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The Impact of Physical Activity on Cognitive Function in Children and Adolescents with Intellectual Disabilities: A Meta-Analysis

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Abstract This study is designed to explore the effects of physical activity interventions on cognitive function in children and adolescents with intellectual disabilities. A systematic search was performed in databases, from inception to January 23, 2023, for relevant literature on the impact of physical activity or exercise interventions on cognitive function in individuals with intellectual disabilities. A total of 2,393 articles were retrieved, and after screening, 13 articles comprising 16 studies were included in the final analysis. Review Manager 5.4 software was used to assess the risk of bias in the included studies, calculate the overall effect size, perform heterogeneity tests, and conduct sensitivity analyses. Physical activity has a positive impact on overall cognitive function in children and adolescents with intellectual disabilities (SMD=0.76, 95%CI=[0.29, 1.23], P=0.002). It also demonstrated positive effects on memory updating (SMD=0.83, 95%CI=[0.51, 1.15], P<0.00001), attentional focus (SMD=1.30, 95%CI=[0.45, 2.15], P=0.003), and attentional allocation (SMD=-0.81, 95%CI=[-1.14, -0.49], P<0.00001). However, the effects of physical activity on attentional switching(SMD=1.00, 95%CI=[0.02, 1.97], P=0.05), attentional span(SMD=0.95, 95%CI=[-0.00, 1.89], P=0.05), visual reaction time (SMD=-1.08, 95%CI=[-2.50, 0.33], P=0.13), and auditory reaction time (SMD=-0.56, 95%CI=[-1.80, -0.68], P=0.37) did not reach statistical significance when compared to the control group. Physical activity can effectively improve cognitive function in children and adolescents with intellectual disabilities. It has significant intervention effects on overall cognitive ability, memory updating, attentional focus, and attentional allocation. The effects on attentional switching, span, visual and auditory reaction time, were improved but insignificant. The intervention methods, duration, and severity of intellectual disabilities may contribute to the heterogeneity observed among the studies.

Keywords Intellectual Disabilities, Physical Activity, Cognitive Function, Executive Function

1. Introduction

Intellectual disability (ID) is a neurological disorder characterized by significant delays in intelligence and adaptive behavior, resulting in a severe lag in academic and daily life skills behind normal children of the same age [1]. Individuals with ID have a lower overall level of intellectual functioning due to organic brain damage or incomplete brain development, and they exhibit heterogeneous cognitive impairments [2]. According to statistics, the prevalence of ID among children aged 0-14 in China is 1.2% [3]. The number of individuals with ID

in China is increasing annually, and the cost of their support and rehabilitation is substantial. Additionally, ID typically persists throughout a person's lifetime and has a lasting impact on families and individuals. Therefore, the rehabilitation, education, and social adaptation of children with intellectual disabilities are pressing issues that must be addressed. Cognitive function is crucial in everyday human life and development [4]. It forms the foundation of human intelligence and psychological abilities, representing the advanced neural capacity of the human brain for thinking, memory, attention, learning, and problem-solving. However, children with ID exhibit heterogeneous impairments in cognitive function, particularly in executive function, attention, memory, calculation, and orientation [5-7]. Their cognitive performance is lower than typically developing peers, leading to difficulties in learning, communication, attention, problem-solving, and social interaction. In severe cases, it can progress to dementia, rendering individuals unable to care for themselves independently.

Previous research and practice have shown that intervention measures to improve symptoms in children with ID include educational interventions, cognitive training, social skills training, family support, and government resources [8]. In China, the "Action Plan for the Development and Enhancement of Special Education" has been implemented to ensure education and enhance self-care abilities [9]. Some studies have pointed out that relying solely on instrumental subjects like language arts is insufficient to develop the social independence and semi-independent living skills of children with ID [10]. Attention should be given to language training and skill development to improve their social adaptation abilities. With the result of relevant research, physical exercise has shown significant effects in enhancing cognitive skills and improving executive function in children [11-12]. Exercise can induce changes in brain regions associated with cognition, decision-making, and behavior, particularly the prefrontal cortex [13]. Therefore, physical activity (PA) interventions have been shown to effectively improve the condition of children with ID and enhance their social adaptation abilities [8]. PA has been proven to be an effective means of improving cognitive function and delaying cognitive decline in various populations, including Alzheimer's disease patients, dementia patients, adolescents, and sedentary older adults. Personalized intervention plans have positively impacted cognitive function, executive function, memory, and physical health [14-18].

This study conducted a meta-analysis to examine the impact of PA on cognitive function in children and adolescents with ID. The aim was to investigate whether PA can improve cognitive function in this population and whether it has positive effects on different domains of cognitive function. These findings can serve as a valuable reference for physical education and rehabilitation interventions tailored to children and adolescents with ID.

2. Data and Methods

2.1. Inclusion and Exclusion Criteria

2.1.1. Study Type

RCTs examining the effects of PA interventions on cognitive function in children and adolescents with ID.

2.1.2. Study Participants:

Children and adolescents (aged ≤ 18 years) with intellectual disabilities.

2.1.3. Intervention Measures

The experimental group received interventions through physical exercise, including but not limited to sports games, agility training, table tennis training, aquatic exercise, and running exercises. The control group received either a blank control or standard treatment, such as conventional rehabilitation or cognitive training. The intervention duration, frequency, and period were consistent between the experimental and control groups.

2.1.4. Outcome Measures

The Cognitive Assessment System (*CAS*) scores, D2 attention test, and self-developed attention and memory test systems for adolescents with intellectual disabilities were used as assessment tools. These measures assess various cognitive domains, including attention, working memory, reaction time, and executive function.

2.1.5. Exclusion Criteria

(1) Studies not related to physical activity interventions for children and adolescents with intellectual disabilities;
(2) Studies with incomplete outcome measures or unavailable data;
(3) Duplicate publications;
(4) Non-English or non-Chinese publications;
(5) Conference abstracts or articles with unavailable full texts.

The registration has been completed on the International Prospective Register of Systematic Reviews (CRD42022377990).

2.2. Literature Search Strategy

Computer-based searches were conducted in the following databases: CNKI, WanFang Data, VIP, PubMed, Web of Science, The Cochrane Library, Embase, and SinoMe. The search period was from the inception of the databases to January 23, 2023. The English search terms included "Intellectual Disability," "Physical Activity," "Cognition," "Working Memory," "Attention," "Executive Function," "Children," and "Adolescents." The Chinese search terms included "智力障碍," "体力活动,"

"认知功能," "工作记忆," "注意," "抑制控制," "儿童," and "青少年." For example, the search strategy for PubMed is shown in Table 1.

Table 1. Example of search strategy in PubMed

Number	Search Content
#1	“Intellectual Disability”[Mesh]
#2	(Intellectual disability) OR (Disabilities, Intellectual) OR (Mental Retardation) OR (Mental Deficiency) [Title/Abstract]
#3	#1 OR #2
#4	“Physical Activity”[Mesh]
#5	(Physical Activity) OR (Exercises) OR (Exercise Training) [Title/Abstract]
#6	#4 OR #5
#7	“Cognition” [Mesh]
#8	(Cognitions) OR (Cognitive Function) OR (Attention) OR (Working memory) OR (inhibitory control) [Title/Abstract]
#9	#7 OR #8
#10	“Child” [Mesh]
#11	(children) OR (adolescents) [Title/Abstract]
#12	#10 OR #11
#13	#3 AND #6 AND #9 AND #12

2.3. Literature Screening and Data Extraction

EndNote was used for literature management. Two reviewers independently reviewed all the literature, removed duplicates, and conducted an initial screening based on the inclusion and exclusion criteria using the titles and abstracts. Preliminarily included articles were further assessed by carefully reading the full text to identify the final papers that met the inclusion criteria. In cases where the two reviewers had conflicting screening results, a third reviewer was involved in the discussion to make a joint decision on inclusion. Data extraction included publication year, country, sample size, age of the intervention targets, intervention period, intervention measures, and outcome measures.

2.4. Quality Assessment

Two reviewers independently assessed the quality of the included literature, based on "The Cochrane Handbook for Systematic Reviews of Interventions". The assessment criteria encompassed random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases [19]. According to the degree of bias, the judgment of each assessment item included in the study is described as "low", "high", and "unclear".

2.5. Statistical Analysis

The data analysis and creation of relevant charts are performed using Review Manager 5.4 software. The sample size, mean, and standard deviation reported in the included studies will serve as the original data for this meta-analysis, since all the outcome measures included in this study are continuous variables. To avoid errors caused by differences in data types, measurement methods, and units reported in the literature, when the measurement units of the included literature results are consistent, the mean difference (MD) is used as the effect size; If the measurement units of the included results are not consistent, the standardized mean difference (SMD) is chosen as the effect size, and it is calculated with a 95% confidence interval.

I^2 represents the level of heterogeneity among studies. When $I^2 = 0$, there is no heterogeneity among the studies; If $0\% < I^2 < 25\%$, low heterogeneity; If $25\% < I^2 < 50\%$, moderate heterogeneity; If $50\% < I^2 < 75\%$, high heterogeneity; If $75\% < I^2 < 100\%$, the heterogeneity is substantial, and it cannot be ignored. In addition, when $I^2 \leq 50\%$, a fixed-effects model is used for effect size calculation. Conversely, a random-effects model is used when $I^2 > 50\%$. A sensitivity analysis is conducted by systematically excluding each study one by one. Significance is determined by $P < 0.05$.

Outcomes of this study: We will conduct a meta-analysis on cognitive function and its subcomponents, including attention, memory updating, and reaction time.

3. Results

3.1. Literature Search Results

A total of 2392 relevant articles were retrieved through computer searches; in addition, two reports were obtained through other sources (obtained full-text through conference abstracts). After removing duplicate articles (391 articles), a preliminary screening of titles and abstracts resulted in 57 articles. After a full-text review, 13 articles were included in the analysis. [20-32]. See Figure 1.

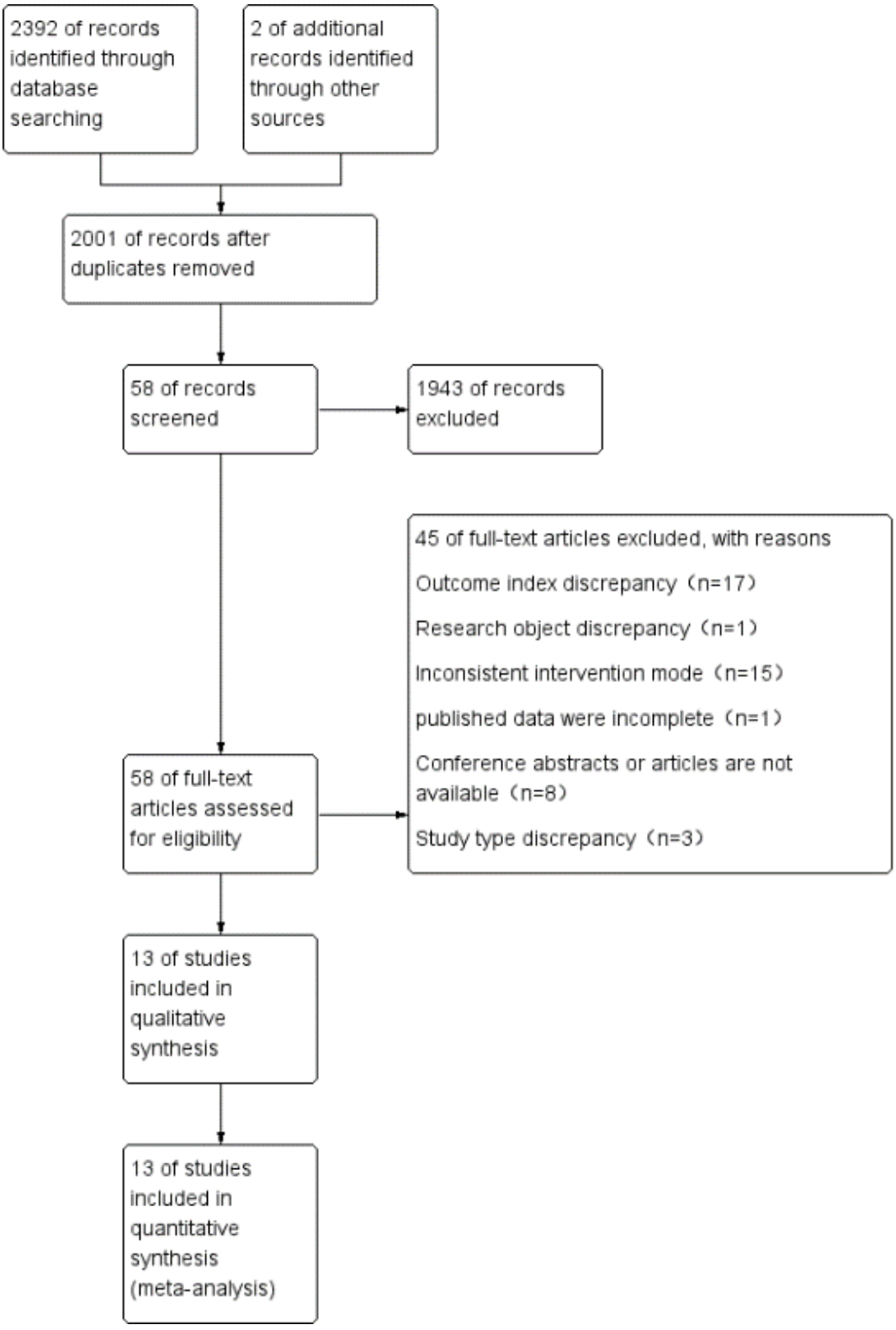

Figure 1. Literature screening flow diagram

3.2. Characteristics of Included Studies

This study included 13 studies [20-32], with a publication period from 2007 to 2022. In total, seven articles are from China [21, 22, 24, 26, 27, 30, 31], three articles are from Turkey [23, 25, 32], two articles are from Tunisia [28, 29], and one article is from South Korea [20]. From the perspective of the severity of ID in the participants, eight articles reported participants with mild ID [21, 23, 24, 25, 26, 28, 29, 32], two articles reported participants with both mild and moderate ID [20, 27], and three articles did not report the severity of ID in the participants [22, 30, 31]. The number of participants varied from 10 to 120, and all participants were under 18 years of age; among them, three articles reported that the participants were all below ten years old [22, 24, 31]. Regarding the type of exercise intervention, nine studies utilized simple physical activities (including running, sports games, physical activities, etc.) [21-24, 27, 28, 29, 31, 32]. In addition to that, the types of exercise also included aquatic exercise, dual-task balance training, table tennis training, and agility training [20, 25, 26, 30]. In these 13 studies, the majority of interventions had a duration of 3-6 months [20, 22-27, 29, 30-32], one study had an intervention period of 22 months [21], and one study did not report the intervention duration [28]. The time of a single intervention varied from 30 minutes to 100 minutes. Among the studies, five interventions were conducted twice a week [23, 25, 28, 29, 32], four interventions were conducted three times a week [20, 21, 26, 30], two interventions were conducted four times a week [24, 27], and two studies were reported as five times and seven times per week [22, 31]. From the reported outcome measures, four studies reported cognitive function [20, 22, 24, 31], four studies reported attention [25, 27, 30, 32], three studies reported reaction time [23, 28, 29], and three studies reported memory [21, 28, 30]. Eight studies reported that the experiments were randomized controlled trials [23-28, 31, 32]. Table 2 lists the characteristics of the included literature.

Table 2. Characteristics of Included Studies

Included in the literature	year of publication	nation	Number of cases (T/C)	age	Intervention duration	intervention	outcome measures
Lixiuqing	2007	China	60/60	7-14	3 months	Sports games 4 times/week, 40min/time	Depth, breadth, stability, shift of attention
NECM İ YE ÜN YILDIRIM et al.	2010	Turkey	25/25	11-18	3 months	Physical fitness plan 2 times/week, 30-60min/time	Reacting time
LeeInHo et al.	2014	South Korea	5 out of 5	13-18	3 months	Water exercise 3 times/week, 50min /time	Cognitive function test K-WAB
Chen et al.	2015	Taiwan, China	45/41	6-12	4 months	Table tennis training 3 times/week, 60min/time	The Stroop test assesses executive function.
Ridha Aouadi et al.	2015	Tunisia	17/17	14-16	3 months	Aerobic exercise 2 times/week, 60min/time	Reacting time
Genghaixia	2019	China	10/10	12-17	3 months	Sensitive training 3 times/week, 40min/time	attention, memory
ZhaoYuxia et al.	2020	China	21/23	4-8	6 months	Simple activities 4 times/week, 30min/time	Cognitive Assessment System (CAS)
Weichongxia et al.	2021	China	55/55	3-8	3 months	Sports training + cognitive function training 5 times/week, 30min times	Cognitive Assessment System (CAS)
Sevda Korkusuz et al.	2021	Turkey	11/11	9-13	3.5 months	Physical activity and attention training 2 times/week, 100min/time	D2 Attention Test, Benton Visual Persistence Test
S. Affes et al.	2021	Tunisia	11/13	13-17		Running exercise 4 times/week, 120min/time	reaction time, working memory
Ebrar Atak et al.	2022	Turkey	15/15	6-13	3 months	Cognitive training + dual-task balance training group 2 times/week	MOXO Attention Test
Xiaorang	2022	China	17/20	12-18	22 months	Long-term exercise 3 times/week, 60min/time	Inhibitory control, working memory, cognitive flexibility

3.3. Risk of Bias Assessment of Included Studies

In this study, 7 studies reported using randomization methods [23-28,31,32], and 1 study reported using blinding [26]. The data reported in the studies were complete, and the data processing was reported. According to the assessment of literature quality and risk, we know that 6 studies were found to have a high risk of bias [20-22, 24, 29, 30], while 7 studies were considered to have a low risk of bias [23, 25-28, 31, 32]. Details are shown in Figure 2.

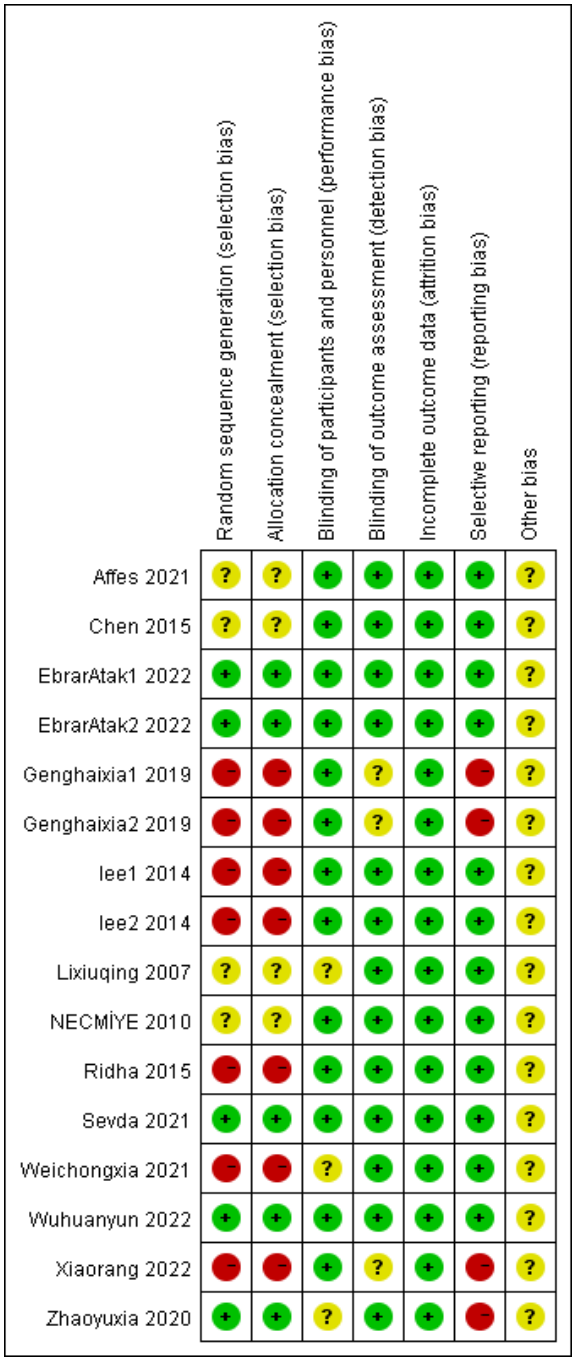

Figure 2. Risk of bias assessment

4. Meta-Analysis Results

4.1. Cognitive Function

Four studies [20, 22, 24, 31] conducted research on the effects of PA on cognitive function in children and adolescents with ID, involving a total of 275 participants. The analysis was performed using a random-effects model (I^2=*61%*). The result which reflected the effect was significant (*SMD=0.76, 95% C= [0.29, 1.23], P=0.002*). See Figure 3.

4.2. Executive Function

4.2.1. Attentional Focus

Four studies [25, 27, 30, 32] conducted research on the effects of PA on attention and concentration in children and adolescents with ID. The studies involved a total of 217 participants. The analysis was performed using a random-effects model (I^2=85%). The overall effect was significant (SMD=1.30, 95% CI=[0.45, 2.15], P=0.003). The detail is shown in Figure 4.

4.2.2. Attentional Span, Switching, and Allocation

Two studies [27, 30] conducted experiments on attention-related abilities in 150 children and adolescents with ID. The analysis used a random-effects model (I^2=*77%*). The overall effect on attention span was insignificant (*SMD=0.95, 95% CI=[-0.00, 1.89], P=0.05*). A random-effects model was used for attentional switch (I^2=*78%*). The results indicated that the effect was insignificant (*SMD=1.00, 95% CI=[0.02, 1.97], P=0.05*). In the meta-analysis of attentional allocation, a fixed-effects model was used for the analysis (I^2=*38%*). The results indicated that the overall effect was highly significant. (*SMD=-0.81, 95% CI=[-1.14, -0.49], P<0.00001).* The results of attention span, switch, and allocation are shown in Figure 5-7.

4.2.3. Memory Updating

Three studies [21, 26, 30] investigated the effects of PA on memory updating. A fixed-effects model was used (I^2=*0%*), which showed that PA has a positive and stable impact on memory updating in children and adolescents with ID (*SMD=0.83, 95% CI=[0.51, 1.15], P<0.00001*). See Figure 8 for details.

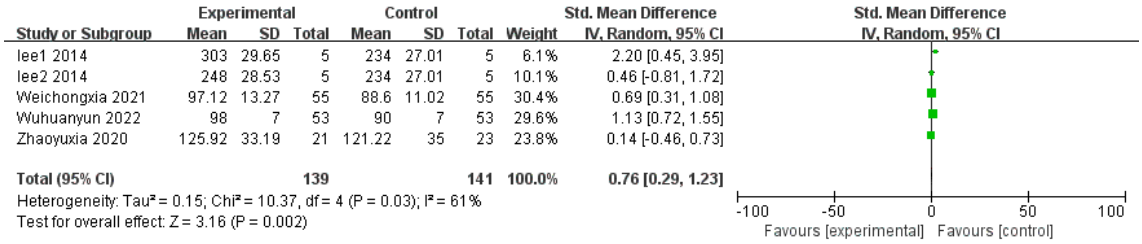

Figure 3. Forest plot of cognitive function

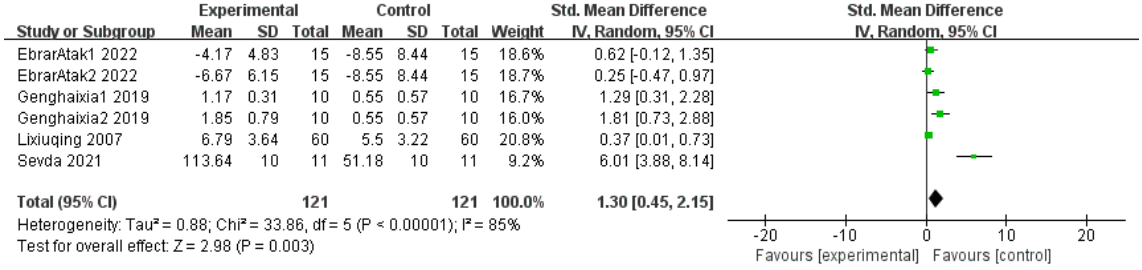

Figure 4. Forest plot of attentional focus

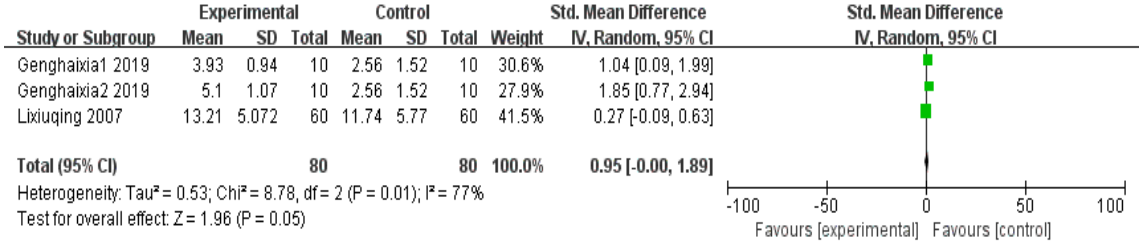

Figure 5. Forest plot of attentional span

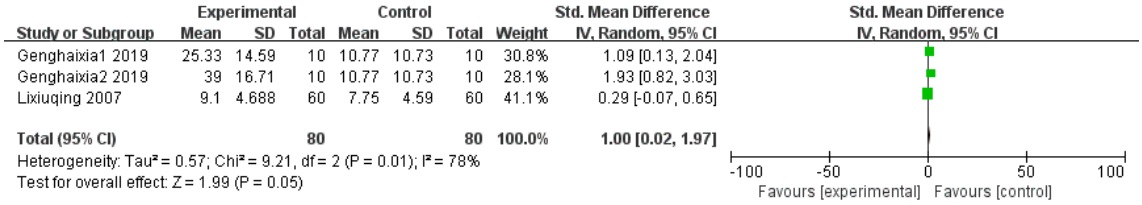

Figure 6. Forest plot of attentional switching

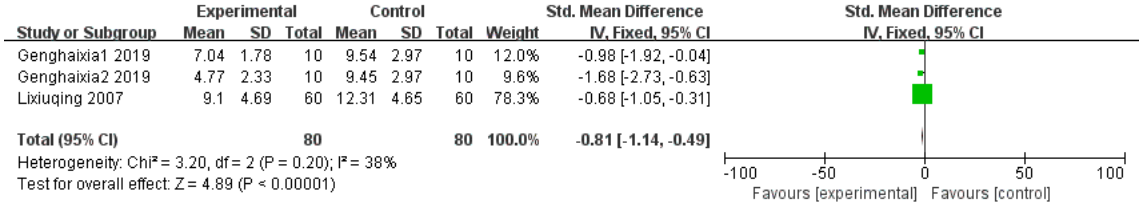

Figure 7. Forest plot of attentional allocation

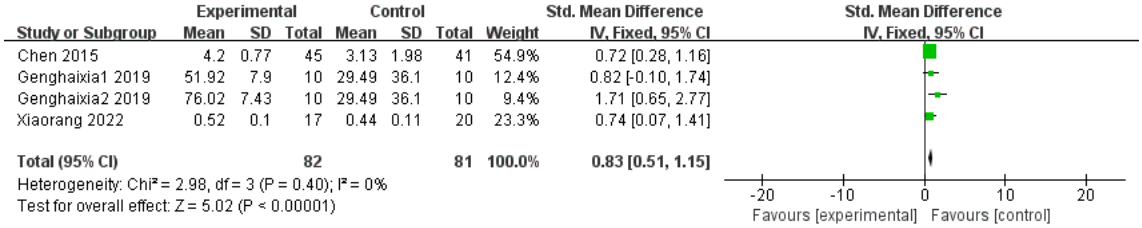

Figure 8. Forest plot of memory updating

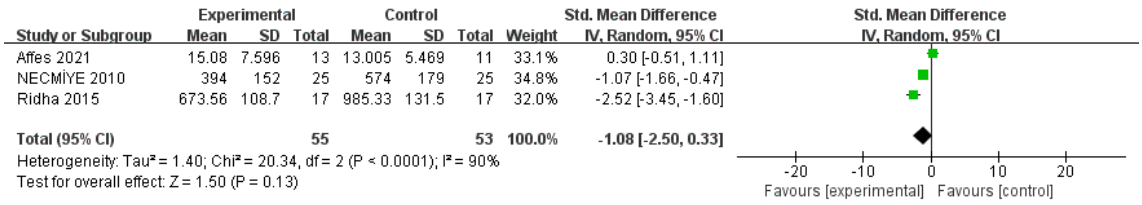

Figure 9. Forest plot of visual reaction time

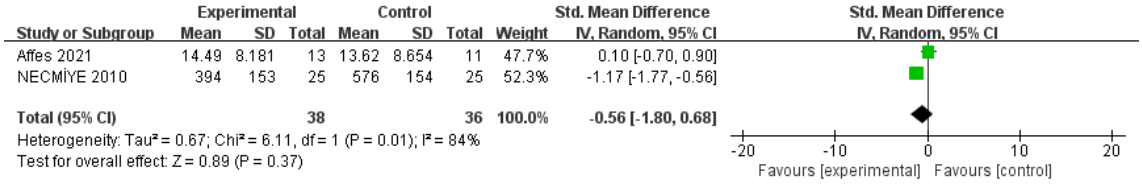

Figure 10. Forest plot of auditory reaction time

4.3. Reaction Time

4.3.1. Visual Reaction Time

Three studies [23, 28, 29] investigated the effects of PA on visual reaction time in children and adolescents with ID, involving a total of 108 participants. The random-effects model analysis (I^2=90%) did not reveal any significant impact on visual reaction time in children and adolescents with ID (*SMD=-1.08, 95% CI=[-2.50, 0.33], P=0.13*). See Figure 9 for details.

4.3.2. Auditory Reaction Time

Two articles [23, 28] compared auditory reaction time in 74 participants. This analysis used a random-effects model (I^2=84%), revealing that PA had no statistically significant impact on auditory reaction time in children and adolescents with ID. (*SMD=-0.56, 95% CI=[-1.80, -0.68], P=0.37*). The result of auditory reaction time is shown in Figure 10.

4.4. Sensitivity Analysis

To test the stability of the findings, a sensitivity analysis was conducted using the method of systematically excluding individual studies. The results showed that the heterogeneity of attention span and attention switch decreased significantly after excluding the study by Lixiuqing[27]. Following the analysis using a fixed-effects model, significant differences were observed in attention span (*SMD=1.39, 95% CI=[0.68, 2.10], P=0.0001*) and attention switching (*SMD=1.45, 95% CI=[0.73, 2.17], P<0.0001*). The remaining analyses showed statistically significant results after excluding individual studies, indicating a certain level of stability in the results of this meta-analysis.

5. Discussion

This study conducted a meta-analysis on the potential of PA in improving cognitive function in children and adolescents with ID. A total of 13 studies were included, involving 699 individuals with ID. By analyzing the overall cognitive function, memory updating, attentional focus, attentional allocation, attentional span, attentional switch, and reaction time outcomes, we found that PA interventions have a positive and effective impact on improving cognitive function in children and adolescents with ID. The present study represents the first comprehensive systematic review and meta-analysis conducted on PA's impact on cognitive function among children and adolescents with ID. This study synthesizes and integrates the research findings in this field, providing clear evidence of the effects of PA on cognitive function in children and adolescents with ID. It provides preliminary evidence for future related research, enriches the development of adapted physical education theory, and serves as an essential reference for physical rehabilitation in children and adolescents with ID.

5.1. Cognitive Function

The results of our research demonstrate that PA can effectively improve overall cognitive function in children and adolescents with ID, leading to enhanced cognitive performance and stable intervention effects. Although there have been no direct meta-analyses or systematic reviews indicating a positive impact of PA on cognitive function in children with ID, previous studies have found a close relationship between PA and cognitive development [33]. For example, A review suggests that PA has a positive effect on the cognitive development of preschool children [34]. Ilona Bidzan-Bluma et al. [35] also reported a positive impact of sports events on cognition in late childhood. The reasons for this change can usually be explained from two aspects. On the one hand, PA can improve cerebrovascular function, thereby increasing oxygen supply to the brain [36], stimulating the secretion of neurotransmitters, influencing the excitability

of neurons [35], and increasing the speed of neural signal transmission related to cognitive function [33]. On the other hand, the complex motor environment during exercise (such as aquatic exercise) can stimulate the senses, enhancing individuals' limb coordination, motor control, and spatial perception, ultimately promoting the development of cognitive function. In this regard, participation in comprehensive sports rehabilitation training, aquatic training, and other activities has a positive impact on the brain, cardiovascular system, muscles, and other aspects of children and adolescents with intellectual disabilities. This has a positive effect on their spatial perception, language barriers, as well as their comprehension and judgment abilities.

5.2. Executive Function

We find that PA has a positive effect on executive function in children and adolescents with ID. It significantly improves attentional allocation and working memory and has a positive impact on attentional focus and allocation. This result is supported by previous research in both general and particular populations. For example, a meta-analysis study found that PA has a positive impact on executive function in children and adolescents, suggesting that they should be encouraged to engage in sports activities [37]. In terms of special populations, Wangyifan et al. [38] found that badminton intervention significantly improved inhibitory control, the accuracy of working memory, and reaction time in individuals with ID, thereby enhancing their executive function. Bennett et al. [39] found a significant improvement in functional working memory after intervention in individuals with autism; the executive functions also showed positive transfer. In this study, memory updating showed considerable improvement after exercise intervention. Memory updating is continuously updating working memory based on the iterative updating of acquired information [40], which is controlled and regulated by executive functions. The reason for this positive change may be that during the exercise intervention, children and adolescents with ID need to respond quickly and accurately to different commands and directions, adapt their movements accordingly, combine with proper breathing, and fully engage the whole body to complete the exercises, which enhances individuals' focus and spatial perception abilities, leading to a decrease in inhibitory synaptic activity and an increase in excitatory activity [40]. During this process, children and adolescents with ID experience an increase in the efficiency of receiving and processing information, improved focus and recognition of target stimuli, effective inhibition of irrelevant information, and enhanced physical response speed, thereby improving their updating ability. Based on this, children ID included in the literature need to concentrate their attention during table tennis training and agility training. They must continuously repeat the process of acquiring external stimulus information and providing feedback. As a result, their executive functions are positively influenced, and their memory-updating abilities are further improved.

One of the common characteristics of children with ID is attention issues, manifested as a lack of concentration, easy distractibility, and difficulty in sustaining tasks. In this study, PA has a positive impact on attentional focus and allocation. Furthermore, the findings of this study are consistent with previous research. Some scholars have effectively improved attention deficits in adolescents with intellectual disabilities by combining flexibility training with medical rehabilitation [41]. Meanwhile, research has also indicated that moderate-intensity aerobic exercise can effectively improve attentional stability, shifting, and breadth in ID adolescents [42]. From a physiological perspective, attention is regulated by the nervous system and involves the interaction of multiple brain regions, neurotransmitters, and neural circuits. Specifically, firstly, PA can improve blood circulation, and increase cerebral blood flow, thereby increasing oxygen and nutrient supply to the brain, and optimizing the connectivity between the brain [43]. Secondly, PA promotes the activation of the brain's neural networks [44], particularly in regions associated with attention, effectively increasing neurotransmitter metabolism in the prefrontal cortex [45]. Thirdly, PA promotes the release of neurotransmitters such as norepinephrine and serotonin. These neurotransmitters can enhance attentional focus [46,47]. In addition, encouraging behavior and strengthening their motivation to participate in PA during exercise not only promote the development of attention but also help children with ID to build confidence and courage. However, the effects on attention switch and attention span are not as pronounced as the former, which may be due to the limited understanding, judgment, and cognitive abilities of individuals with ID to correctly interpret the meaning of tasks when processing information in complex environments, resulting in adverse outcomes in attention switch and attention span. It could also be because the intensity of movement is insufficient to affect the range of attention switches and attention spans.

5.3. Reaction Time

The effects of PA on visual reaction time and auditory reaction time in children and adolescents with ID were not statistically significant. However, previous studies have shown some controversy regarding the effects of exercise interventions on reaction time in this population. Vogt et al. found that moderate-intensity running exercise did insignificantly change reaction time in individuals with ID [48]. However, a study on acute auxiliary cycling showed that reaction time improved after physical exercise [49]. The possible factors contributing to this phenomenon could be attributed to the duration of activity and the specific demographic under investigation. In the study by

Vogt et al. [48], the participants were adults with ID, who were not in the developmental period of individual reaction time. Additionally, a single exercise may stabilize the existing reaction speed but may insignificantly improve it. It is worth noting that the original included literature consistently indicated that reaction time in adolescents with ID can be enhanced through PA. However, the results of our findings are contrary to this, which may be attributed to the limited number of included studies and the high heterogeneity; thus caution should be exercised when interpreting these results. Although the results of our study suggest that PA has no significant effect on reaction time improvement in children and adolescents with ID, we still hope that future research will provide more studies in this area to further demonstrate the effectiveness of exercise interventions on reaction time in this population.

6. Strengths and Limitations

Our study demonstrates that PA has a positive impact on cognitive function in children and adolescents with ID. The strengths are as follows: Firstly, we rigorously followed the inclusion and exclusion criteria for literature screening, including studies on the effects of PA interventions on cognitive function in children and adolescents with ID. This enhanced the accuracy and specificity of the research results. Secondly, in selecting of outcome measures, we included various subcomponents of cognitive function, improving the comprehensiveness of the results of this study. Thirdly, to our knowledge, this study is the first to conduct a meta-analysis on the effects of PA interventions on cognitive function in children and adolescents with ID. This has significant implications for future scientific research and physical rehabilitation practices. PA intervention, as a non-pharmacological treatment approach, should receive more attention.

At the same time, when interpreting these results, we need to consider the following aspects: Firstly, there is a limited number of RCTs on the effects of exercise on cognitive function in children and adolescents with ID. We included non-RCT studies that met the criteria in the meta-analysis, which may introduce some bias. Therefore, the results of the study should be interpreted with caution. Secondly, we acknowledge the presence of heterogeneity in the included literature. However, the limited number of studies precluded subgroup analysis, thereby hindering our ability to identify the underlying sources of heterogeneity. We will continue to pay attention to this aspect in future research. Thirdly, the participants included in this study were primarily children and adolescents with mild ID, with very few participants with moderate ID and no with severe ID. Therefore, further investigation is needed to explore the effects of PA on cognitive function in children and adolescents with mild to strict ID. In conclusion, the results of this study confirm that PA has a significant positive impact on cognitive function in children and adolescents with ID. It can be considered as an intervention measure for children and adolescents with ID, while also taking into account the limitations of this study.

7. Conclusions

This study conducted a meta-analysis of 13 articles and 16 studies, indicating that PA intervention is a highly feasible measure for improving cognitive function in children and adolescents with ID; significant improvements were observed in overall cognition, memory updating, attentional focus, and attentional allocation dimensions. This conclusion expands the evidence of the impact of PA intervention on cognitive function in children and adolescents with ID, making it a non-pharmacological treatment approach for their rehabilitation. Furthermore, in future research, more RCTs are needed to investigate the optimal targeted intervention strategies for improving cognitive function in children and adolescents with ID through PA interventions. This will contribute to rehabilitation for children and adolescents with ID.

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Author Contributions

GZ and KC: Data analysis, writing and revising manuscript. GZ, LC and PZ: Collecting and sorting out data. GZ, LG: Determine the research topic and framework, and revise the manuscript.

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