ISSN: 1813-4890

Meta-analysis of the effects of exercise intervention on children with sensory integration disorder

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Abstract

Objective To explore the effects of exercise intervention on the indicators of children with sensory integration disorder, to provide scientific basis for the optimisation of the intervention strategy or to explore the practical ways of intervention, and to provide reference for practice. Methods Literature on the effects of exercise intervention on children with sensory integration disorder was searched in five databases: China Knowledge Network, Wanfang Database, VIP, PubMed, and Web of Science from 2003 to 2023. Reviewer Manager 5.4 and Stata18 software were used to analyse the studies, and standardised mean difference (SMD) and 95% confidence intervals were used to assess the effectiveness of exercise intervention to improve the indicators of children with sensory integration disorder. Meta-analysis was performed using fixed-effects or random-effects models, respectively, according to the heterogeneity of the studies, and further subgroup analyses were performed. The results showed that motor intervention improved children's vestibular balance function (SMD =0.98 , 95%Cl 0.72-1.23 , P< 0.00001), tactile defence function (SMD =1.09 , 95%Cl 0.85-1.34, P< 0.00001), proprioceptive function (SMD =1.03, 95%Cl 0.80-1.26, P< 0.00001), and the ability to improve the functioning of their sensory integration. P< 0.00001), and learning ability (SMD =1.39, 95%Cl 0.84~1.94, P< 0.00001), the experimental group's improvement in all dimensions was significantly better than that of the control group, which indicated that the improvement effect of exercise intervention was better. Meanwhile, the results also showed that motor intervention can also effectively improve children's autistic behaviour. Conclusion: Motor intervention can improve children's sensory integration ability and improve the symptoms of sensory sensory integration disorder.

Keywords

Motor intervention; sensory sensory integration disorder; children; Meta-analysis.

1. Introduction

Sensory Integration Dysfunction refers to when the sensory system is unable to integrate and analyze in the central nervous system, and cannot make the sensory organs control the body to make a series of responses, individuals will have learning or behavioral disorders and difficulties, mainly referring to vestibular balance, tactile defense, proprioception, audio-visual language and other aspects of the disorder, this phenomenon is called sensory integration disorder[i,ii]。 With the development of the economy and the progress of society, people's lifestyles have also changed, affected by these biological factors, environmental factors and changes in educational concepts, the incidence of sensory integration disorder has also tended to increase, according to the research and survey report of scholars, the rate of sensory integration disorder abroad is 10%-30%[1]， In different regions of our country, the rate of sensory integration disorder in school-age children is also different, between 20.1% and 42.2%, and the rate of sensory integration disorder in boys is higher than that of girls[iii,iv,5]，

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Children's sensory integration disorder has manifestations such as inattention, learning difficulties, hyperactivity, poor self-control, poor coordination, emotional instability, and indifference in interpersonal relationships, which have a significant impact on academic performance and behavioral abnormalities. Investigations have shown that these abnormal behaviors are not intellectual and general education problems, but are caused by uncoordinated brain development[v]Studies have found that although there are other abilities that make up for sensory integration disorder to some extent as we age, sensory integration disorder does not disappear, and some of its symptoms hinder the development of intelligence and ability in the future[vi]。Xiao Xiaohong believes that the best period for sensory dysfunction treatment is 3~6 years old[vii]。Therefore, the impact of sensory integration disorder should not be ignored, and early detection and intervention should be achieved. In recent years, as the term sensory integration disorder has entered the public eye, a series of treatment and improvement methods have been produced, such as Western medicine, acupuncture, language, exercise, etc., among which exercise can not only effectively improve the symptoms of sensory integration disorder, but also has the advantages of enhancing physical fitness and painlessness, but there is no further discussion on exercise intervention for sensory integration disorder in project selection, age, and population. This study intends to explore the effects of motor intervention on children with sensory integration disorder in four dimensions: vestibular dysbalance, tactile overdefense, proprioceptive disorder, and insufficient learning ability, so as to provide more theoretical basis for motor intervention to improve children's sensory integration disorder.

2. Methods

2.1. Data Sources and Search Strategy

Literature search strategy This study was conducted by searching China Knowledge Network, Wanfang Database, Wipo Database, PubMed, Web of Science for relevant journal articles, and the time range of the literature search was January 2003-October 2023, and the search was conducted by using the search strategy of subject words plus free words. The search was conducted using a subject plus free word search strategy, with the search terms ‘sensory integration, sensory integration disorder, sensory integration ability, sensory integration disorder, sensory integration training, physical activity, exercise intervention, training, sport’ in Chinese and ‘sensory integration, Autism Spectrum Disorder, intervention, Behavior Therapy, exercise sport’ in English, Behavior Therapy, exercise sport, Exercise Therapy" as the search terms, and the search was conducted by combining subject words with free words, supplemented by manual search, with additional references included in the literature when necessary, and without searching for unpublished literature.

2.2. Literature inclusion criteria

(1) The study subjects were children aged 1 to 12 years, regardless of race or gender; (2) The intervention used was a motor intervention (various sports, physical exercise or targeted sensory integration training); (3) The intervention period was no less than 12 weeks, and the duration of a single intervention was no less than 30 min; (4) The outcome indicators of the study included any one or several of the following: vestibular function, tactile defence, proprioception and learning ability; (5) The mean and standard deviation of the outcome indicators before and after the intervention can be obtained directly or indirectly for the experimental group and the control group.

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2.3. Literature exclusion criteria

(1) Repeatedly published literature; (2) Incomplete data of outcome indexes, which do not meet the conditions for data extraction; (3) Non-Chinese and English literature; (4) Master's and doctoral dissertations, conference papers, reviews, cross-sectional studies, and case studies.

2.4. Literature Screening and Quality Evaluation

The literature was searched according to the search strategy, and the retrieved literature was screened according to the inclusion and exclusion criteria. Literature that did not meet the inclusion criteria was excluded by reading the title and keywords, and the remaining literature was further screened by reading the full text, and finally the included literature was compared. The quality of the included literature was assessed using the cochrane risk of bias assessment tool, which includes: selection bias (generation of random sequence, allocation concealment), implementation bias (double blinding of implementers and participants), measurement bias (blinding in assessment of endpoints), lost to visit bias (publication of incomplete data), publication bias (selective publication), and other bias, with a total of seven entries. Based on the content of the original literature, three levels of bias, high risk, low risk and uncertain risk, were made, with a third researcher adjudicating if disputes arose.

2.5. Data extraction

The basic information of the literature was extracted by two independent researchers according to the self-made scale entries, and the basic information extracted included: the name of the first author, the time of publication, the sample size, the basic information of the research subjects, the means of intervention in the experimental/control group, the time and frequency of intervention, and the outcome indicators.

2.6. Statistical methods

Excel 2016 was used to summarise the basic characteristics and outcome indicators of the extracted literature; Review Manager 5.4 was used to analyse the outcome indicators (vestibular function, tactile defence, proprioception, learning ability) of each study. The data in this study were all continuous variables, and their effects were expressed using standardised mean differences and their 95% confidence intervals (Cl). I2 was used to test for heterogeneity between studies, and P values were used to determine the effect model to be used: when $I2 \leq 50\%$ and $P \geq 0.1$ indicated that there was no heterogeneity or less heterogeneity between studies, a fixed-effects model was used; conversely, when $I2 > 50\%$ and $P < 0.1$ indicated that there was heterogeneity between studies, a random-effects model was used, and subgroup analyses and sensitivity analyses were carried out to identify the source of heterogeneity, and if no source could be found, a subgroup analysis was conducted to identify the source of heterogeneity. source, and descriptive analysis was performed if the source of heterogeneity could not be found or the heterogeneity results were too large.

3. Results

3.1. Search Results

A total of 3111 relevant literatures were retrieved through searching 5 databases, and 21 articles were finally included through screening and exclusion, of which 18 articles reported the three outcome indicators of vestibular function, tactile defense, and proprioception, and 12 of the 18 studies reported the outcome indicator of learning ability. The specific literature screening process is shown in Figure 1. Through the evaluation of literature quality, it can be seen that there is a certain bias in the included literature, which can be seen in Figure 2.

ISSN: 1813-4890

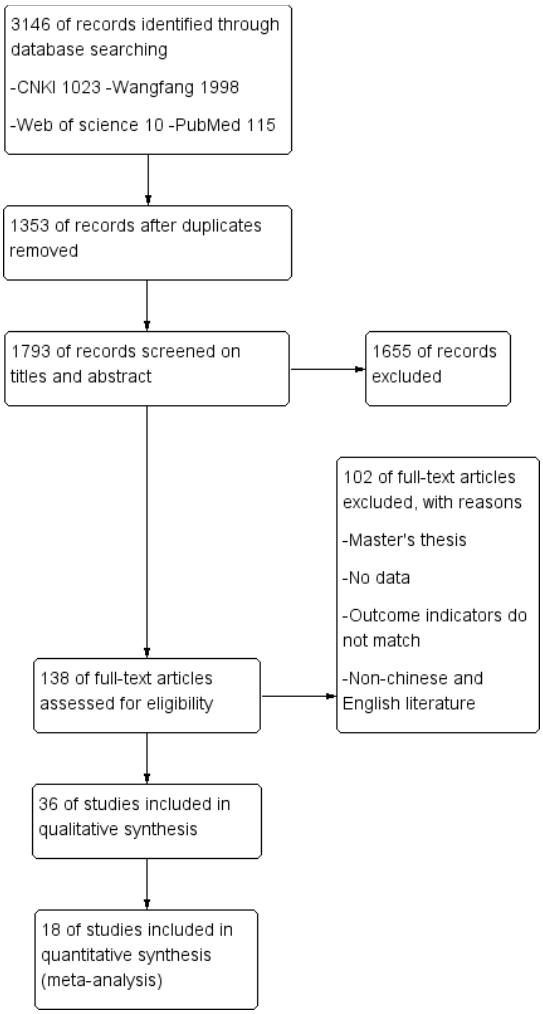

Figure 1 Literature Screening Flowchart

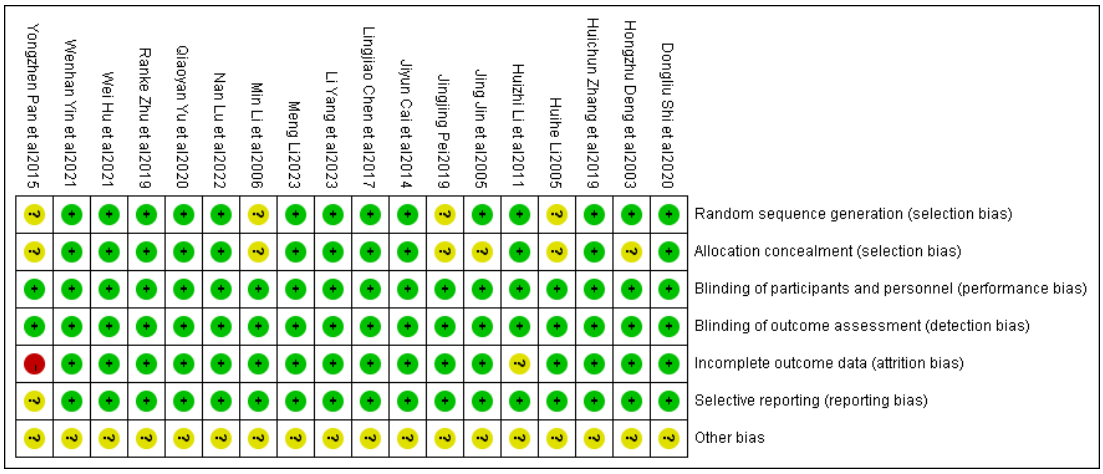

Figure 2 Summary of Bias Risk in Included Studies

3.2. Inclusion of study information

In the 18 [14-31] articles included, a total of 1622 participants were Chinese children. One study included children with attention deficit and hyperactivity disorder (ADHD), nine studies included children with sensory integration disorder, and eight studies included children with autism spectrum disorder (ASD), as detailed in Table1.

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Table1 Characteristics of included studies

Study	Object of study	Experimental group vs. control group			Frequency and intensity of exercise	measuring tool
		Age	Sample capacity	Intervening measure		
Min Li et al2006	SID	4~11	54	Sensory Integration Training (Group Training Combined with Parental Cooperation)	The training time is 1.5-2 hours each time, 2~3 times a week, according to the degree of sensory integration disorder and individual differences of the child, the training course is generally 3~4 courses, each course of treatment is 20 times, and severe children need 6-8 courses	Sensory Integration Development Assessment Scale，Rutter Behavior Rating Scale
Wei Hu et al2021	FAD with SID	5.67±1.17	70	Sensory integration training + speech correction	Single training was 30~80min/time, 5 times/week, and the children in both groups were treated for 6 months and	FAD，Children's Sensory Integration Scale
Huihe Li2005	SID	3.5~13.5	108	Sensory integration training	The time is 1.5~2h, 3 times a week, and the course of treatment is determined according to the degree of disorder and individual differences of the child. Generally, it is 3~5 courses of treatment, and each course of treatment is 2O times. The training time of severe children needs to be	Sensory Integration Development Assessment Scale，Rutter Behavior Rating Scale
Huizhi Li et al2011	ADHD	6～11	72	Pharmacological Ritalin Treatment + Sensory Integration Training VS Pharmacological Ritalin	Each training session is 40 minutes, 5~6 times a week, 20 times is 1 course of treatment, a total of 3 courses of training.	Children's Sensory Integration Development Scale，DSM—IV— R
Meng Li2023	ASD	3~10	150	Speech Training + Sensory Integration Training VS Speech Training	30 min/time, 3 times/week, individual training + group activities, 3 times/week, 10 months	Childhood Autism Behavior Rating Scale，WISC，ATEC，Sensory Integration Dysfunction Scale
Wenhan Yin et al2021	ASD	3~4	60	Conventional rehabilitation + vestibular activation training versus	In addition to 2 sessions of ABA per day, all other items are 1 session per day for 12 weeks, and you can rest halfway after every 4 weeks of treatment, the rest time does not	Children's Sensory Integration Development Scale，ABC
Qiaoyan Yu et al2020	SID	3~6	27	Gymnastics rehabilitation, physical activity VS none	60 minutes per session, 3 times a week for 16 weeks	Health Examination，Children's Sensory Integration Development Assessment Scale

3.3. Meta-Analysis Results

3.3.1 Effects of motor intervention on vestibular function in children with sensory integration disorders

A total of 18 papers have been published on the vestibular function indicators of children with sensory integration disorders before and after the intervention, and after the test of heterogeneity, it was shown that there was heterogeneity between the studies (I^2=79%,P<0.001) therefore the random effects model was used for the analysis. Vestibular function scores of children with sensory integration disorders in the motor intervention group were higher in the experimental group than in the control group and the difference was statistically significant.

3.3.2 The effect of exercise intervention on tactile defence in children with sensory integration disorder

A total of 18 papers have been published on the tactile defence indicators of children with sensory integration disorder before and after intervention, and after the test for heterogeneity, it was shown that there was heterogeneity between the studies (I^2=75%,P<0.001) Therefore, a random effects model was used for the analysis. The tactile defence scores of the children with sensory integration disorder in the motor intervention group were higher than those of the control group and the difference was statistically significant.

3.3.3 Effect of motor intervention on proprioception in children with sensory integration disorders

A total of 18 studies expressed the tactile defense indicators of children with sensory integration disorder before and after the intervention, and after the heterogeneity test, it was shown that there was heterogeneity between the studies (I^2=75%, P<0.001), so the random-effects model was used for analysis. The proprioceptive score of children with sensory integration disorder in the motor intervention group was higher than that in the control group, and the difference was statistically significant.

3.3.4 Effect of motor intervention on learning ability in children with sensory integration disorders

ISSN: 1813-4890

A total of 18 studies expressed the tactile defense indicators of children with sensory integration disorder before and after the intervention, and after the heterogeneity test, it was shown that there was heterogeneity between the studies (I^2=99%, P<0.001), so the random-effects model was used for analysis. The learning ability score of children with sensory integration disorder in the motor intervention group was higher than that in the control group, and the difference was statistically significant.

3.4. Subgroup analysis

3.4.1 Subgroup analysis of different affected populations

Subgroup analyses based on whether children are defined as sensory integration disorders showed that exercise interventions had a significant effect on sensory integration in both groups, and had a better effect on children without sensory integration disorders, as shown in Table 2.

Table 2 Subgroup analysis of different affected populations

Subgroups	category	Studies	I^2	SMD,95%Cl	P
SID	a	10	82	0.67(0.54，0.79）	P＜0.00001
	b	10	81	0.92(0.79，1.05）	P＜0.00001
	c	10	73	0.73(0.60，0.85）	P＜0.00001
	d	7	96	0.76(0.61，0.90）	P＜0.00001
Non SID	a	8	80	0.88(0.70，1.06）	P＜0.00001
	b	8	79	1.03(0.85，1.21）	P＜0.00001
	c	8	77	1.10(0.93，1.26）	P＜0.00001
	d	5	76	0.97(0.73，1.22）	P＜0.00001

Vestibular Balance:a;Tactile Defensiveness :b;Proprioceptive Function:c;Learning Ability:d

3.4.2 Subgroup analysis of different interventions

Subgroup analysis was conducted according to different interventions, which were divided into single intervention methods and compound intervention methods. The results showed that exercise intervention had a significant effect on the sensory integration ability of both groups, and the results of a single intervention were more significant, as shown in Table 3.

Table 3 Subgroup analysis of different interventions

Subgroups	**category**	**Studies**	**I^2**	**SMD,95%Cl**	**P**
Composite intervention strategies	a	10	81	0.64(0.52，0.77）	P＜0.00001
	b	10	64	0.93(0.81，1.06）	P＜0.00001
	c	10	72	0.78(0.65，0.91）	P＜0.00001
	d	6	80	0.72(0.56，0.88）	P＜0.00001
Single means of intervention	a	8	80	0.94(0.76，1.13）	P＜0.00001
	b	8	88	1.00(0.82，1.19）	P＜0.00001
	c	8	82	1.01(0.82，1.19）	P＜0.00001
	d	6	97	0.97(0.77，1.18）	P＜0.00001

Vestibular Balance:a;Tactile Defensiveness :b;Proprioceptive Function:c;Learning Ability:d

3.4.3 Subgroup analysis by age group

According to the age of the children, the subgroup analysis was divided into 6 years old and 6~11 years old, and the results showed that the exercise intervention had a significant effect on the sensory integration ability of the two groups, but the intervention effect was better for children over 6 years old, which may be due to the influence of factors such as intervention time, cycle and cooperation. This is shown in Table 4.

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Table 4 Subgroup analysis by age group

Subgroups	category	Studies	I^2	SMD，95%Cl	P
＜6 years old	a	4	69	0.89(0.36，1.42）	P＜0.00001
	b	4	41	0.94(0.55，1.32）	P＜0.00001
	c	4	52	0.85(0.43，1.27）	P＜0.00001
	d	2	65	1.03(0.38，1.67）	P＜0.00001
6-11 years old	a	4	94	1.29(0.46，2.12）	P＜0.00001
	b	4	92	1.41(0.69，2.14）	P＜0.00001
	c	4	90	1.12(0.46，1.77）	P＜0.00001
	d	3	89	1.07(0.23，1.90）	P＜0.00001

Vestibular Balance:a;Tactile Defensiveness :b;Proprioceptive Function:c;Learning Ability:d

3.4.4 Subgroup analysis of different intervention cycles

According to the length of the intervention period, the subgroup analysis was divided into greater than or equal to 6 months and less than 6 months, and the results of subgroup analysis showed that after exercise intervention, the sensory integration ability of both groups had a significant impact, and the intervention effect greater than or equal to 6 months was better. This is shown in Table5.

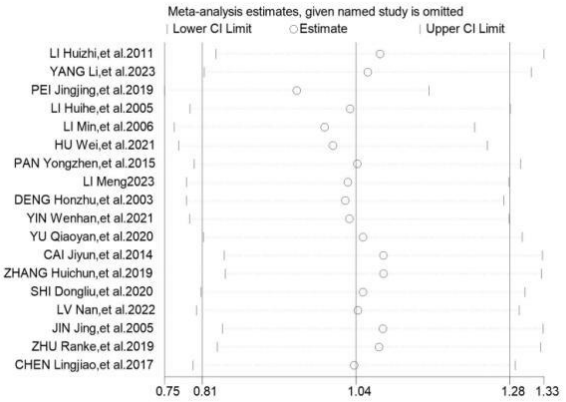
Table5 Subgroup analysis of different intervention cycles

Subgroups	category	Studies	I^2	SMD,95%Cl	P
≥6 months	a	10	83	1.09(0.70，1.48）	P＜0.00001
	b	10	86	1.31(0.87，1.75）	P＜0.00001
	c	10	81	1.25(0.88，1.63）	P＜0.00001
	d	6	87	1.38(0.74，2.01）	P＜0.00001
<6 months	a	8	79	0.86(0.52，1.20）	P＜0.00001
	b	8	49	0.90(0.68，1.12）	P＜0.00001
	c	8	50	0.76(0.54，0.98）	P＜0.00001
	d	6	58	0.70(0.45，0.96）	P＜0.00001

Vestibular Balance:a;Tactile Defensiveness :b;Proprioceptive Function:c;Learning Ability:d

3.5. Sensitivity analysis

Sensitivity analysis used Stata to analyze the sensitivity of the four dimensions of sensory integration disorder, as shown in the figure, the results showed that the outcome indicators were distributed on both sides of the midline, and the sensitivity of the four dimensions was stronger.



ISSN: 1813-4890

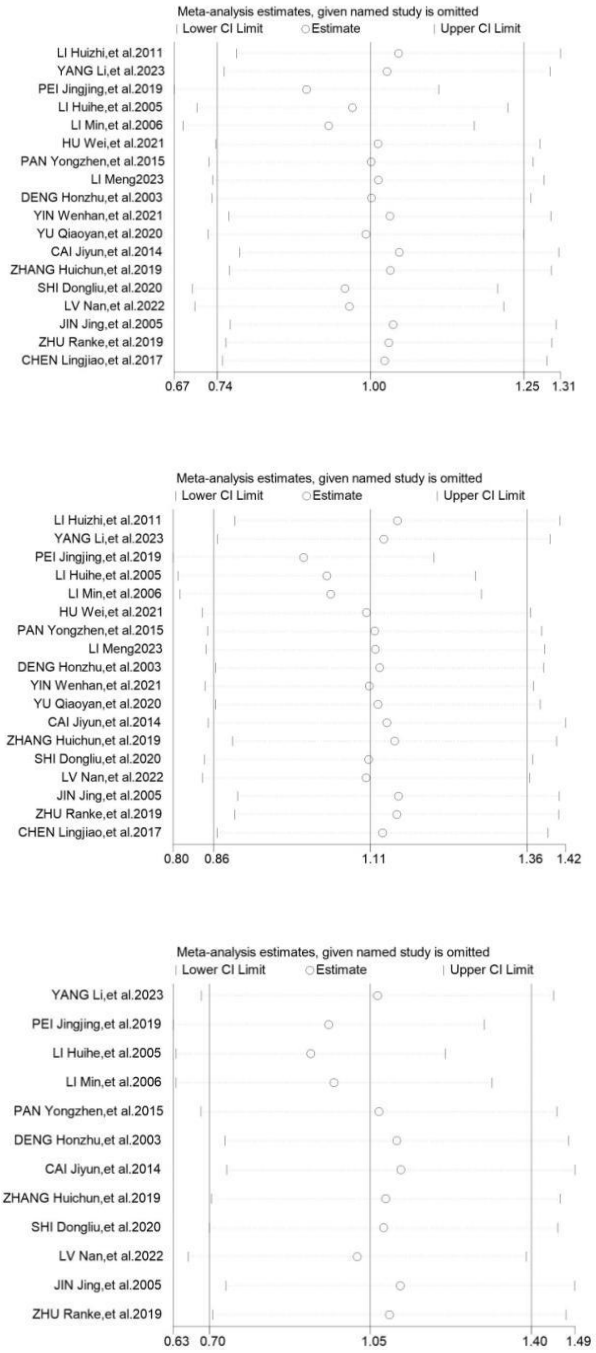


Figure 3 Sensitivity Analysis of the Impact of Different Exercises on a,b,c,d

3.6. Publish offset analysis

The funnel diagram of tactile defense and proprioception affected by motor intervention in children with sensory integration disorder was basically symmetrical, and there was no obvious bias. See the figure for details, and the results of vestibular imbalance and learning ability funnel diagram suggest that there is a certain publication bias. which can be seen in Figure 4.

ISSN: 1813-4890

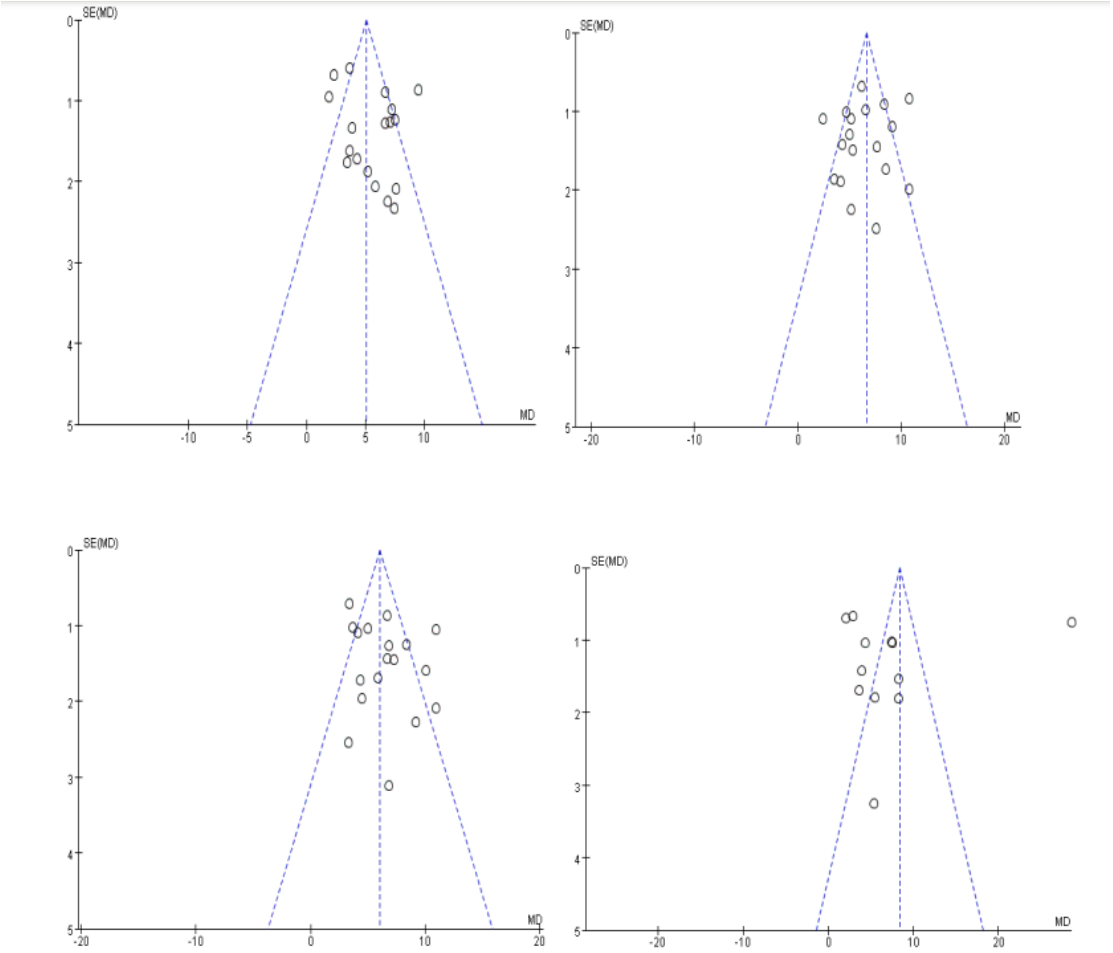


Figure 4 Publish offset analysis of a,b,c,d

4. Discussion

A total of 18 articles were included in this study, including the changes of vestibular dysfunction, tactile overdefense, proprioceptive disorder, and insufficient learning ability in children before and after exercise intervention, in order to explore the effect of motor intervention on children's sensory integration ability. The results showed that exercise intervention could improve children's vestibular balance function, tactile defense function, proprioceptive function, and learning ability, and the improvement degree of each dimension in the experimental group was significantly better than that of the control group, indicating that the improvement effect of exercise intervention was better. Exercise intervention can also effectively improve the symptoms of loneliness in children.

Twelve of the studies had data on the improvement of learning ability, and the results showed that motor intervention had a positive effect on vestibular imbalance, tactile defense, proprioception, and learning ability, which was consistent with the conclusions of all included literature. Six of the studies in the study subjects were children with autism, and the results showed that exercise intervention could effectively improve the symptoms of autism, which was consistent with the beneficial results of physical activity in the meta-analysis of related studies.

Children with sensory integration disorder usually manifest as dysfunction in learning, concentration, postural control, fine motor coordination, emotions, life functions and other aspects. Severe interpersonal disorders that lead to persistent learning difficulties, behavioral problems, low self-esteem and inability to communicate and interact with others normally, and

ISSN: 1813-4890

have no friends. In the long run, it will seriously affect its quality of life and limit communication after growth, and 1-6 years old is a critical period for brain development and personality formation, scholar also believes that the prevention period of sensory integration disorder is 0-3 years old, 3-6 years old is the best treatment period, and 6-12 years old is the compensation period， Intervention during this period will achieve better results, and some studies have pointed out that sensory integration training promotes the formation of a healthy personality in preschool children[viii]。According to the subgroup analysis, the subgroup analysis of different ages showed that the intervention effect was better in the age group of 6-11 years, which was inconsistent with the better intervention effect in the period of 3-6 years old, which showed that the intervention effect in the make-up period seemed to be better, which may be related to the intervention time, cycle, parents' attention and children's cooperation. However, it should not be ignored that the stage of 1-6 years old is a critical period for the development of children in all aspects, and in this critical period, it is necessary to pay attention to the development of children's abilities in all aspects, and the development of sensory integration ability will affect the development of children's learning and social skills. Through sensory integration training, it can not only improve children's physical motor ability, but also fundamentally solve the problem of children's sensory integration disorder.At the same time, subgroup analysis of different intervention cycles showed that for children with sensory integration disorder, the longer the cycle, the better the intervention effect, and the above other studies found that the younger the child, the higher the intelligence level, the longer the training time, and the higher the parental attention, the better the training effect[ix]。Analysis of different population subgroups showed that compared with children with non-sensory dysregulation, the intervention effect of children with non-sensory integration disorder was better, which may be related to the degree of sensory integration disorder, but exercise intervention could promote the development of their sensory integration ability and improve symptoms. It is worth noting that with the development of society, the improvement of living standards, and the change of education methods, the above diseases are showing an upward trend[11]， It may be related to the child's sensory integration disorder and gender, age, living area, gestational age at delivery, history of vaginal bleeding during pregnancy, parental educational attitude, and parental cultural level[12]。There was no significant difference in the intervention effect between exercise intervention and exercise intervention and other auxiliary means. This paper includes a number of studies comparing sensory integration training with other interventions compared with sensory integration training alone[24,25]， It shows that multiple stimuli are more effective than sensory integration training alone, because sensory integration is a very complex mechanism, which can develop faster under the stimulation of multiple factors. Among them, personalized vestibular training can significantly improve children's vestibular function compared with other dimensions. This can be used as an idea to adopt this more targeted measure in the formulation of future intervention plans.

5. Conclusion

In summary, exercise intervention can improve children's sensory integration abilities, with varying effects observed across different age groups, intervention methods, and populations. Therefore, future interventions should develop more personalized programs based on the specific conditions of each child.

6. Limitation

The limitations of this study include: (1) the number of included studies was small, only 18 articles were included, and it was not a fully randomized controlled trial. (2) The included

literature is all published Chinese literature, and there is no foreign language literature, which may be related to the fact that sensory integration disorder is not presented as an independent disease unit abroad, so there may be a certain risk of publication bias. (3) All the literature was included, and all the results were positive, but it was related to the fact that sensory integration ability will improve with age even without intervention, so it will be supplemented with exercise stimulation to get better results. (4) This study did not conduct subgroup analysis of each dimension of sensory integration disorder, and could not explain which of the four dimensions was most significantly improved by motor intervention.

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