

Indoor Motor Exercise Regimens Improve Social Cognition in Children with Autism Spectrum Disorder: A Systematic Review

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Abstract

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterised by persistent deficits in social communication and social interaction and restricted, repetitive patterns of behaviour, interests or activities. This systematic review is conducted to analyse the effects of motor exercises on the improvement of social cognition among autistic children aged between 4 to 12 years old. PRISMA guidelines and NHLBI, NIH critical appraisal tool were utilised in this review. The search for studies were made in PubMed, Ebsco Host as well as Google scholar and finally 11 articles were included in the systematic review. This study demonstrated that impact of physical activity intervention (table tennis) has the highest efficacy in improving social cognition among autistic children. According to other studies throwing ball with two hands, standing on one leg, jumping zigzag, and balancing also has some significant effect in improving social cognition among ASD kids. Studies shows that rock climbing, trampoline jumping and gymnasium exercise has less effect on improvement of social skills. According to the study, video games mostly increase attention by requiring players to engage in face to face interactions. This systematic review concluded that indoor exercises have positive impacts on autistic children to improve social cognition by either biological or non-biological ways.

Keywords: Motor exercise, social cognition, autism spectrum disorder, children, systemic review.

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INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterised by persistent deficits in social communication and social interaction and restricted, repetitive patterns of behaviour, interests or activities (1). The prevalence of ASD rising worldwide with 1 in 160 people affected (2), while recent prevalence estimates in the US run as high as 2.22% (3). As autism is understood as a “spectrum disorder”, each autistic person has different strengths and skills. this will be influenced by genetic or environmental factors. Moreover, the way they think, learn, and solve problems can vary from one another. Therefore, they will be either highly skilled or severely challenged who need constant

care and support. There are few exceptional people with autistic syndrome having outstanding talents and skills (4).

The American Psychiatric Association (APA) has updated the characteristics of ASD in the Diagnostic and Statistical Manual of Mental Disorders (5) (DSM, 2013) to include (a) social interaction and communication and (b) restricted, repetitive patterns of behaviours, interests, or activities.

As suggested by a research published in 1998, the main factor for social cognitive deficit in autistics is due to low plasma oxytocin level which is the hormone responsible for social behaviours (6). Thus, as exercises are commonly known for increasing oxytocin level, we are

interested in studies that used exercise interventions in improving social cognition of autistic children.

As shown by the studies reviewed (7,8), exercises improved social cognition and social communication among autistic children through various mechanisms. Studies also stated that bicycle riding is an important developmental skill supporting adaptive functioning to children with ASD (9). Physical activities such as martial arts and SPARK (Sports, Play and Active Recreation for kids) able to increase the synthesis of serotonin and oxytocin which play vital roles in the social skills and behaviour (10). Moreover, treadmill walk workout is said to upregulate cerebral oxygenation and co-activate prefrontal lobe which is dominant for cognitive processes (11). Other physical activities such as jogging and basketball training proven to develop social cognition among the children by creating cooperation, verbal or non-verbal communication, eye contacts, problem solving skills.

Study shows that physical education program conducted in gymnasium (12,13) will result significant improvement after intervention. Another study prove that paying attention during the session of rhythm (14) and robot group will improve in body coordination (15) and control. As suggested that videogames (16) are also considered as exercise. Studies suggested that video games specifically improve social attention by enhancing eye gaze and facial engagement among autistic children.

Studies also suggest that indoor training of SPARK (kicking ,throwing ball) (3) will improve fine motor skill as compared with the control group. Another study evaluates the effect of table tennis (17) in 12 week which prove that there is improvement of experimental group as compare with control group. Experimental group shows much proficiency on motor skills. A Quasi experimental design was conducted to prove the effect of mini basketball training (18) trampoline jumping (19) program and its effect on improvement in social awareness, social cognition.

Therefore, this review is conducted to systematically analyse the impact of exercises (table tennis, gymnasium exercise, trampoline jumping, jogging, video games, exergaming, basketball training, adventure programmes, circuit-based workouts, and SPARK) on the improvement of social cognition among autistic children aged 4-12 years old.

Objectives

To evaluate the impact of indoor /classroom motor exercises on improving social cognition among autistic children aged 4-12 years old.

Methods

This study is sanctioned by Perdana University Institutional Review Board (PU-IRB). The study is ethics exempted. This systematic review is conducted according to Preferred Meta-Analyse (PRISMA) 2009. The PRISMA protocols on reporting systematic review is strictly followed by utilising the PRISMA statement (PRISMA checklist 2009).

Inclusion & exclusion criteria

The inclusion criteria for this systematic review were Children diagnosed with autism spectrum disorder, aged 4-12 years old. Main intervention is indoor/classroom Aerobic exercises, studies with or without comparison group, studies that compared exercise intervention group with non-exercise intervention group, studies that assessed outcomes based on social cognition (social communication, emotional adaptation, social behaviour, social skills, emotional regulation, behavioural functioning, social attention).

However, studies were excluded based on criteria: incompatible age range of participants, systematic review and meta-analysis, difference in outcome assessed, non-exercise intervention as main intervention, articles with only abstract and articles which are published in language other than English.

Information sources

The following databases were used for this review: PubMed, EBSCO Host and Google Scholar.

The keywords used for the searching of articles in the databases were as follows: (Autism or Autism spectrum disorder or ASD and aerobic exercise, indoor exercise AND social Cognition or social intelligence).

Study selection

Eligible studies were reviewed and screened. Firstly, author reviewed the titles and abstracts of the studies and sort them according to relevancy. Relevant articles were included for further review. Then author assessed the

articles, screened based on the titles and abstracts and provided justification for eligibility.

The flow chart of study selection was constructed based on PRISMA flow chart diagram (Figure 1). The flowchart consisted of 4 stages: identification, screening, eligibility and included studies. From the databases, 426 articles were identified using keywords. During screening, duplicates were removed and resulted in 391 articles. Then, 98 articles were screened based on title and abstract and 24 articles were excluded as they do not meet the selection criteria. For eligibility, remaining 11 articles underwent full-text critical appraisal. Finally, 11 articles were included in this systematic review.

Assessment of risk bias

All articles were critically appraised according to the Study Quality Assessment by National Heart, Lung and Blood Institute (NHLBI, NIH) checklist⁸. Articles were appraised based on the study types. The criteria set for randomised controlled studies were study described as

randomised, adequate randomisation, presence of allocation concealment, binding, group similar at baseline, overall dropout, participants' adherence, avoiding other intervention, reliable measures, power calculation, priorly mentioned outcome and intention to treat analysis. The criteria set for case-control studies differ in the aspects of clear research question, specified study population, sample size justification, differentiation of case and control, random selection, use of concurrent control and statistical analysis. Lastly, criteria set for case studies differ from controlled studies in the fronts of case consecutive, comparable subjects, describing intervention, adequate follow-ups and describing results.

Data extraction

The review of the full articles has been conducted and data was extracted and arranged in the tables using Microsoft Word. The characteristics of the studies were arranged in Table 1 and summarised result of the articles. The criteria for the data extraction were developed based on research objective.

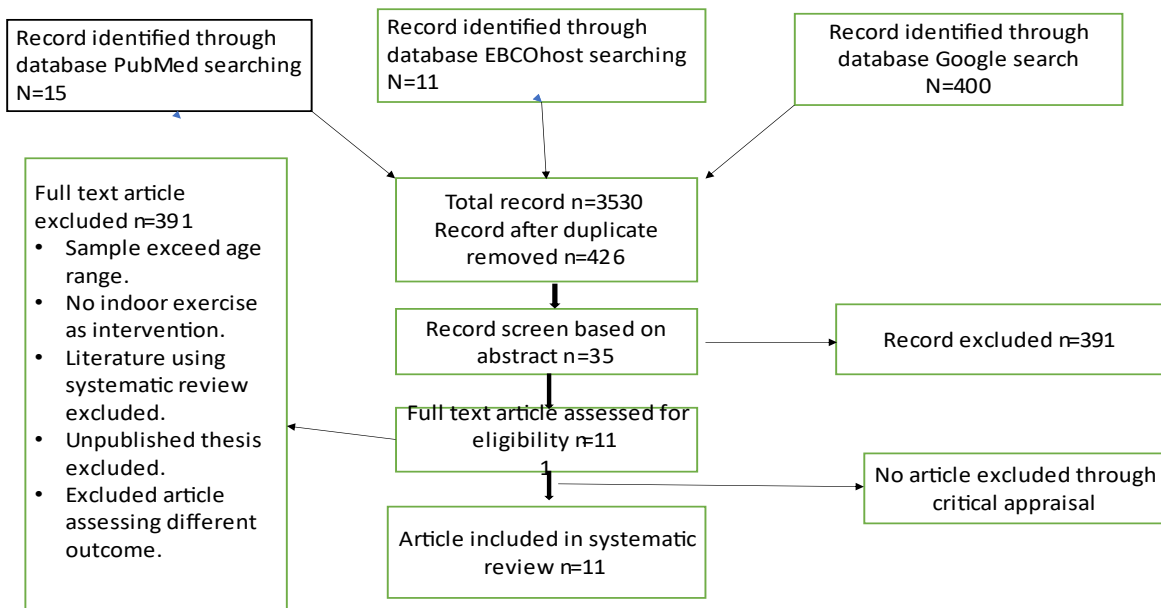


Figure 1: Flow chart of study selection

Results

Risk of bias within studies

All moderate or high qualities articles were selected. The tables of quality assessment are attached in appendix 3.

Table 1 Study Characteristics

The characteristics of studies are tabulated in Table 1.

Most of the studies used as pre/post-test designed (3,12,13,16,17,19–21). One study used Quasi experiment (18) also one study is RCT (15) design.

The study with largest sample size (37) used physical education program in gymnasium. None of the studies have equal ratio of male to female participants and all the studies have majority of male participants. Articles were chosen as high quality and with moderate quality.

Table 1: Characteristics of the studies.

Author (Year)	Study type	Participants	Age range	Intervention approach	Intervention length	Settings	Outcome measures	Results
Edwards et al(16)	Pre- and post-test experimental design	N = 30 (11 ASD, 8m/3f; 19 TD, 10m/9f)	6–10 years (ASD =7.64 ±1.12 ; TD = 7.89 ± 1.45)	Active Video Games (AVGs) like Kinect Sports Season 1, Kinect Sports Season 2, Sports Rivals and Kinect Adventures (TD group only)	ASD = 6 session (45/60 min each one, 3 times per week for 2 weeks) TD = 6 session (50 min each one, once a week for 6 weeks)	For ASD at home, for TD group at school during lunch time	• Test of Gross Motor Development-3 (TGMD-3) for OC (object control) skill improvement; • Pictorial Scale of Perceived Movement Skill Competence (PMSC) for perceived OC skills.	There was no increase between pre- and postintervention for actual OC skill both in ASD and in TD group. Only in children with ASD, there was an increase of perception of skill.
Hassani et al.(3)	Pre-/posttest design	30 ASD (10f/20m) 3 groups: EG-training 1 (4f/6m); EG-training 2 (3f/8m); CG (3f/6m)	8–11 years (EG-training 1 = 9.10 ± 0.87; EG-training 2 = 8.55 ± 0.68; CG = 8.70 ± 0.70)	• Training 1- SPARK: this protocol consisted of ten minutes for warm-up and 40 min for MS like balance skills, locomotor skills such • Training 2—I Can Have a Physical Literacy (ICPL): this program focuses on MS like locomotor, balance, kicking, throwing, and using of various tools such as visual cards	Sixteen indoor sessions, with two sessions of 60 min each per week performed after school.	Sport arena	Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)	Both treatments incremented gross MS in comparison with the control group, with a major effect of ICPL group. Interestingly ICPL training also improved fine MS, unlike SPARK training.

Henderso n et al(12)	Pre- /posttest design	37 ASD (35m, 2f)	5–12 (8.4 ± 2.06)	Physical education program targeting the six locomotor and six object control skills of the TGMD-2	40 min twice a week for six months, total: 40 classes	Gymnasiu m at a center for children with ASD	Test of Gross Motor Developmen t-2 (TGMD- 2)	Significant improvement after intervention for both gross motor skills and object control skills.
Ketcheso n et al(13)	Pre-/post- follow-up test design	N = 20 ASD 2 groups: EG N = 11 (2f/9m); CT N = 9 (3f/6m)	4–6 years (EG = 4.87 ± 0.61; CG = 5.04 ± 0.61)	The intervention implies a weekly rotation between the Test of Gross Motor Development-2 (TGMD-2) subtests: locomotor skills and object control skills, using the eight components from the Classroom Pivotal Response Teaching (CPRT) manual as the framework for delivery of instruction	4 h per day, 5 days per week for 8 weeks	Gymnasiu m and outdoor environme nt	• Test of Gross Motor Developmen t-2 (TGMD- 2); • Physical Activity monitor wearable; • Playground Observation of Peer Engagement (POPE), only for EG	Significant increase in motor proficiency in EG (locomotor skills, object control and gross quotient TGMD-2) compared with CG. A decrease in solitary scale in POPE was found. For all levels of PA, no significant group differences were observed. For joint engagement, parallel play and onlooking, no significant effects of time were found.
Srinivasa n et al. (14)	RCT; pre- /post-test	N = 36 ASD 3 groups: EG1 N = 12 (2f/10m) ; EG2 N = 12 (1f/11m) ; CG N = 12 (1f/11m).	5–12 years (EG1 =7.88 ±2.56 ; EG2 = 7.52 ± 2.22; CG = 7.36 ± 2.02)	In the Rhythm and Robot group, gross motor skills including balance, bilateral coordination, imitation, interpersonal synchrony, and manual dexterity were trained whereas in the comparison group fine motor skills such as symmetrical and asymmetrical grips and pinches, coloring,	32 sessions (16 expert and 16 parent sessions) of 45 min each one over 8 weeks	Participant s' home	• Bruininks- Oseretsky Test of Motor Proficiency (BOT-2); • Training- Specific Test of Imitation/Pra xis; • Training- Specific Test of Interpersonal Synchrony.	Improvements in body coordination for both rhythm and robot group. Improvements on the fine manual control composite for the control group. Improvements on Imitation/praxis for all groups and on interpersonal synchrony for the two EGs. No improvement in fine motor performance for both rhythm and robot group. No

				drawing, cutting, and gluing were promoted. In all three groups, training enhanced social communication skills.				improvement in the body coordination composite for the control group.
Brand et al.(20)	pre-post	N=10	ASD: N = 10 (ages 7–13, 5 males ; 6A, 3AS, 1 HFA SD)	explore if aerobic and motor skills training intervention lead to positive changes in sleep and motor skills	Motor skills: recorded each session, ball skills and balancing	Classroom practice	aerobic exercise and motor skills training: 3x/week for 3 weeks, 30 min biking, 30-min coordination and balance training	Intervention improved specific motor skills†† (catching, throwing, and balancing) - Improved objectively assessed sleep on nights following PA††
Kaplan-Reimer et al. (21)	Pre-post	ASD: N = 2 (ages 11 and 6, both female)	11 and 6, both female	Evaluate use of an intervention package for teaching indoor rock climbing. Non concurrent multiple baseline design across participants	Rock climbing: 45-min sessions, 3x/week	teaching indoor rock climbing	observational: Did participants grab correct hold color on path 1 outcome	Both participants successfully learned how to rock climb
Neely et al. (19)	Pre-post	ASD: N = 2 (ages 7–8, 1 male)	7-8 age	Evaluate effects of antecedent physical exercise on stereotypy and academic engagement.	trampoline jumping jumped until specified level of satiation prior to instructional session 3x/week	Trampoline jumping	Stereotypy: 10-s partial interval recording procedure Academic engagement: 10s-whole interval recording procedure 2 outcomes	- Greatest reduction in stereotypy was following exercise until satiation condition†† - Academic engagement was highest in the exercise until satiation condition
Pan et al. (22)	Pre-post	SD: N = 22 (ages 6–12, all male)	6-12 age	evaluate effects of PA intervention (table tennis exercise) on motor skill proficiency	table tennis: 12 weeks, 2x/week, 70-min/session	Indoor table tennis exercise	motor skill proficiency: The BOT-2 Executive function: WCST 2 outcomes	Improvements in the experimental vs. control group in total motor composite†† and executive functioning†† - Effect sustained for 12 weeks
J hum kenet,	Quasi-experimental design	25 males; 4 females	N=29	Mini basketball training program (MBTP) for 12		Indoor/classroom	Mini basketball training	Improvement in social awareness,

Cai et al. 2020(18)			weeks - each session for 40 min - include many levels of difficulty for teachers to choose appropriate level.	basketball activities.	improves social cognition by encouraging participants to imitate teachers' movement and communicate with peers and parents during the sessions.	social cognition, social communication, and autistic mannerisms	
Hassani, Fhimeh 2020(3)	post-test	NM	compare two programs on motor skills. Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)	Sixteen indoor sessions, with two sessions of 60 min each performed after school	<ul style="list-style-type: none"> • Training 1- SPARK: 10 minutes for warm-up and 40 min for MS like balance locomotor skills such • Training 2—I Can Have a Physical Literacy (ICPL) focuses on MS like locomotor, balance, kicking, throwing, and using of various tools such as visual cards 	Both treatments incremented gross MS in comparison with the control group, with a major effect of ICPL group. Interestingly ICPL training also improved fine MS, unlike SPARK training.	exercise programs designed to enable children with ASD to participate greatly improve their MS. PL may, therefore, provide a useful framework for PA programming

RCT: Randomised controlled trial; NA: Not applicable; NR: Not Reported; ASD: Autism Spectrum Disorder; DSM: Diagnostic and Statistical Manual of Mental Disorder; SCQ: Social Communication Questionnaire; ADOS: Autism Diagnostic Observation Schedule; GARS: Gilliam Autism Rating Scale; CARS: Childhood Autism Rating Scale

According to Cohen's D d=0.2 small effect, d=0.5 medium effect and d=0.8 large effect while when referring to Cohen's f, f=0.10 small effect, f=0.25 medium effect and f=0.40 large effect (23).

$$f = \sqrt{\frac{\eta_p^2}{1 - \eta_p^2}}$$

In terms of Cohen's f effect size, largest effect in cognitive outcome is shown in the study using mini-basketball training program (f=0.25).

Discussion

The current study analysed the impact of exercise regimen on social cognition of children aged 4-12 years old with ASD. The review suggested that Relationships Between Motor Skills and Social Cognition with Autism Spectrum Disorder kids have strong relation.

Mini-Basketball Training Program Improves Physical Fitness and Social Communication in Children with Autism Spectrum Disorders (18) Study explained that there is a significant difference between control and experimental group. Like shuttle run for experimental group $F=12.22$ and for control group 5.532 , long jump for experimental group $F=20.756$ and for control group $F=4.384$, SRS2(social response scale) for experimental group is $F=0.286$ and for control group is $F=0.001$. Study is with highest effect size ($d=1.59$) (22) and total improvement ($d=1.02$) (22), study explain that impact of physical activity (table tennis) intervention on motor skill proficiency.

Another study Impact of aerobic exercise on sleep and motor skills in children with autism spectrum disorders – a pilot study also predicts significant Cohen's d values. Throwing ball with two hands is $d =0.57-2.40$, standing on one leg, jumping zigzag and balancing was $d=0.51-5.16$.

Studies also mentioned that intense physical activities can synthesis more oxytocin and serotonin that can enhance cognition and socializing skills (21,28). The identification of hyperserotonemia in ASD is widespread and this demonstrate the relation between autism and serotonin is responsible for social, communication, repetitive and sensory behaviours (6). According to a theory, changes in peripheral serotonin regulating proteins lead to rise in serotonin concentration in the peripheral compartment. However, this cause impact in central serotonin compartment by inhibiting the development of serotonin neurons, leading to the anatomical and functional alterations of the brain and cause autism (38). Therefore, increasing the synthesis of serotonin through martial arts training could be a good therapeutic choice to induce social cognition among autistic children.

However, studies that used video games as intervention does not show as much efficiency as other interventions do. These studies commonly examine the eye gaze and engagement to face among the autistic children but did not explore more on communication, interaction, social behaviour, and emotional regulation (25). None of the videogame intervention provide biomechanism for the improvement of social cognition. A study mentioned that the efficacy of videogames on social attention modification could be affected by severity of the autism which means it is subjective (17). Even though

videogames are considered as exercises in this modern era, it is no equal to other physical exercises where the children move, sweat and interact with each other.

Exergames, on the other hand, demonstrate the effectiveness of videogames. Exergames are not your typical video games; they're made using cutting edge technology and requires players to be physically active to play (15). The exergames necessitate complete body mobility with players partaking in virtual sports.

According to one of the research evaluated, exergaming enhances executive function since it is linked to the development of working memory, metacognition, and plays an important role in the human cognitive system (28). The benefits of exergames on autistic people were explained in a report published in 2020. Report investigated the advantages of exergames on ASD kids in 5 studies with completely different styles (30). The researcher has proved that exergames will improve cognitive functions together with condition repetitive behaviour. (29) At last, he directed that health care professionals should be careful on applying the intervention on autistics due to insufficient evidence that support the statement he made.

Limitation

Many studies didn't provide the measurement of intensity (light, moderate or hard) of intervention clearly. It will be more helpful to know the effect precisely if the intensity is stated in the studies.

Conclusion

It is systematically verified that the exercise regimens improve social cognition among children aged 4-12 years old with ASD through different ways. It is recommended that in future studies, easy and cost-effective intervention can be used so that families with low socioeconomic status can manage to help their autistic children. Secondly, researchers should focus on the assessment of biological mechanisms on how exercise improves social cognition as this can result in long-term effect. At last, need to check whether the level of social cognition is influenced by exercise intensity or not, for that exercise should be monitored very closely.

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