Efficacy of Cognitive Behavioral Intervention in Improving Executive Function of Children with High Functioning Autism Spectrum Disorder: A Meta-analysis

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ABSTRACT:

This meta-analysis examines the efficacy of the cognitive behavioral approach to interventions toward the improvement of executive function for children/adolescents with high-functioning autism spectrum disorder (HF-ASD). This meta-analysis paper has identified ten studies involving 437 participants with high-functioning autism spectrum disorder aged between 5 and 18. All the participants reported IQs were at or above 70. A random effect meta-analysis yielded a moderately significant effect (Hedge g = 0.72) with significant heterogeneity [Q(10) = 228.36, p < .001]. There were considerable variations in the executive function domain, i.e., working memory (hedge g = 1.23) and inhibition (g = 0.47), showing significant treatment effects.

On the other hand, cognitive flexibility (g = -0.51) and planning (g = -0.07) show non-significant effects toward cognitive behavioral interventions. The finding suggests that the cognitive behavioral approach to intervention demonstrates efficacy in improving executive function in children or adolescents with high-functioning autism spectrum disorder. All the cognitive behavioral intervention studies were conducted in developed countries, so differences between the approaches between developed and developing countries were inconclusive. Future studies are needed to investigate the effectiveness of cognitive behavioral techniques in intervention for low-functioning autism spectrum disorder children.

Keywords: Autism Spectrum Disorder, Cognitive Behavioral Approach, Executive Function

INTRODUCTION

Social cognition, communication, and executive function (EF) are the basic requirements for the quality of life of an individual. Sometimes, it is deficits in some individuals, e.g., children with autism spectrum disorder (ASD). ASD children are characterized by persistent deficits in social communication (eye contact, facial information), social interaction (American Psychiatric Association, 2013) as well as in executive function (Hill, 2004). Executive function is an umbrella term that includes domain working memory (manipulation of information), inhibition (giving appropriate response), cognitive flexibility (adjusting to the demands), and planning (Diamond & Lee, 2011). Literature and metanalysis show evidence related to the deficit in the domain of executive function (working memory, inhibition, cognitive flexibility, and planning) in children with ASD (Ozonoff et al.,2002; Hill, 2004; Demetriou et al., 2018; 2019; Kaur & Pany, 2020). Executive function is a predictor of school readiness (Bull & Scref, 2001), academic success (Hughes, 1998), social cognition (Kouklari et al., 2018), mental health, and lifelong outcomes (Zimmerman et al., 2017). It clearly shows that executive function influences ASD phenotype, and researchers need to work on the improvement of executive function among children with ASD.

However, multiple interventions were designed to improve executive function, i.e., behavioral interventions (Myers & Johnson,2007; De Vries et al., 2010), cognitive interventions, and computer training programs (Klingberg et al., 2009). The majority of the interventions are primarily focused on behavioral approaches (National Research Council, 2001). In the past few years, researchers have focused on new approaches, i.e., cognitive behavioral interventions (CBT), artificial intelligence, and virtual environments (Diedhbani et al., 2016), to improve executive function.

Cognitive behavioral interventions are effective for normal children. Still, it is adaptable to ASD children is a matter of concern for the research society due to a variety of reasons: difficulty in the theory of mind, perspective taking, cognitive flexibility, and central coherence (Carlson & Moses, 2001; Baron-Cohen et al., 2001; Brunsdon & Happé, 2015) and impairment in executive function (Tsatsanis, 2014) but still CBT approach is suitable for the ASD children due to specific characteristics i.e. Individual sessions, more engaging elements (Kennerley et al., 2016), emphasis on practice and generalization of skills.

Reviews and Meta-analyses indicate that CBT is an effective treatment for mental health symptoms, anxiety disorders (Cardaciotto & Herbert, 2004; Perihan et al., 2020; Solish et al., 2020; White et al., 2010), and depression (Wigham et al., 2017; Beck et al., 1979; Ellis, 1962). CBT also addresses social skills in individuals with ASD because social skills deficits contribute to anxiety, which intensifies social problems (White et al., 2010). Literature also indicates that everyday executive function deficits related to social skills and anxiety among children with ASD (Chan et al., 2013; Lewis et al., 2007). In this context, in the past few years, studies have focused on improving executive function using a cognitive behavioral approach. Still, the cognitive-behavioral approach is not considered an evidence-based intervention for ASD children for the improvement of executive function. So, the present metanalysis paper tries to shed more light on the efficacy of CBT for high-functioning autism spectrum disorder (HF-ASD) children for improving the levels of executive function. The present metanalysis paper tries to answer the following questions;

Research Aims

1. To examine the efficacy of cognitive behavioral interventions for improving executive function among children with high-functioning autism spectrum disorder.
2. To investigate the differences in the approaches towards cognitive behavioral interventions between developed and developing countries.

METHODS

Identification of Studies

PubMed, Web of Science, and Google Scholar databases were searched from 2001 to 2020.The search keywords are ASD and CBT, HFASD interventions and CBT, Executive Function and CBT, ASD and EF, ASD and CBT, HFASD interventions, and Executive Function and CBT. The process of identification and selection was done by all the authors independently. The primary author initially evaluated 1,846 papers retrieved from various sources (n = 980 from Google Scholar, n = 180 from PubMed, n = 140 from ScienceDirect, and n = 546 from other databases) by screening the titles and abstracts. Following the initial screening process, a total of 26 full-text articles were subjected to a thorough assessment to ascertain their adherence to the predefined inclusion criteria.

During the secondary screening phase, wherein we meticulously examined the statistical data presented in

each paper, intending to extract relevant information for subsequent meta-analysis, only ten studies were identified from the pool of 26 papers that fulfilled the criteria essential for aligning with the intended aims of the research. This stringent screening process ensures the inclusion of only high-quality and pertinent studies in the meta-analysis, enhancing the robustness and reliability of the subsequent findings.

Selection of Studies

The criteria for selection of the study are a) Cognitive behavioral interventions primarily focus on executive function skills, b) ASD children were diagnosed according to the International Classification of Disease (9th and 10th) or Diagnostics and Statistical Manual of Mental Disorders (III, IV, V), c) Participants age range were between 5 to 18 and diagnoses with high functioning autism spectrum disorder, d) Only experimental studies with the control group were included which had sufficient data (Mean, Standard Deviation and Effect Size), e) published in between 2001 to 2020. (Figures 1.)

RESULTS

Study Characteristics

The ten studies included 437 participants aged between 5 and 18 (mean age is 9.8). Two hundred sixty-six participants received CBT intervention, whereas 171 participants were in the control group. The experimental group sample size ranged from 5 to 55, whereas the control group's range varied from 5 to 35. In ten studies, most participants were males (n = 154), and the remaining were females (n = 52). Three studies (de Vries et al.,2015; Bauminger et al., 2006; Fisher & Happer et al., 2005) did not report gender distribution.

All extracted information on high-functioning autism is presented in Table 1, which reports that the IQ of children with autism spectrum disorder is above 70. Children with ASD were diagnosed with a variety of measures; three studies used diagnostic statistically manual-V, two used an autism diagnostic observation schedule, two studies used both an autism diagnostic observation schedule and autism diagnostic interview, and three studies used certification given by a clinical psychologist.

We chose the participants from different sources; seven studies recruited their sample from a particular school, and two studies recruited children with ASD from mental health care institutions. One study did not state the source of the sample. Among the ten studies, three were conducted in the US, two in the Netherlands and Italy, and one in Israel, China, and the UK.

Five studies used a pre-post-test design comparing CBT to a control group (Solomon et al.,2004; Fisher et al., 2005; de Vries et al., 2015; Traverso et al., 2017).
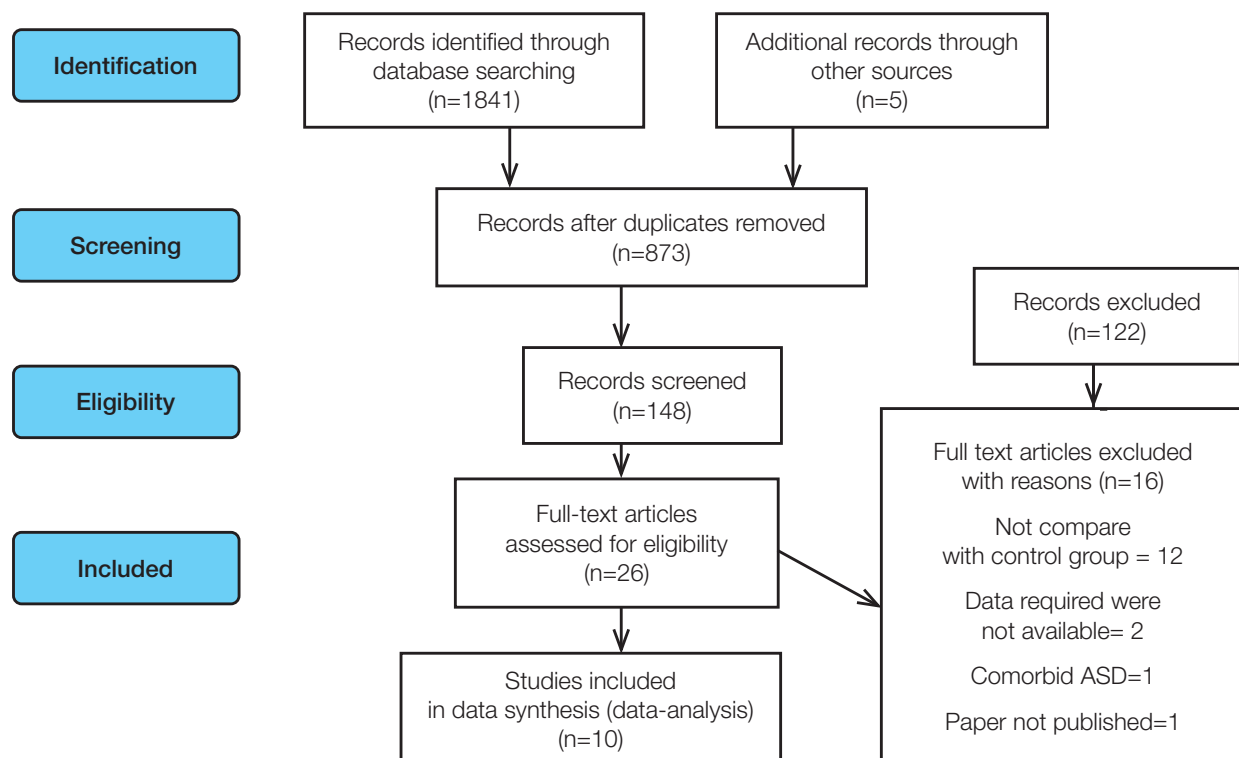

Figure 1. Systematic review search process according to the PRISMA guidelines

Kouijzer et al. (2013) and Chan et al. (2013) used randomized controlled trials comparing CBT with the waitlist control group. Three studies out of ten compared the CBT group with the non-ASD group.

Intervention Characteristics
The duration of CBT sessions ranged from 20 minutes to 120 minutes, and the intervention period varied from 3 weeks to 32 weeks. The intervention focuses on children and adolescents. Two interventions occurred in the school settings (Traverso et al., 2017; Kenworthy et al., 2014), and eight studies were conducted in the clinical settings. Six studies conducted CBT in individual child sessions (Fisher et al., 2005; Kouijzer et al.,2013; Traverso et al., 2015; Christ et al., 2017; de Vries et al., 2015), and four studies were conducted CBT in group sessions (Kenworthy et al., 2014; Solomon et al., 2004; Greco et al.,2020; Chan et al., 2013). A detailed description of each intervention is provided in Table 1.

Outcome Measures
Executive function was measured through nine performance tasks and five tests. Each sub-component of the executive function was measured through different tasks and tests. For example, in three studies, working memory was measured through digit span; one study used a corsi black tapping task. Cognitive flexibility was measured through challenge tasks, trail-making tests, Wisconsin card sorting tests, and Tower of London tasks.

Data Extraction
Data such as the mean age, intelligence quotient, intervention duration, and study location were extracted. The different studies focus on the various domains of the executive function, and the exact domains were measured through additional tests. For example, de Vries et al. (2015) focused on working memory and cognitive flexibility (measured through Corsi-BTT N-Back). In contrast, Didehbani et al. (2016) used an estimated analogical reasoning task strongly linked to executive function (Kouijzer et al., 2013). Hence, in that case, the gross value of each study's mean and standard deviation was considered for analysis, as Borenstein et al. (2009) suggested only the quantitative aspects were included (e.g., parental reports were not analysed as reported in Chan et al. (2013) study.

Data Synthesis and Analysis
Pre- and post-test intervention mean standard deviations and sample size were extracted to compare effect size. If the data required for metanalysis were not reported, then attempts were made to contact authors to get the required data (the study was excluded if authors did not note the relevant data, i.e. Johnston et al., 2019). When multiple outcome measures of executive function were used, then pooled mean and standard deviation were used (e.g., in the study of Christ et al. (2017), working memory scores were measured through digit span, and inhibition scores were measured through flanker visual filtering task pooled together to get total scores). In a sub-sub-group analysis of the executive function domain, the different domain was calculated separately in a given study (e.g., in de Vries et al. study (2015), working memory and cognitive flexibility training scores were calculated separately). Parents' and teachers' ratings were not taken into account (e.g., Kenworthy et al., 2014) study; only executive function scores were calculated). Other variables (e.g., theory of mind, social problem solving) scores were also excluded from the study.

Extruded methods, SD, and sample size f pre-submission interventions were included in RevMen 5.4. A random result model was used to produce the result size. The hedge g formula for the defined definition difference with a confidence interval of 95% was used to report the size of the result. Publish bias was calculated by funnel plot.

CBT Treatment Efficacy
Randomized meta-analysis revealed a significant effect of CBT treatment on high performance in adolescents with high-functioning children with ASD (g = 00.72, 95% confidence interval [CI] 0.56,0.95, z = 2.42.p <.001 with significant heterogeneity [Q (10) = 228.36, p <.001, I2 = 98% (see Figure 2 and 3).

Visual Inspection of the funnel plot identified two studies as an outlier but still show statistically significant.

Sub-Group Analysis
Working Memory
The randomized model revealed a significant therapeutic effect of CBT on high performance in adolescents with high-functioning children with ASD (g = 1.23, 95% confidence interval [CI] [111.91,2.28], z = 1.33 with significant heterogeneity [tau2 = 51.04, I2 = 99% (see Figure 4).

Inhibition
The randomized model revealed an essential therapeutic effect of CBT on high performance in adolescents with high-functioning children with ASD (g = 0.47, z = 1.33 with significant heterogeneity [tau2 = 24.16, I2 = 94% (Figure 5).

Table 1. **Cognitive behavioral intervention characteristics**

Study	Country	Sample	Study Type	Method	Summary
1. Kenworthy et al., 2014	USA	N = 167 (M = 59; F = 8)	RCT pre-test-post test Intervention: Unstuck on Target	Unstuck and on Target 28 lessons,30-40 min each	Significant improvement in problem-solving, flexibility, planning/organization
2. Christ et al., 2017	USA	N = 22 Age = 10-15	Baseline design Intervention = Social Competence Intervention (SCI)	20 hours of group intervention in one-hour lessons twice weekly for 10 weeks	Intervention-related improvements were observed in the working memory
3. Kouijzer et al., 2013	Netherland	N = 38	RCT Pre-post test Intervention = Biofeedback	40 sessions	Improvement in cognitive flexibility
4. Greco et al., 2020	Italy	N = 28	Baseline Design Intervention = Karta technique	12 week karate training (2 times per week)	Greater improvement in socio-emotional competence such as communication, cooperation and engagement, better executive functioning ability
5. Fisher & Happé, 2005	UK	Group-1 = 10 (TOM) Group-2 = 10 (EF) Group-3 = 7 (control group)	RCT Pre-post test	25 minutes per day for 5-10 days	Significant improvement in the theory of mind
6. Bauminger, 2006	Israel	n = 26	Single group pre and post test Intervention = CBT social skills training	Intervention for 7 months	Improvement in cognitive flexibility
7. de Vries et al., 2015	Netherland	N = 121 Age = 8-12	RCT-Pre-test and post-test and 6 week follow up	Training for 6 weeks and 6 weeks follow up Total = 25 sessions	Improved in working memory and cognitive flexibility
8. Chan et al., 2013	China	n = 48 Age = 6-17	Randomized Controlled parallel trials	Twice per week for four week	Improved self-regulation
9. Solomon et al., 2004	U S	n = 9 age = 8-12	Baseline design Intervention = social enhancement curriculum	20 week	Improvement in problem behaviour and reduction
10. Traverso et al., 2015	Italy	N = 75 Age = 5	Baseline design Intervention = group based intervention	12 sessions	Improved in working memory and cognitive flexibility

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Agnes S.Chan et al.,2013	-5.1	30.21	20	-16.52	41.3	19	1.6%	11.42 [-11.39, 34.23]
Bauminger et al.,2007	9.785	2.61	11	7.84	4.08	15	11.9%	1.95 [-0.63, 4.52]
Christ et al.,2017	55.68	11.65	22	64.335	9.15	14	8.0%	-8.65 [-15.49, -1.82]
Fisher et al.,2005	5.4	3.24	10	3.86	1.74	7	12.1%	1.54 [-0.85, 3.93]
Gianpiero et al.,2020	2.92	3.4	14	0.5	0.05	14	12.5%	2.42 [0.64, 4.20]
Kenworthy et al.,2014	0.65	0.33	47	-0.26	0.4	20	13.0%	0.91 [0.71, 1.11]
Koujizer et al.,2013	17.14	6.41	25	15.09	6.22	13	10.5%	2.05 [-2.16, 6.26]
Soloman et al.,2014	11	0.75	5	17.8	0.75	5	12.8%	-6.80 [-7.73, -5.87]
Traverso et al.,2015	2.174	0.844	55	5.83	2.21	35	12.9%	-3.66 [-4.42, -2.89]
Vries de Marieke et al.,2016	-29.56	24	57	37.56	27.44	29	4.6%	-67.12 [-78.89, -55.35]
Total (95% CI)			**266**			**171**	**100.0%**	**-3.87 [-7.00, -0.74]**

Heterogeneity: Tau² = 19.60; Chi² = 504.84, df = 9 (P < 0.00001); I² = 98%
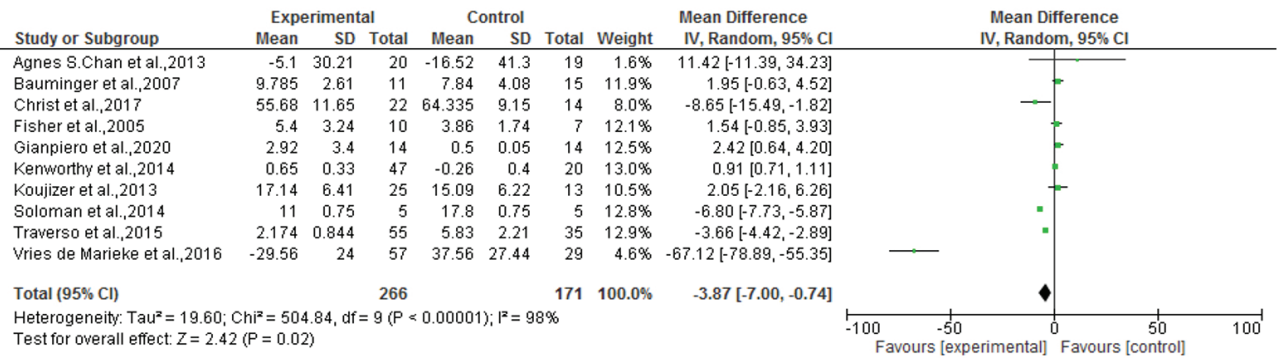Test for overall effect: Z = 2.42 (P = 0.02)

Figure 2. Forest plot on a total of ten studies: the mean difference between the experimental group(ASD children) and control group
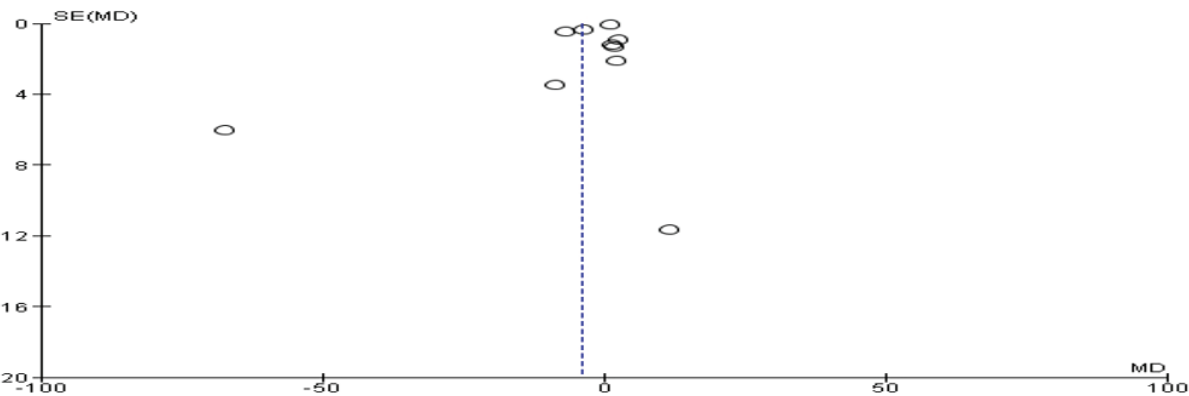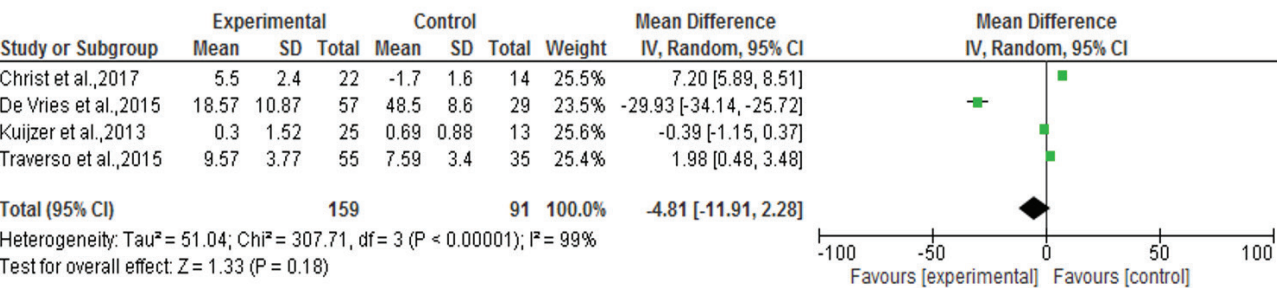
Figure 3. Funnel Plot

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Christ et al.,2017	5.5	2.4	22	-1.7	1.6	14	25.5%	7.20 [5.89, 8.51]
De Vries et al.,2015	18.57	10.87	57	48.5	8.6	29	23.5%	-29.93 [-34.14, -25.72]
Kuijzer et al.,2013	0.3	1.52	25	0.69	0.88	13	25.6%	-0.39 [-1.15, 0.37]
Traverso et al.,2015	9.57	3.77	55	7.59	3.4	35	25.4%	1.98 [0.48, 3.48]
Total (95% CI)			**159**			**91**	**100.0%**	**-4.81 [-11.91, 2.28]**

Heterogeneity: Tau² = 51.04; Chi² = 307.71, df = 3 (P < 0.00001); I² = 99%
Test for overall effect: Z = 1.33 (P = 0.18)

Figure 4. Forest Plot on working memory: mean difference between experimental group (ASD children) and control group

Study or Subgroup	Experimental Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Agnes S.C.et al.,2013	-17.29	20.79	20	-2.2	6.9	19	16.0%	-15.09 [-24.72, -5.46]
Christ et al.,2017	5.5	2.4	22	-1.7	1.6	14	31.3%	7.20 [5.89, 8.51]
Kouijzer et al.,2013	-10.28	4.56	25	-3.39	11.8	13	21.6%	-6.89 [-13.55, -0.23]
Traverso et al.,2015	9.57	3.77	55	7.59	3.4	35	31.1%	1.98 [0.48, 3.48]
Total (95% CI)			**122**			**81**	**100.0%**	**-1.02 [-6.47, 4.42]**

Heterogeneity: Tau² = 24.16; Chi² = 54.33, df = 3 (P < 0.00001); I² = 94%
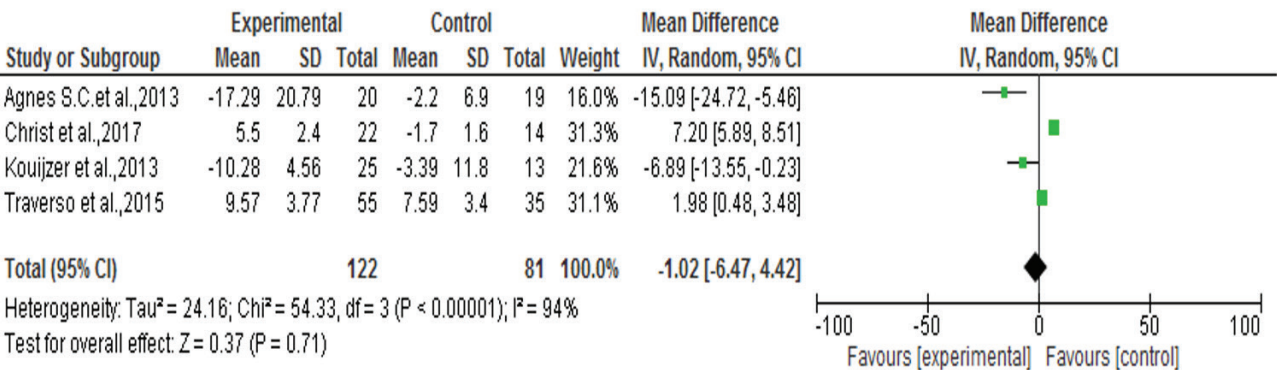Test for overall effect: Z = 0.37 (P = 0.71)

Figure 5. Forest Plot on inhibition: mean difference between the experimental group (ASD children) and control group
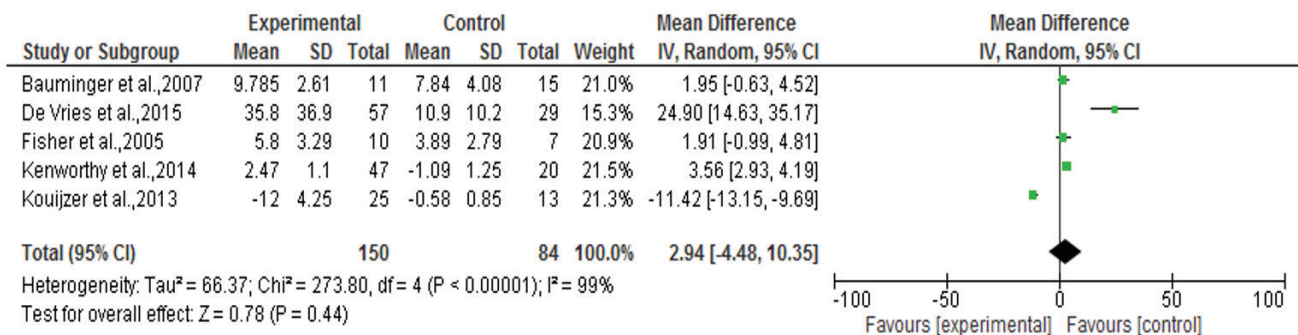
Figure 6. Forest Plot on cognitive flexibility: mean difference between the experimental group (ASD children) and control group
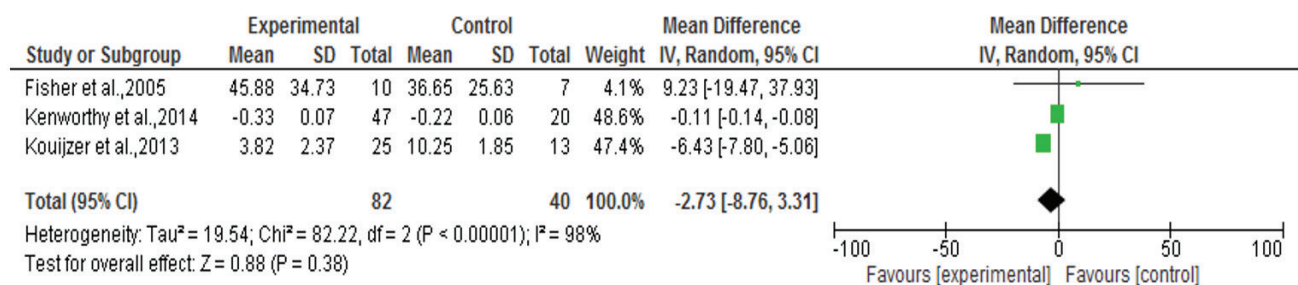

Figure 7. Forest Plot on planning: the mean difference between the experimental group (ASD children) and control group

Cognitive Flexibility

A random effects meta-analysis has revealed a statistically non-significant treatment effect for CBT on executive function in youth with high-functioning children with ASD (g = -0.51,95% confidence interval [CI]-4.48,10.35, z = 0.78 with significant heterogeneity [tau² ⁼ 66.37, I² = 99% (Figure 6).

Planning

A random effects meta-analysis revealed a statistically non-significant treatment effect for CBT on executive function in youth with high-functioning children with ASD(g = -0.078,95% confidence interval [CI]-8.76,3.31, z = 0.88 with significant heterogeneity [tau² = 19.54, I² = 98% (Figure 7).

Risk of Bias

Visual analysis of the external structure outside and outside suggested no evidence of publication bias. Evaluation analysis and testing of funnel plot asymmetry were not used due to a few power reduction studies (see Figure 3).

DISCUSSION

The present metanalysis study tried to determine the efficacy of CBT intervention on the executive function (working memory, inhibition, planning, and cognitive flexibility)of children with high-functioning autism. A meta-analysis of the pre-posttest was completed using the PRISMA guidelines. The study identified ten studies involving 437 participants with high-functioning ASD. As hypothesized, CBT had a moderate treatment effect size (g = 0.72). Inspection of the funnel plot revealed no evidence of publication bias. Visual inspection of forest plots has suggested that confidence interval poor overlaps indicate statistical heterogeneity. There is much uncertainty in measures such as I² and tau² when there are few studies. A low p-value provides, or extensive chi statistics provide evidence of heterogeneity effects. Included studies' effect size has suggested that CBT may be beneficial for children with ASD. It is assumed that CBT intervention benefits those with a certain level of executive function (Mohlman & Gorman, 2005). Still, ASD children have a deficit in executive function (Demetriou et al., 2018).

Based on a visual inspection of forest plot and Q statistics, the observed heterogeneity was primarily attributed to the inclusion of one study (Traverso et al., 2015), which reported greater treatment effect size than any other studies, and two studies favour' control group (Chan et al., 2013; Koujizer et al., 2013) that was included in metanalysis.

Intervention Approaches

There are different approaches to the intervention used to trained the executive function of ASD children with two

training programs, i.e., working memory and cognitive flexibility training with game elements. Bauminger et al. (2007) trained executive function with the help of cognitive behavioral ecological intervention. In Chan and colleagues' study (2013), executive function is considered to have indirect treatment effects. On the other hand, one study exposed ASD children to social competence intervention and measured executive function as an outcome. Different intervention approaches focus on various domains of the executive function. For example, Tundra et al.,2010 focused on working memory and cognitive flexibility, whereas Fisher et al. (2005) had given training on cognitive flexibility. However, the relationship between the different interventions and their outcomes has not been systematically examined due to the limited number of studies.

Intervention Length

The period of intervention varies from 4 weeks to 32 weeks. CBT was administered over one year (Kenworthy et al.,2014), commonly more extended than the usual four weeks, widely reported by other studies. There is a possibility that the more sessions are conducted, the more output, as participants may have more time to practice the skills in the training sessions compared to the other studies included in the meta-analysis. Despite this, we cannot clearly say that the length of intervention affects the outcome due to a small number of studies that follow inclusion criteria in this metanalysis; intervention length was not explored as a moderator of treatment outcomes.

Domain of Executive Function

Different studies focus on various domains of the executive function. For example, Chan (2013) trained children with ASD on flexibility and inhibition, and other studies (Traverso et al., 2005) only trained on working memory. Three studies (Demetriou et al.,2018; Solomon et al., 2004; Bauminger et al., 2007) focused on the overall executive function, measured through a behavior rating inventory of executive function and test of problem-solving elementary was revised. Differential analysis shows that four studies focused on working training showed higher effect sizes (g = 1.23) as compared to the other domains included in this meta-analysis. On the other hand, those studies focused on cognitive flexibility (n = 5, number of studies), and planning (n = 3) showed adverse effects of CBT interventions.

The above could be the reason for the heterogeneity in this metanalysis. This estimate's average intervention effect (random effects) and precision (95% CI) require many studies.

This metanalysis includes a limited number of studies with significant heterogeneity in treatment effect size that the only sub-group analysis of the domain of executive function could not explain. This may cause variability in obtaining weight mean differences and affect the homogeneity results. We could not find the role of potential moderators, i.e., parents' training and length of intervention with outcomes, due to a few studies. Sub-group analysis of executive function was not conducted to compare the effect as a function of intervention characteristics, i.e., types of intervention (e.g., computerized game, social skills-based intervention), settings (clinic, home or school), the focus of intervention (child, parent, peer or teacher).

Including studies from diverse population settings and using various control groups may pose challenges in generalizing the findings to a larger population. Despite these variations, all studies demonstrated positive research outcomes. However, this diversity also instills confidence in the applicability of the results across different settings and environments. The implications of these findings on the generalization of Cognitive Behavioral Therapy effectiveness in diverse contexts need further exploration and consideration.

The analysis of parental reports was omitted from consideration due to the limited availability of relevant data, with only the study conducted by Chan providing such information. The predominant focus across the selected studies was directed toward quantitative aspects, necessitating the exclusion of the qualitative component to maintain homogeneity in the dataset. This deliberate decision was made to enhance the ecological validity of the analysis, ensuring a consistent and comparable approach to the quantitative aspects within the scope of the study.

To know the efficacy of CBT, it is essential for the therapist for better treatment of children with ASD. The present study reports the moderate effect size of CBT intervention on executive function of children with ASD. Future studies can analyze the potential moderators (length of intervention, parents' involvement, types of intervention, and its relationship with the outcomes.

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