefficient of variation (Leonard et al. 2013). Three out of the 11 variables were from objective measures such as pen-pencil tests which consisted of the Trail Making Test A and B (Purohit and Pradhan 2016) and the Dortmund Attention Test (DAT; Haffner et al. 2006). The remaining one other significant outcome variable was the attention deficit symptoms subscale from the subjective measure FBB-HKS (Haffner et al. 2006).

Two of the 13 included studies had data that was able to be pooled into the a meta-analysis investigating effects of Yoga on EF outcome as measured by the Stroop test (Purohit and Pradhan 2016; Telles et al. 2013) (see Fig. 4). The meta-analysis did not reveal a significant treatment effect for the Word condition (95% CI −0.36 to 0.27; $p = 0.78$), the Color condition (95% CI −0.44 to 0.19; $p = 0.43$), or the Color-Word condition (95% CI −0.48 to 0.15; $p = 0.30$) from the Stroop test.

Out of the 13 studies included in this review, only two studies reported using a Mindfulness outcome measure, namely, the Cognitive and Affective Mindfulness Scale Revised (CAMS-R; Britton et al. 2014) and the Mindful Attention Awareness Scale for Children (MAAS-C; Schonert-Reichl et al. 2015). Only one of these studies found a significant intervention effect for Mindfulness, but it also found no intervention effect for attention or EF (Schonert-Reichl et al. 2015). Mindfulness outcomes of the included studies were tabulated in Table 5.

Exploring Study Characteristics

The characteristics of the included studies were inspected visually to see if there were any observable patterns or relationships between study characteristics and the results found from the analysis and effect size calculations performed in this review. Visual inspections did not find any obvious patterns or relationships between study characteristics and findings. Further statistical analyses were conducted to explore this in more detail. A chi-square analysis revealed that there were no relationships between the type of interventions, namely, Mindfulness-Based Psychological Intervention, Yoga and Traditional Meditation, and significant findings χ^2 (2, $N = 13$) = 2.94, $p = .23$. The relationships between the types of variable, namely, attention vs EF outcomes, was marginally significant, χ^2 (1, $N = 21$) = 3.23, $p = .072$; the relationship was trending towards attention outcomes and significant findings.

Other study characteristics explored included the total dosage time of the intervention, the total number of participants, and the study's methodology quality score on the PEDro. In studies where the dosage time was a range, the average time

Table 4 Included studies' effect sizes for attention and executive function

Study	Age (years)	Assessment Measure	Treatment		Control		*p* value	Effect Size, *d* (95% CI)	Direction effect favours
			n	Mean (SD)	n	Mean (SD)	MD		
Britton et al. 2014	11-12	YSR - Attention Problems subscale	52	3.8 (2.6)	48	3.5 (2.8)	0.58	0.11 (-0.28, 0.50)	Control
Felver et al. 2014	9-12	Attention Network Test (ANT) –Conflict Monitoring	22	77 (42.0)	19	111 (44.0)	**0.02**	-0.79 (-1.41, -0.14)	Treatment
		Attention Network Test (ANT) – Orienting	22	20 (55.0)	19	52 (33.0)	0.12	-0.50 (-1.11, 0.13)	Treatment
		Attention Network Test (ANT) –Alerting	22	33 (41)	19	19 (41)	0.28	0.34 (-0.28, 0.95)	Control
Flook et al. 2010	7-9	Parent BRIEF – Metacognition (MI)	32	43.23 (9.31)	32	46.99 (11.31)	0.15	-0.36 (-0.85, 0.14)	Treatment
		Parent BRIEF – Behavioral Regulation Index (BRI)	32	42.40 (7.42)	32	46.22 (10.13)	0.09	-0.43 (-0.92, 0.07)	Treatment
		Parent BRIEF – Global Executive Composite (GEC)	32	42.51 (8.61)	32	46.52 (11.16)	0.11	-0.40 (-0.89, 0.10)	Treatment
		Teacher BRIEF - Metacognition (MI)	32	45.17 (5.63)	32	47.63 (9.23)	0.20	-0.32 (-0.81, 0.18)	Treatment
		Teacher BRIEF - Behavioral Regulation Index (BRI)	32	46.87 (7.85)	32	51.96 (12.96)	0.06	-0.48 (-0.97, 0.03)	Treatment
		Teacher BRIEF - Global Executive Composite (GEC)	32	45.53 (5.98)	32	49.21 (10.43)	0.09	-0.43 (-0.92, 0.07)	Treatment
Haffner et al. 2006	8 - 11	Dortmund Attention Test (DAT)	8	8.37 (1.80)	11	4.36 (3.10)	**0.00***	1.52 (0.43, 2.47)	Treatment
		Fremdbeurteilungsbogen für hyperkinetische Störungen (FBB-HKS) - Attention Deficit subscale	8	0.92 (0.50)	11	1.65 (0.65)	**0.02***	-1.23 (-2.16, -0.19)	Treatment
Kratter 1983	7-11	Fruit Distraction Test (FDT) - Latency, Card 1	na	40.31 (9.05)	na	42.38 (10.91)	na	-0.21 (na, na)	Treatment
		Fruit Distraction Test (FDT) - Latency, Card 2	na	44.81 (10.26)	na	49.69 (13.91)	na	-0.40 (na, na)	Treatment
		Fruit Distraction Test (FDT) - Latency, Card 3	na	45.69 (8.86)	na	53.38 (16.15)	na	-0.59 (na, na)	Treatment
		Fruit Distraction Test (FDT) - Latency, Card 4	na	70.75 (8.91)	na	83.44 (20.58)	na	-0.80 (na, na)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 1	na	2.25 (1.39)	na	2.38 (1.41)	na	-0.09 (na, na)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 2	na	1.13 (0.83)	na	2.13 (1.25)	na	-0.94 (na, na)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 3	na	1.38 (1.30)	na	3.50 (1.41)	na	-1.56 (na, na)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 4	na	2.88 (1.36)	na	5.00 (2.83)	na	-0.96 (na, na)	Treatment
Leonard et al. 2013	16-18	Attention Network Test (ANT) – Overall Accuracy	114	89.77 (0.11)	87	85.07 (0.19)	**0.00***	32.03 (28.59, 34.82)	Treatment
		Attention Network Test (ANT) – Overall Reaction Time	114	675 (113.18)	87	663.3 (121.16)	0.48	0.10 (-0.18, 0.38)	Control
		Attention Network Test (ANT) – Intra-individual coefficient of variation (ICV)	114	0.30 (0.11)	87	0.33 (0.09)	**0.04**	-0.30 (0.00, 0.06)	Treatment
Moretti-Altuna 1987	6-10	Fruit Distraction Test (FDT) - Latency, Card 2	9	53.06 (25.46)	8	56.38 (23.21)	0.78	-0.14 (-1.08, 0.82)	Treatment
		Fruit Distraction Test (FDT) - Latency, Card 3	9	60.11 (38.98)	8	65.94 (30.79)	0.74	-0.16 (-1.11, 0.80)	Treatment
		Fruit Distraction Test (FDT) - Latency, Card 4	9	85.89 (42.95)	8	86.25 (20.39)	0.98	-0.01 (-0.96, 0.94)	Treatment
		Fruit Distraction Test (FDT) - Latency, Total Score	9	247.72 (117.77)	8	256.06 (89.23)	0.87	-0.08 (-1.03, 0.88)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 2	9	3.56 (2.51)	8	3.88 (3.14)	0.82	-0.11 (-1.06, 0.85)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 3	9	3.56 (1.51)	8	4.25 (4.23)	0.65	-0.22 (-1.17, 0.74)	Treatment
		Fruit Distraction Test (FDT) – Error, Card 4	9	3.33 (3.08)	8	6.38 (10.04)	0.40	-0.42 (-1.36, 0.56)	Treatment
		Fruit Distraction Test (FDT) – Error, Total Score	9	12.11 (6.77)	8	16.75 (16.37)	0.45	-0.38 (-1.32, 0.60)	Treatment
Purohit 2016	11-16	Stroop – Word	40	73.18 (21.67)	32	72.06 (25.13)	0.84	0.05 (-0.42, 0.51)	Control

Table 4 (continued)

Study	Age (years)	Assessment Measure	Treatment		Control		*p* value	Effect Size, *d* (95% CI)	Direction effect favours
			n	Mean (SD)	n	Mean (SD)	MD		
		Stroop - Color	40	54.95 (11.86)	32	56.22 (12.44)	0.66	-0.10 (-0.57, 0.36)	Control
		Stroop – Color Word	40	33.43 (8.71)	32	34.50 (8.20)	0.60	-0.13 (-0.59, 0.34)	Control
		Trail Making Test - A	40	37.25 (10.40)	32	43.92 (15.18)	**0.03***	-0.52 (-0.99, -0.05)	Treatment
		Trail Making Test - B	40	72.50 (21.10)	32	86.65 (32.90)	**0.03***	-0.52 (-0.99, -0.05)	Treatment
		Digit Symbol Substitution – Total Score	40	39.05 (8.42)	32	35.94 (9.77)	0.15	0.34 (-0.13, 0.81)	Treatment
		Digit Symbol Substitution – Wrong Score	40	1.85 (2.62)	32	1.31 (1.42)	0.30	0.25 (-0.22, 0.71)	Control
		Digit Symbol Substitution – Net Score	40	37.20 (8.94)	32	34.63 (10.22)	0.26	0.27 (-0.20, 0.73)	Treatment
Schonert-Reichl et al. 2015	9-11	Flanker – Switch, Reaction Time	48	811.22 (208.02)	51	864.75 (227.68)	0.23	-0.25 (-0.64, 0.15)	Treatment
		Flanker vs Reverse Flanker – Reaction Time	48	577.65 (148.28)	51	625.51 (149.72)	0.11	-0.32 (-0.71, 0.08)	Treatment
		Hearts and Flowers – Congruent vs Incongruent, Reaction Time	48	389.63 (88.79)	51	412.18 (98.06)	0.23	-0.24 (-0.63, 0.16)	Treatment
Semple et al. 2010	9-13	Parent report Child Behavior Checklist (CBCL) – Attention Problems subscale	13	58.69 (10.23)	12	59.33 (8.82)	0.87	0.07 (-0.72, 0.85)	Treatment
Sidhu 2013	7-12	Test of Variable of Attention (TOVA) – RT, half 1	15	100.43 (15.26)	14	87.25 (8.23)	**0.01***	1.06 (0.26, 1.81)	Treatment
		Test of Variable of Attention (TOVA) – RT, half 2	15	102.37 (15.80)	14	90.54 (9.16)	**0.02**	0.91 (0.12, 1.65)	Treatment
		Test of Variable of Attention (TOVA) – RT Variability, half 1	15	99.47 (18.35)	14	95.00 (13.25)	0.46	0.28 (-0.46, 1.00)	Treatment
		Test of Variable of Attention (TOVA) – RT Variability, half 2	15	94.33 (21.39)	14	101.25 (19.15)	0.37	-0.34 (-1.06, 0.40)	Control
		Test of Variable of Attention (TOVA) – Omission Errors, half 1	15	94.73 (17.09)	14	97.89 (10.01)	0.55	-0.22 (-0.95, 0.51)	Control
		Test of Variable of Attention (TOVA) – Omission Errors, half 2	15	85.90 (27.11)	14	98.29 (10.17)	0.12	-0.60 (-1.32, 0.16)	Control
		Test of Variable of Attention (TOVA) – Commission Errors, half 1	15	100.53 (16.44)	14	85.11 (11.77)	**0.01***	1.07 (0.27, 1.82)	Treatment
		Test of Variable of Attention (TOVA) – Commission Errors, half 2	15	101.27 (12.55)	14	87.61 (12.91)	**0.01***	1.07 (0.27, 1.82)	Treatment
		Test of Variable of Attention (TOVA) – Inattention, half 1	15	98.21 (14.85)	14	93.38 (7.80)	0.29	0.04 (-0.34, 1.13)	Treatment
		Test of Variable of Attention (TOVA) – Inattention, half 2	15	94.2 (20.28)	14	96.69 (9.78)	0.68	-0.15 (-0.88, 0.58)	Control
		Conners' Parent Rating Scale (CPRS-R: L) – Inattention subscale	15	71.93 (9.70)	14	73.14 (4.09)	0.67	-0.16 (-0.89, 0.57)	Control
		Behavior Assessment System for Children (BASC-2) – Attention Problems subscale	15	63.96 (6.40)	14	66.14 (4.15)	0.28	-0.41 (-1.13, 0.34)	Treatment
Telles et al. 2013	8-13	Stroop – Word	43	68.70 (21.26)	43	68.65 (18.14)	0.99	0.00 (-0.42, 0.43)	No effect
		Stroop - Color	43	48.63 (9.21)	43	50.02 (9.83)	0.50	-0.15 (-0.57, 0.28)	Control
		Stroop – Color Word	43	29.30 (8.43)	43	30.86 (6.97)	0.35	-0.20 (-0.62, 0.22)	Control
		Stroop – Interference (Color Word – Word)	43	-19.56 (8.43)	43	-19.35 (7.34)	0.90	-0.03 (-0.45, 0.40)	Control
		Teacher's Rating on Attention	43	7.42 (1.19)	43	7.71 (1.41)	0.27	-0.22 (-0.62, 0.18)	Control
Verma et al. 1982	12-18	Cancellation of number 9	23	34.90 (8.50)	15	39.30 (8.80)	0.13	-0.51 (-1.16, 0.16)	Control

* Clinically significant difference (Mean difference >1 pooled SD between groups)

n: Number of participants, *d*: Hedges' *d*, CI: confidence interval, SD: standard deviation, **bold**: significant values are bolded, YSR: Youth Self Report Scale, ANT: Attention Network Task, BRIEF: Behavior Rating Inventory of Executive Function, FBB-HKS: Fremdbeurteilungsbogen für hyperkinetische Störungen, DAT: Dortmund Attention Test, FDT: Fruit Distraction Test, DSST: Digit Symbol Substitution Test, TMT: Trail Making Test, CBCL: Child Behavior Checklist, CPRS-R:L: Conners' Parent Rating Scale –Revised: Long, BASC-2: Behavior Assessment System for Children, TOVA: Test of Variables of Attention; RT: Reaction Time.

within the range was used for analysis. The scores on the PEDro were treated as a continuous variable, and the distribution was normally distributed. The Mann-Whitney test indicated that there were no significant differences between the studies with significant findings and the studies with non-significant findings regardless of the dosage of the intervention ($U = 13.00$, $p = .465$), the number of participants in the study ($U = 17.00$, $p = .935$), or the methodological quality as reflected in the PEDro scores ($t(11) = -0.03$, $p = 0.98$).

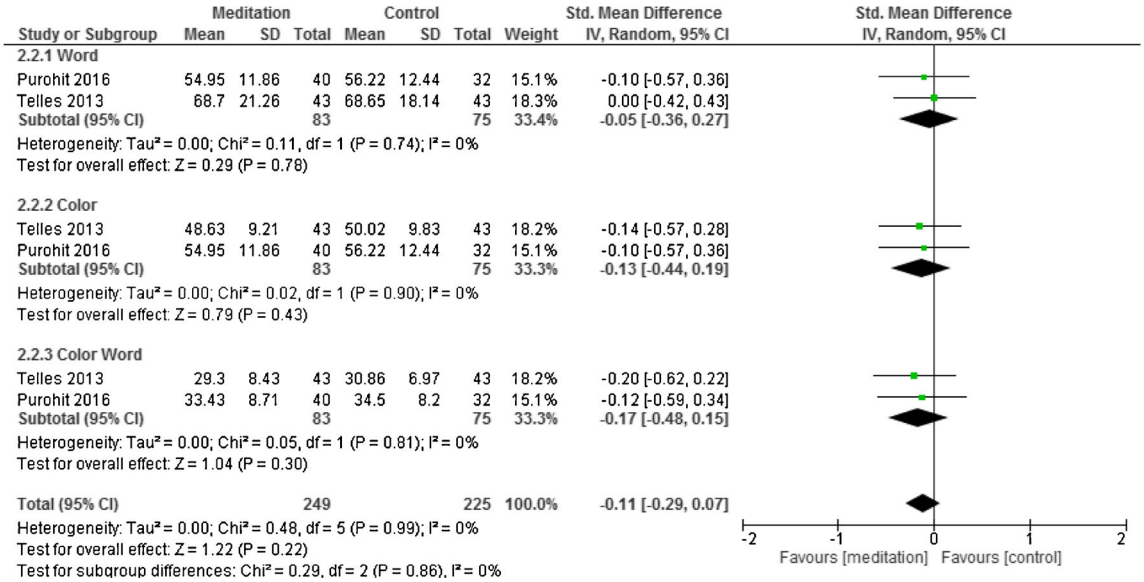

Fig. 4 Meta-analysis of EF as measured by Stroop test post-mindfulness-based intervention for children 8–13 years old (Telles et al. 2013) and orphans 11–16 years old (Purohit and Pradhan 2016)

Discussion

Five of the 13 reviewed studies of mindfulness-based interventions demonstrated efficacy in improving aspects of child and adolescent attention or EF outcomes, with the efficacy independently confirmed by calculated effect sizes (range 0.30–32.03). Overall, the efficacy of mindfulness-based interventions for enhancing attention or EF in children and adolescents remains to be established. The results to date are promising, especially coupled with a systematic literature review showing efficacy of mindfulness practices at enhancing cognitive abilities in adults (Chiesa et al. 2011). Further high-quality research in children and adolescents is needed.

The five studies that found significant effects for attention and EF were based on different facets of attention and EF (Felver et al. 2014; Haffner et al. 2006; Leonard et al. 2013; Purohit and Pradhan 2016; Sidhu 2013). For example, the included studies found significant effects for sustained attention (Sidhu 2013), conflict monitoring (Felver et al. 2014), inhibition and switching executive abilities (Purohit and Pradhan 2016), and overall attention performance (Haffner et al. 2006; Leonard et al. 2013). Most of these significant effects were predominantly based on attention tasks that require visual attention. It is unclear, however, whether mindfulness-based interventions improve specific aspects of attention or EF.

The five studies that found a significant intervention effect for attention or EF did so with mostly quantitative computerized outcome measures (Felver et al. 2014; Leonard et al. 2013; Sidhu 2013). This suggests that the type of assessment used may be crucial to detecting attentional effects of mindfulness. One possible explanation for this may be that computerized assessments are more sensitive to change. Most computerized tests capture the speed of responses (reaction time) measured in milliseconds, making it possible to detect very mild changes in an average reaction time (Collie et al. 2001). In contrast, many pen-paper neuropsychological tests of attention are measured based on accuracy, which means that the maximum level of performance would depend on the number of responses required for that particular test (Collie et al. 2003). As a consequence, most pen-paper tests

Table 5 Included studies' effect sizes for Mindfulness

Study	Assessment measure	Treatment		Control		*p* value	Effect size, *d* (95% CI)
		n	Mean (SD)	*n*	Mean (SD)		
Britton et al. 2014	Cognitive and Affective Mindfulness Scale—Revised (CAMS-R)	52	3.8 (2.6)	48	3.5 (2.8)	0.58	0.11 (−0.28–0.50)
Schonert-Reichl et al. 2015	Mindful Attention Awareness Scale for Children (MAAS-C)	48	4.68 (0.82)	51	4.26 (0.74)	**0.01**	0.54 (0.13–0.93)

Significant values are bolded

n number of participants, *d* Hedges' *d*, *CI* confidence interval, *SD* standard deviation, *CAMS-R* Cognitive and Affective Mindfulness Scale—Revised, *MASS-C* Mindful Attention Awareness Scale for Children

would have fewer possible levels of performance compared to the possible levels of performance from a computerized test measuring reaction time. An example of this difference in the sensitivity to detecting change between computerized and pen-paper tests in a pediatric population was illustrated in a study that examined the attentional processes in children treated for cancer (Butler and Copeland 2002). This study demonstrated that the computerized attention measure, namely, Conner's Continuous Performance Test, was the most sensitive to measuring change in attention (estimated effect size $d = 0.84$) compared to the other pen-paper attention measures they selected which only showed moderate levels of change (Digit Span, $d = 0.48$; sentence memory, $d = 0.55$; Butler and Copeland 2002; Raskin 2011). On the basis of this review, future studies should consider including a computerized assessment task for enhanced sensitivity. Further, psychophysiological measures of attention such as those explored in adult literature, for example, measures of attention using EEG and ERP (Moore et al. 2012), using the attentional blink paradigm (Slagter et al. 2007; Slagter et al. 2009), or measuring eye movements (Oken et al. 2006), should be considered for the pediatric population as well. Psychophysiological measures have the potential to measure ones' continuous attentional state (Vanhala et al. 2006) and, in recent studies, the ability to obtain functional brain networks of attentional performance (Rosenberg et al. 2015). For example, physiological changes would be more sensitive to detecting the exact reaction response (e.g., reaction time, pattern, and behavior) to an unexpected stimulus (Vanhala et al. 2006).

Another characteristic of the studies that could not be explored in this review is who delivered the mindfulness-based interventions. This characteristic could not be explored because not all the studies reported this information. This characteristic may be crucial in determining what outcomes the intervention may find. For example, if the yoga intervention was developed and delivered by a psychologist, then the intervention may have more of an emphasis on psychological and emotional well-being and mindfulness. Conversely, if the yoga intervention was delivered by a physiotherapist, then the intervention may have more of an emphasis on physiological aspects such as more focus on posture and alignment; and if the intervention was delivered by a teacher, the intervention may have more of an emphasis on behavior. These types of emphasis, mostly due to disciplinary bias, are not well reported in protocols of studies. The findings of studies may depend on what content was emphasized, participants' desires, and the intervention content being targeted. Future studies need to clarify who developed and delivered the intervention and if there was emphasis on particular aspects such as attention, psychological well-being, physical improvements, or behavior.

The second aim of this study was to examine mindfulness outcomes within the included studies. Unfortunately, only two of the 13 included studies reported Mindfulness as an outcome measure, despite the fact that all of the 13 included studies were trialing a mindfulness-based intervention. The two studies that reported a Mindfulness outcome, including the study that reported a significant effect for Mindfulness, did not find a significant intervention effect for attention or EF. The paucity of mindfulness assessment within this literature makes the interpretation of the results challenging as it remains unclear whether or not the interventions tested sufficiently improved mindfulness as it is usually measured in research and clinical practice.

Mindfulness-based interventions may need to specifically target attention to have an effect on attention. In the 13 included studies, four of them specifically targeted attention as their primary outcome (Felver et al. 2014; Leonard et al. 2013; Semple et al. 2010; Sidhu 2013), four of the studies targeted EF (Flook et al. 2010; Purohit and Pradhan 2016; Schonert-Reichl et al. 2015; Verma et al. 1982), while three of the studies primarily focused on all ADHD symptoms which consisted of attention and executive outcomes. The primary focus of the two remaining studies were physical fitness (Telles et al. 2013) and acceptability of mindfulness (Britton et al. 2014). In addition, heterogeneity in the types of mindfulness-based interventions used may account for lack of clarity within the current literature. This suggests that it may be necessary to carefully test standardized mindfulness-based intervention protocols, such as Mindfulness-based Stress Reduction (MBSR) (Kabat-Zinn 1991). MBSR has been used in multiple studies and research on a range of different conditions and populations (Cramer et al. 2012; Gotink et al. 2015; Hughes et al. 2013; Khoury et al. 2015; Lao et al. 2016; Ledesma and Kumano 2009; Niazi and Niazi 2011; Parswani et al. 2013; Praissman 2008; Rosenzweig et al. 2010).

Mindfulness-based training in the existing literature all consist of body awareness training (e.g., observing the breath) where people focus *internally* on their own bodily sensations and state. Yet, the majority of the attention outcomes reviewed in this paper consisted of (1) monitoring how well participants attend to an *external* stimuli—that being a stimuli on paper ($n = 8$) or on a computer screen ($n = 5$); and/or (2) attention ability in real life as *reported by parents or teachers* ($n = 7$). Improvements in attending to internal bodily states would be difficult to observe by another person so these measures too are measures of attention to external stimuli. This is potentially problematic. If improving attention to external stimuli is the goal, then the object of focus for mindfulness should be external stimuli. Alternatively, if improving attention to internal stimuli is the goal then that should be measured, such as measuring participants' physiological responses (e.g., EEG) while they perform a mindfulness practice observing their breath.

In addition to limitations already discussed, many of the studies had small sample sizes, limiting power to find significant effects on attention. Further, the existing research is heterogeneous in terms of participation, participant populations, assessment measures, and types of intervention, making it challenging to draw clear conclusions.

Future studies in this area may enhance the evidence base for mindfulness-based intervention in children and adolescents with more rigorous experimental design. Randomized controlled trials with larger sample sizes, mindfulness trainings that are compatible with the focus of the outcome measures (e.g., mindfulness trainings with a focus on external stimuli if the outcome measure assesses attention to external stimuli), and having a standardized intervention are recommended additions to the experimental design. Further, the additions of blinded and sensitive outcome measures, such as computerized or psychophysiological measures of attention, to future trials would help avoid biases and strengthen the results. Although a conclusive evaluation cannot be drawn from the existing literature, this review suggests that mindfulness-based interventions are promising. High-quality studies are required in pediatric populations with attention or EF problems other than ADHD, such as children with cerebral palsy (CP) or acquired brain injury (ABI), as the findings will help determine the use of mindfulness-based interventions in clinical and rehabilitation settings.

The effects of mindfulness-based interventions on attention and EF in children and adolescents cannot be clearly concluded from the current literature; however, there is promising data, indicating the need for future research. Further high-quality studies focusing on standardized mindfulness-based interventions and using standardized attention measures are needed.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Appendix

Table 6 Description of measures by the included studies

Measure	Study/studies	Type of measure	Type of Outcome	Description	Significant finding?
Attention Network Test (ANT)	Felver et al. 2014 Leonard et al. 2013	Computerised	Attention	"A computerized task used to assess subsystems of attention based on the tripartite model of attention postulated by Posner and Petersen (1990). The ANT subsystems include alerting (ability to maintain a state of vigilance or preparedness to environmental stimuli), orienting (directing and limiting attention to specific stimuli), and conflict monitoring (prioritizing cognitive attentional resource allocation among competing stimuli)." (Felver 2014) "Participants are instructed to focus on a fixation cross in the center of the computer screen. At the start of each trial, a warning cue (asterisks) provides spatial and temporal information about the upcoming target. Participants are instructed to press the right or left arrow key when the target appears as quickly and as accurately as possible. There are four cue conditions. In the no-cue condition, the fixation cross remains on the screen, and the target can appear either above or below the cross; in the double-cue condition, cues appear above and below the fixation cross, and the target can appear either above or below the cross. In the center-cue condition, the fixation cross is replaced with a cue, and the target can appear either above or below the cross. In the spatial cue condition, one cue appears at the location of the target; the spatial cue was 100% predictive of the target position and was equally likely to occur above or below the fixation point. Targets were groups of five arrows pointing in the same direction (congruent), the central arrow pointing in the opposite direction (incongruent), or the solitary central arrow (neutral). The participant's task was to indicate the direction of the central arrow by responding with a left- or right-click on a mouse using the left or right index finger." (Leonard, 2013)	Yes
	Sidhu 2013		Attention		No

Table 6 (continued)

Measure	Study/studies	Type of measure	Type of Outcome	Description	Significant finding?
Behavior Assessment System for Children-2 (BASC-2)		Parent/Teacher/Participant report		"Behavior Assessment System for Children (BASC) (Reynolds & Kamphaus, 1992) is a multidimensional scale that measures numerous aspects of behavior and personality, including positive (adaptive) as well as negative (clinical) dimensions. The age range covered by the test is 4 to 21 years. The parent rating scale (PRS) was used for this study – it has a total of 150 statements describing positive and negative behaviors. These statements are grouped into 10 to 12 scales with each scale relating to a specific are of behavior. For this study, the 6-item BASC-2 Attention Problems scale was assessed." (Sidhu, 2013)	
Behavior Rating Inventory of Executive Function (BRIEF)	Flook et al. 2010	Parent/Teacher/Participant report	Executive Function	"Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000). The BRIEF assesses executive function behaviors that serve to guide and organize cognition, emotion, and behavior in children ages 5 to 18. The teacher and parent versions of the BRIEF each contain 86 items that are rated on a 3-point scale indicating whether each behaviour occurs never, sometimes,or often. For the purposes of this study, we asked parents and teachers to rate children's behaviors over the past month. The 8 clinical scales (Inhibit, Shift, Emotional Control, Initiate, Working Memory, Plan/Organize, organization of Materials, and Monitor) form two broad indices (Metacognition Index and Behavioral Regulation Index), as well as an overall Global Executive Composite (GEC)." (Flook, 2010)	No
Cancellation of #9	Verma et al. 1982	Pen-Paper	Attention	"For measure of concentration" (Verma, 1982)	No
Child Behavior Checklist: Parent report	Semple et al. 2010	Parent/Teacher/Participant report	Attention	"Child Behavior Checklist: Parent Report Form (Achenbach 1991) is designed to obtain multi-axial data on emotional and behavioral problems, and social and academic competencies, in children. Three separate CBCL forms can be independently rated by parents, teachers, or direct observers. Parents provided the only source information used in this study. The CBCL consists of 113 problem-behavior items and provides sub-scores for eight specific Problem Scales, an Internalizing Problems Scale, an Externalizing Problems Scale, and a Total Problems Scale. The Attention Problems scale, Internalizing Problems Scale, and the Total Problems Scale were outcome variables of interest for the present study." (Semple, 2010)	No
Conners' Parent Rating Scale-Revised: Long (CPRS-R-L)	Sidhu 2013	Parent/Teacher/Participant report	Attention	"Conners' Parent Rating Scale-Revised: Long (Conners', 1997), consisting of 14 scales (80 questions), is a multimodal parent and teacher assessment rating scales of ADHD and related behavioral problems" (Sidhu 2013)	No
Dortmund Attention Test (DAT)	Haffner et al. 2006	Pen-Paper	Attention	"Dortmund Attention Test (paper and pencil version) by Lauth, 1993; Lauth & Schlottke, 1994. The DAT tests exactness of observation and cognitive impulsivity during tasks of visual perception. Here 6 pictures, which differ only in a small detail, are compared with an original and the one identical picture must be chosen. Low response latency (under 20 seconds) combined with a high rate of error (fewer than 8 correct of 12 tasks) suggest an attention deficit in the sense of this testing result." (Haffner, 2006)	Yes
Digit Symbol Substitution Test (DSST)	Purohit 2016	Pen-Paper	Executive Function	"Digit Symbol Substitution Test (DSST) was used in order to access various cognitive components as scanning, matching, switching, and writing operations which are reflective of several higher cognitive functions such as perception, encoding and retrieval processes, transformation of information stored in active memory and decision making.52 It has a worksheet with a specified row of six different symbols matched with six different digits with pairs, which were to be canceled and had a working section consisting of different pairs arrange randomly in 22 rows and 14 columns. Participants were asked to cancel the correct pairs as much as possible in 90 s with any possible strategy. The	No

Table 6 (continued)

Measure	Study/studies	Type of measure	Type of Outcome	Description	Significant finding?
				total number of canceled pairs in the test (DSST_T), wrong targets (DSST_W) and net scores (DSST_N) (total attempted wrongly attempted) was calculated for the analysis." (Purohit, 2016)	
Fremdbeurteilungsbogen für hyperkinetische Störungen (FBB-HKS)	Haffner et al. 2006	Parent/Teacher/Participant report	Attention	"The FBB-HKS is a rating scale for ADHD symptoms for parents, teachers and educators: from the "Diagnostic System for Psychic Disorders in childhood and adolescence according to ICD-10 and DSM-IV" (DISYPS-KJ) by Döpfner & Lehmkuhl (2002). The FBB-HKS (Döpfner & Lehmkuhl, 2000; Brühl et al., 2000) measures symptom criteria according to ICD-10 and DSM-IV for the diagnosis of an attention-deficit hyperactivity disorder using 20 items each with 4 levels (0=not at all, 1=a little, 2=to a large extent, 3=especially), that can be summarized in 3 symptom groups: attention-deficit (9 items), hyperactivity (7 items), and impulsiveness (4 items)." (Haffner, 2006)	Yes
Fruit Distraction Test (FDT)	Kratter 1983 Morietta-Altuna 1987	Pen-Paper	Executive Function	"Fruit Distraction Test (FDT), developed by Santostefano (1978), assesses the cognitive control principle of field articulation. This concerns the manner in which a person deals with a stimulus field that contains information defined as relevant and irrelevant. "The hallmark of this control… is selective deployment of attention… It emphasies that attention is to be withdrawn and withheld from irrelevant information and directed at and sustained on relevant information" (Santostefano,, 1978, p. 431). The materials consist of four test cards and three practice cards used to train the child in the test requirements. Basically, the child is asked to name colors presented with and without distractions and contradictions. Cards I and II serve as control. Cards for the interference cards (III and IV). Cards III and IV can be viewed as alternate forms of the same test when compared with the performance observed on card II." (Kratter, 1983)	No
Flanker	Schonert-Reichl et al. 2015	Computerised	Executive Function	"The task consisted of three conditions: (a) standard flanker, (b) reverse flanker, and (c) mixed trials. In the standard flanker condition, the fish were blue. Children were instructed to press the key on the side of the keyboard that represented the direction in which the middle fish was facing, ignoring the two distractor fish on either side of the middle (target) fish. This task required remembering the rule for the task, regulating attention on the task, and inhibiting distraction from the flanker fish on either side of the target stimuli. In the reverse flanker condition, the fish were pink. In contrast to the previous task, children were instructed to press the key that represented the direction in which the four fish on either side of the central fish were facing. Not only did this task require remembering the new rule for the task and selective attention, it also required the cognitive flexibility needed to change from the strategy used for the standard flanker task. In the third condition, standard flanker (blue fish) and reverse flanker (pink fish) tasks were randomly intermixed, requiring flexible application of the rules for each. This task put a heavy demand on all three core EFs. It required first recalling which rule applied; then focusing one's attention on only the relevant stimuli, registering which direction the relevant fish was or were facing; and finally choosing the correct response. A successful response was followed by positive feedback (cheers such as "yummy" or "yippee" produced by the computer program), whereas an incorrect response was followed by negative feedback (e.g., "oops"). The stimulus presentation time was 1,500 ms, the feedback interval was 1,000 ms, and the interstimulus interval was 500 ms." (Schonert-Reichl, 2015)	No
Hearts and Flowers Task	Schonert-Reichl 2015	Computerised	Executive Function	"We also administered the hearts and flowers task to measure students' working memory, response inhibition, and cognitive flexibility (Diamond et al.,	No

Table 6 (continued)

Measure	Study/studies	Type of measure	Type of Outcome	Description	Significant finding?
				2007; Wright & Diamond, 2014). This task required students to learn and follow a rule and then to switch to a second rule. Stimulus presentation time was 750 ms, and the interstimulus time interval was 500 ms. In all conditions of this task, a red heart or flower appeared on the right- or left-hand side of the screen. In the congruent condition, one rule applied ("press the key on the same side as the heart"). The incongruent condition required students to remember another rule ("press the key on the side opposite the flower"). However, the incongruent trials also required students to inhibit the natural tendency to respond on the side where the stimulus appeared. In the mixed condition, incongruent and congruent trials were intermixed (taxing all three core EFs)." (Schonert-Reichl, 2015)	
Stroop	Purohit 2016 Telles et al. 2013	Pen-Paper	Executive Function	"The test was in the form of a booklet containing three pages of word and color conditions. The first page tests how fast the participant can read words; name the colors in the second page; name which color the words were printed in, ignoring the name of the word in the third page. The test extracts three basic scores, namely Stroop Word (STROOP_W) score, Stroop Color (STROOP_C) score and Stroop Color-Word (STROOP_CW) score. The task was administered individually and test instructions were explained before starting the test. Errors of the participants were indicated and asked to be corrected by the examiner before continuing. The participants were given 45 s for each page and the time taken to complete the task was recorded by using a stop watch." (Purohit, 2016) "The test was in the form of a booklet which contains 3 pages. The first page tests how fast the participant can read words, the second page tests how fast the participants can name the colors on the page, and in the third page the participants were asked to name the color of the ink the words were printed in, ignoring the word that was printed for each item. The task was administered individually. For any mistake the participants were asked to stop and proceed after correcting the mistake. The participants were given 45 seconds for each page. Detailed instructions were given to the participants before starting the test. A stop-watch was used to record the time taken to complete the task." (Telles, 2013)	No
Teacher's analogue rating of Attention	Telles et al. 2013	Parent/Teacher/Participant report	Attention	"The teachers' ratings of the (i) obedience, (ii) academic performance, (iii) attention, (iv) punctuality, (v) behaviour with friends, and (vi) behavior with teachers were assessed for each participant using six separate visual analog scales. Each analog scale was a 10 centimeter long doubly anchored scale, with one end (score = 10) of the scale indicating the highest score while the other end (score = 0) indicated the lowest score. There was a separate scale for each of the six variables. Teachers were requested to place a vertical mark on the horizontal line to indicate the level of their rating. For each individual the score for a particular quality assessed was obtained by measuring the distance in millimeters from the end of the line where the score was '0' upto the mark made by the teachers. All the analog scales were scored in one direction (i.e., with '0' on the left). Separate analog scales were provided for each of the six variables. The teachers were requested to place a vertical mark on the horizontal line wherever they felt appropriate for each student." (Telles, 2013)	No
Test of Variables of Attention (TOVA)	Sidhu 2013	Computerized	Attention	"Test of Variables of Attention (TOVA) (Greenberg, Corman & Kindschi, 1997). TOVA is a "stimulus and response" continuous performance test (CPT) in which stimuli flash onto a screen or stimuli beep onto speakers and the participant responds as quickly and as accurately as he or she can with a small hand-held micro switch. CPT measures are designed as detection tasks in which a	Yes

Table 6 (continued)

Measure	Study/studies	Type of measure	Type of Outcome	Description	Significant finding?
				variety of stimuli are presented to subjects who are instructed to respond to a "target" stimulus (Corkum & Siegel, 1993)." (Sidhu, 2013)	
Trail making Test (TMT)	Purohit 2016	Pen-Paper	Executive Function	"This test was used to access the visual search, scanning, processing speed, mental flexibility, and EF. It has two parts, part-A (TMT_A) and part-B (TMT_B). In TMT_A, participants have to draw lines sequentially connecting 25 encircled numbers distributed on a sheet of paper; And in TMT_B the task is similar except the participant must alternate the sequence between numbers and letters (e.g.1, A, 2, B, 3, C, etc.). The score on each part represents the amount of time required to complete the task. Participants were administered part A and B of the TMTand Total time in seconds for both part A and B was recorded." (Purohit, 2016)	Yes
The Youth Self Report scale (YSR)	Britton et al. 2014	Parent/Teacher/Participant report	Attention	"The Youth Self Report (YSR) was used to assess the presence of clinical and subclinical symptoms and measure general wellbeing. The YSR contains 112 questions on a variety of behavioral and emotional problems (Achenbach & Rescorla, 2001). Each question has three response options: 0, 1, and 2, which correspond to not at all or never true, somewhat or sometimes true, and very or often true. The sum of raw scores, rather than T-scores, were used, as recommended by the YSR manual (Achenbach & Rescorla, 2001)." (Britton, 2014)	No

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