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The sensory approaches on improving gross motor skills in children with autism spectrum disorder: a systematic review

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Abstract: Many children with Autism Spectrum Disorder (ASD) have considerable difficulty with gross motor skills. However, the effects of sensory approaches on improving gross motor behaviours in children with ASD from an academic standpoint are still unclear. This review offers a complete investigation of empirical papers on sensory methods, notably those on sensory integration therapy's gross motor skill benefits. A search on medical databases namely Academic Search Complete, Medline Complete, CINAHL, Scopus and PubMed was conducted to identify articles related to sensory in children with ASD. Using PRISMA, a total of 18 articles from 718 articles were selected for the final analytic procedure. After the screening, sorting and organising of the data using thematic analysis, conclusions were derived that were further analysed. Tactile and vestibular sensory techniques improve gross motor abilities, according to the findings. This review supports sensory techniques to increase gross motor skills in ASD children theoretically.

Keywords: sensory approaches; motor skills; children; autism spectrum disorder.

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1 Introduction

Autism Spectrum Disorder (ASD) is defined as ‘a range of neurodevelopmental conditions characterised by difficulties in social interaction, verbal and non-verbal communication and the presence of restricted and repetitive behaviour’ (American Psychiatric Association [APA] 2013). Children with ASD often have trouble processing, integrating and responding to sensory stimuli (Schaaf et al., 2014). There are various symptoms of autism, including sensory and motion deficits which contribute to the inconvenience in their lives (Wang et al., 2018). This is due to the delayed development of the children’s gross motor abilities such as running, galloping, and throwing. Although there are many interventions such as applied behaviour analysis, coaching, DIR/floortime, early Start Denver Model acupuncture (ESDM), play therapy and music therapy (Ferguson et al., 2019; Gerow et al., 2021; Hess, 2015; Waddington et al., 2021), the decision on the interventions depends on the children’s condition and therapist’s clinical judgement. Unfortunately, there is a limited number of interventions specifically on training gross motor skills in children with ASD. However, the sensory approach is a widely used intervention (Morimoto et al., 2021; Camarata et al., 2020) because its correlation with gross motor skills in children with ASD has been established in many articles (Schoen et al., 2019; Lang et al., 2012). Moreover, the effect of sensory approaches on motor skills has been extensively discussed (Karim and Mohammed, 2015; Kuliński and Nowicka, 2020; Günal and Bumin, 2007; May-Benson and Koomar, 2010), with the majority of articles strongly supporting a correlation between the sensory approach and the motor skills of children with ASD (Güenal and Bumin, 2007; May-Benson and Koomar, 2010; Abu-Dahab et al., 2013) and a minority of articles stating no clear evidence to support (Rogers and Ozonoff, 2005; Lang et al., 2012; Baranek, 2002).

Some therapeutic programmes include sensory rooms, sensory groups and sensory kits to assist children with ASD to improve their mental (e.g., emotional, cognitive) and physical conditions (e.g., fine motor, gross motor) (Baranek, 2002). Sensory approaches include therapeutic strategies involving the senses (visual, auditory, gustatory, olfactory, tactile, vestibular and proprioceptive senses). In accordance with that, therapeutic programmes teach children with ASD to use their senses through sensory-stimulating activities. The programmes have evolved into a comprehensive and sensory approach treatment for children with ASD (Lecuona et al., 2017; May-Benson and Koomar, 2010; Lyons and Fitzgerald, 2007). The sensory approach is not only applicable to children with ASD but also to those with other neurodevelopmental conditions (e.g., Attention-

Deficit/Hyperactivity Disorder (ADHD), Neurodevelopmental Disorder (NDDs)) because the approach is intended for individuals with underdeveloped sensory systems and learning disabilities.

Sensory integration therapy is a clinic-based intervention that uses play-based sensory-motor activities to address sensory-motor factors specific to children (Dunbar et al., 2012). Current literature examines sensory as a deficit and outcome factor in children with ASD rather than an intervention factor (He et al., n.d.; Kirby et al., 2022; Fabbri-Destro et al., 2022) and considers sensory and motion as equal factors affecting the lives of children with ASD (Travers et al., 2022; Randell et al., 2022). On the other hand, while motor skills are essential skills that affect primary daily behaviours (Liu et al., 2021; Provost et al., 2007), children with ASD have motor abilities that differ from those of children with Typical Development (TD) (Kondo et al., 2003; Mache and Todd, 2016; Ozonoff et al., 2008) in terms of gross and fine motor skill development (Karim and Mohammed, 2015; Provost et al., 2007; Green et al., 2009). For instance, children with ASD have difficulties with their gross motion, which typically refers to movements involving coordinated action of multiple muscles and joints, such as running, jumping and throwing (Peck et al., 2017).

Balaji et al. (2022), Lang et al. (2012) and Barry and Burlew (2013) addressed sensory approaches as an intervention for children with ASD, with a focus on the overall improvement of their condition (gross motor, fine motor, cognitive, etc.). For example, Schoen et al. (2019), Schaaf et al. (2012) and Kashefimehr et al. (2018) used the sensory approach as the independent variable and the underlying condition of autism as the dependent variable and may include fine motor and gross motor skills. The initial reference to sensory-motor is in the context of the study of sensory and motor as a whole (Balaji et al., 2022; Purpura et al., 2022) rather than as separate entities.

Above all, there is a relative body of literature that demonstrates the enhancement of the sensory approach to various aspects of ASD, but the role and improvement of the approach for gross motor have not been fully elucidated. Omairi et al. (2022) indicated that sensory integration improves participation such as adaptive behaviours of children with ASD while (Donnellan et al., 2012) explores the symptoms of sensory and movement differences and the possible implications for children with ASD. The articles are significant in that they provide research ideas for enhancing the abilities of children with ASD with gross motor problems. Therefore, the objective of this review was to identify and describe sensory approaches that enhance gross motor skills in children with ASD in order to inform clinical intervention.

2 Materials and methods

A systematic review was conducted to evaluate sensory approaches that improve gross motor in children with ASD by examining and identifying the methods and results of related previous literature. To report this systematic review, the methodology followed the PRISMA statement's guidelines.

2.1 Selection criteria

In general, articles on the effect of sensory approaches on the gross motor skills of ASD children were included. The other selection criteria were articles with (i) children with

ASD as subjects, (ii) related to the gross motor or motion, (iii) mentioned sensory approaches, (iv) conducted from 2013 to 2023 and (v) included a viable control group. On the other hand, the exclusion criteria were as follows: (i) no full text available after the research team has exhausted all other options for retrieving the full text, (ii) non-English articles and (iii) grey literature format.

2.2 Search strategy and study selection

A thorough search was carried out using Academic Search Complete, MEDLINE Complete, CINAHL, Scopus and PubMed. The databases listed all identified articles that matched the primary search terms for pertinent trials were manually searched. The specific search strategy was: (autism OR autistic OR ASD OR Asperger OR ‘autism spectrum disorder’) and (‘sensory approaches’ OR ‘sensory integration’ OR ‘sensory training’ OR ‘sensory approaches training’ OR ‘sensory integration therapy’ OR ‘sensory processing’) and (‘gross motor’ OR ‘gross motor function’ OR ‘gross motor skills’). The complete text of pertinent articles was then obtained. After removing duplicate entries, two independent writers (Ma and Li) evaluated the retrieved articles for eligibility based on the inclusion criteria. Any discrepancies between authors were settled through a conversation until an agreement was reached.

2.3 Quality assessment

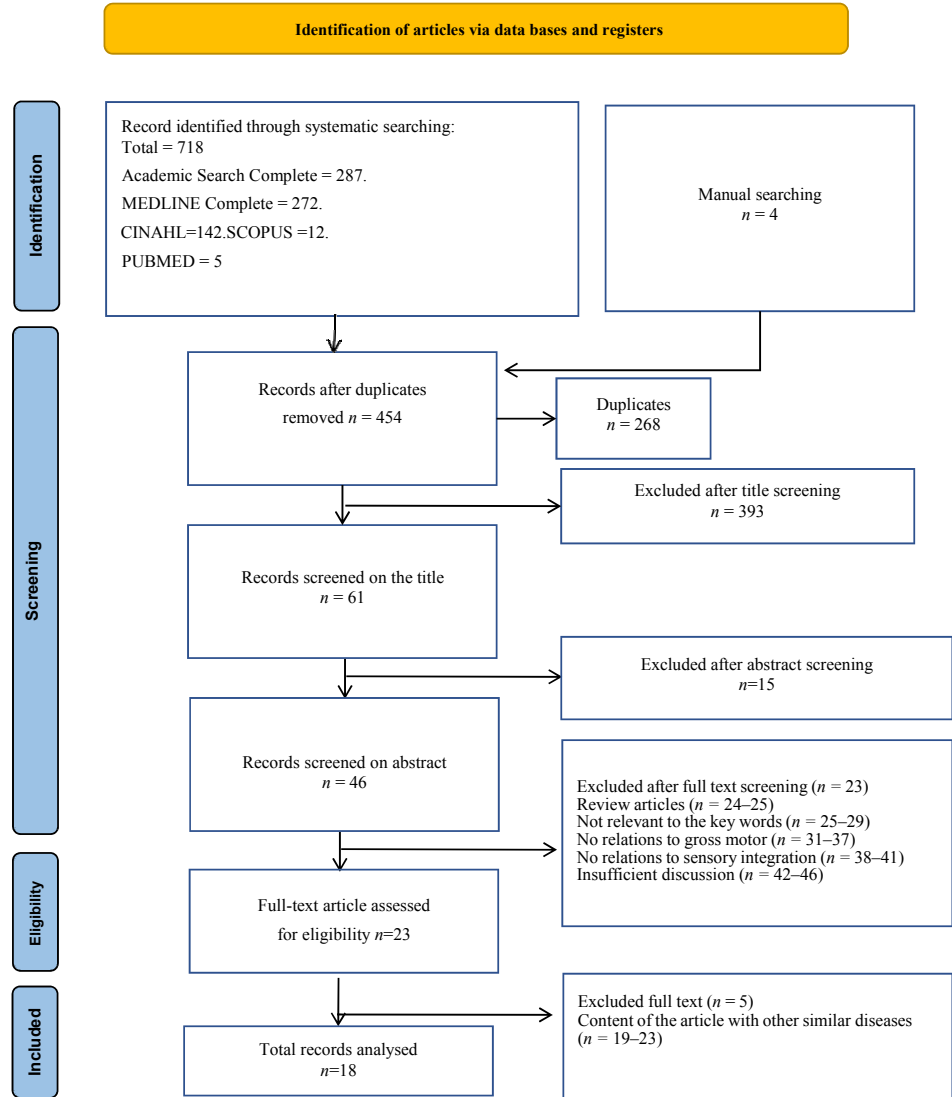
The data from this review could not be analysed using a uniform quantitative scale because (i) the conditions of ASD are anisotropic, (ii) children with ASD often present in a comprehensive manner and (iii) the localised and limited nature of the gross motor and sensory approaches data tested in the literature. Rather, the current review presented the detailed results in a separate graphical format.

The Crowe Critical Appraisal Tool (CCAT) is a qualitative assessment tool created to thoroughly evaluate various publications that use a wide range of qualitative and quantitative research designs, while ensuring acceptable validity and reliability (Crowe et al., 2011). CCAT requires researchers to be knowledgeable about study designs, sample methodologies, ethics, data gathering methods and statistical and non-statistical data processing approaches (Crowe, 2013). As a result, the first author is more acquainted with the research as the assessor at this stage. Following data extraction and quality evaluation, study features and outcomes were summarised in evidence tables and reported in a narrative synthesis of the findings.

2.4 Study selection

A total of nine (9) researchers independently conducted a database search on medical-related databases on 25 March 2023. The search through titles, keywords and abstracts in the databases yielded 718 articles from the last ten years (2013–2023). A total of 287 articles were from Academic Search Complete, 272 from MEDLINE Complete, 142 from CINAHL, 12 from SCOPUS and 5 from PUBMED. In addition, four (4) articles were obtained from manual searching.

Table 1 Screening flowchart



2.5 Data extraction

Data of sensory approaches from selected articles were retrieved and organised into a table of detailed research characteristics in the Excel spreadsheet under the headings of the author, publication year, place of origin, case and control characteristics (e.g., sample size, mean age, sex ratio and sensory approaches), research technique and measurement and results (including different data of effects on conclusions of qualitative and quantitative research articles). This process was completed after training.

Table 2 Characteristic reporting of individual articles

References		Case/Control participants			Research process		Outcomes (compared with control)	
Study country	Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method	Outcomes (compared with control)
1 (Ting, 2013)	32	7.8 (5–11)	26:6	To examine both sensory processing and motor skill performance	sensory processing	SSP–Short Sensory Profile MABC–2 – Movement Assessment Battery for Children–2	Experiment	1 Sensory processing is crucial to children's motor skill acquisition in early childhood 2 It is valuable to establish a strong sensory processing and motor performance foundation early on, to facilitate more complex motor-skill performance and learning later in life. 3 Children with ASD should be individually assessed so that educators can identify their special needs and develop interventions according to each child's unique situation.
2 (Holm et al., 2014)	3	86 6 (5–13)	3:0	To Examine Dosing and Generalisation to the Home and Community	Horseback Riding	ABC-C SRS SP-CQ	Case Design and Experiment	1 Dosing of therapeutic riding was associated positively with the magnitude of changes in target behaviours, but not the number of behavioural changes. 2 The effect of the sessions generalised positively to the home and community for physical Stereotyped behaviours and spontaneous verbalisation, but not for verbal stereotyped behaviours
3 (Karim and Mohammed, 2015)	34	4.43 ± 0.57 (3–6)	21:13	To assess gross motor skills and identify effectiveness of sensory integration	Sensory integration programme	PDMS-2	Experiment	1 The sensory integration therapy was effective in the treatment of autistic children as it helps those children to become more independent and participate in everyday activities.

Table 2 Characteristic reporting of individual articles (continued)

References		Case/Control participants			Research process			Outcomes (compared with control)	
Study country	Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method	Outcomes (compared with control)	
4 (Afzal and Manzoor, 2017)	1	8	1:0	To determine the effect of universal exercise unit on motor function.	universal exercise unit	paediatric evaluation inventory	Experiment	1 Physical therapy treatment combine with other techniques can improve the can improve motor function in a child with ASD.	
5 (Borgi et al., 2016)	28	8.6± 1.7 (6–12)		To discuss the effectiveness of a Standardised Equine-Assisted Therapy Prog	Equineassisted Therapy	VABS	semi-structured inter-view	1 It show a reduced planning time during problems solving task in experimental group at the end of the EAT programme. 2 with taking into account 'riding centre' variable, it represents a better character of equine-assisted therapy programmes and establishment of protocols that allow AAI to become an evidence-based practice for ASD.	
6 (Cascio et al., 2016)	33 ASD 20 DD 56 TD	8.2± 2.4 8.4± 2.5 6.7± 2.3		To discuss effects of Stimulus Material and Bodily Location	Ratings and examiner Code defensiveness	SEQ	Experiment	1 the similar ratings given by adults with and without ASD may reflect a developmental process of learning to inhibit negative affective response to touch in individuals with ASD. 2 significant correlation between current social impairment and behavioural coding of defensiveness at the two bodily sites innervated by the CT afferent system.	

Table 2 Characteristic reporting of individual articles (continued)

References		Case/Control participants		Research process		Outcomes (compared with control)			
Study country		Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method	Outcomes (compared with control)
7	(Columna et al., 2021)	8 ASD (Workshop) 7 ASD (Home Based)	7.25 ± 3.0 7.64 ± 2.5		To examine feasibility of parent-led FMS intervention with two groups, a home-based group and an in-person workshop group	fundamental motor Skill Parent-Mediated Intervention	TGMD-3	Experiment	1 the activity booklets, adapted equipment, and encouragement via text messages provided to the families helped facilitate physical activity participation among children with ASD. 2 participants in the workshop group also perceived the intervention as acceptable and feasible.
8	(Borgi et al., 2021)	19 ASD 19TD	6–12		To determine Behavioural and Physiological Indices of Stress in Domestic Horses	Equine-Assisted Intervention	self-administered scale	Experiment	1 Stress responses in horses involved in EAI's were not affected negatively by short EAI sessions with ASD children compared to TD children of the same age and experience. 2 Lack of novelty expectation during sessions with ASD children is likely to cause lower sympathetic tone, compared with TD.
9	(Wuang et al., 2020)	117	8.0 ± 3.0 5–13	75:42	To investigate the sensory integration and perceptual-motor performances in elementary school children with (ASD)	Sensory integration, visual perceptual skills,	Body - function--Bruininks Oseretsky of Motor Proficiency--Ed2 Visual Perception Skills--Ed3	Experiment	1 School-aged children with ASD had different levels of impairments on body function measures. 2 A significant effect for age and sex on some body functions and activity, correlation analyses indicated strong associations between body function and activity participation across settings in ASD.

Table 2 Characteristic reporting of individual articles (continued)

References	Case/Control participants			Research process		Outcomes (compared with control)			
	Study country	Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method	Outcomes (compared with control)
10	(Kulinski and Nowicka, 2020)	20ASD	3–10	3:1	To explore the effects of sensory integration therapy on selected fitness skills	Sensory integration programme	self-administered questionnaire	Survey	1 Sensory integration therapy contributes to improvement in motor, sensory, cognitive, emotional, communication. 2 Sensory integration therapy improves such fitness skills as throwing a ball, jumping on two legs, and catching ball. 3 Motor function improvements in autistic children depend on early initiation of therapy.
11	(Randell et al., 2019)	216 ASD	4–11		To determine impact of SIT on irritability and agitation.	Sensory integration programme	Aberrant Behaviour Checklist sub-scale ABC-I	Experiment	1 Results of this trial will provide high-quality evidence on the clinical and cost effectiveness of SIT aimed at improving behavioural, functional social, educational, and well-being outcomes for children and well-being outcomes for carers and families. Thereby maxi missing cost-effective roll-out.
12	(Lydon et al., 2017)	12TD 12HAS D 12LAS D	7.75 ± 0.55 7.44 ± 0.57 8.74 ± 0.59 (5–12)	3:9 0:1 2 2:10	To compare of behavioural intervention and sensory integration therapy	Sensory integration therapy (SIT) and behavioural intervention (BI)	self-administered scale on direct observation event recording	Experiment	1 ASD had impairments in gross and fine motor performance, praxis, bilateral coordination, and interpersonal synchrony. 2 Motor performance is correlate with intelligence but not with ASD severity. Praxis errors and time to completion strongly correlated with ASD severity but not intelligence. 3 The need for motor assessments and interventions to promote both motor and to include dyspraxia among the defining features.

Table 2 Characteristic reporting of individual articles (continued)

References	Case/Control participants			Research process			Outcomes (compared with control)	
	Study country	Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method
13 (Tse et al., 2021)	21 ASD	11.0 ± 1.4	17:4	To Investigate the matching relationship between Physical exercise and Stereotypical behaviour	Physical Exercise and Stereotypic Behaviour	self-administered scale	Experiment	1 The ball-tapping exercise was effective in reducing hand-flapping behaviours, whereas the jogging exercise was effective in reducing body rocking behaviours. 2 Exercise was effective in reducing the SB if it was matched with the specific SB.
14 (Valori et al., 2020)	4 children 5 adults	8.7 ± 1.2 (8–13) 28.8 ± 8.3 (23–39)	9:0	To investigate Sensorimotor Research Utilising Immersive Virtual Reality	Immersive Virtual Reality	Intra-class correlation (ICC).	Experiment	1 Inter-individual variability in sensorimotor functioning has a meaningful impact on the possibility for people with the heterogeneous conditions of ASD to be facilitated by perceiving, moving and therefore learning in IVR. 2 The use of an HMD to be acceptable and feasible with the present sample, indicating good potential for future research.

Table 2 Characteristic reporting of individual articles (continued)

References		Case/Control participants			Research process			Outcomes (compared with control)		
Study country	Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method			
15 (Tomchek et al., 2015)	322 autistic 67 PDD–NOS 11 as–Perger	4.1 ± 0.87 4.1 ± 0.88 4.1 ± 0.84 4.7 ± 0.86		to development Performance in ASD	Sensory Pattern	Short Sensory Profile (SSP)	Experiment	1	The sole sensory processing contributor to social behaviour and fine and gross motor skills was Sensory Seeking.	
								2	Taste and smell sensitivity and adaptive behaviour focused on feeding differences affecting mealtime routines in families with ASD.	
16 (LaFrance et al., 2015)	1 ASD	5	1:0	To treat for Stereotype	Auditory integration training	ABCBCA reversal design	Case study and Experiment	1	Intervention was given price of headphones and prescribed music.	
								2	Instruction time was lost as pursuing ineffective intervention.	
								3	The steady increasing trend in the occurrence of VS observed throughout the investigation suggests that the participant engaged in more stereotypical overall.	

Table 2 Characteristic reporting of individual articles (continued)

References	Case/Control participants			Research process			Outcomes (compared with control)		
	Study country	Sample size	Mean age Mean	F:M	Research objective	Sensory approaches	Measure tool details	Research method	Outcomes (compared with control)
17 (Chafar et al., 2022)	38ASD 36TD	9.57 ± 2.08 10.84 ± 2.91 6–14	25:13 21:15		To Assessment of sensory Integration and Balance quantitatively.	Biodex balance system (BBS)	m-CTSIB	Experiment	1 There was a significant impairment in postural control in children with ASD comparing to TD under static postural.
									2 The postural control testing revealed that a failure in the integration of sensory input from the visual and somatosensory afferent systems leads to postural instability in children with ASD.
									3 By better characterising the postural impairment associated with ASD using more objective tools such as BBS.
18 (Hocking et al., 2022)	37 ASD	5.8.8 6–12	32:5		To address the effects of SI and establish a model for RCT research,	Sensory processing disorder (SPD)	Sensory Processing Measure (SPM)	Experiment	1 Using SI interventions in children with ASD, although further research is necessary. 2 The progress toward individualised goals and a decrease in autistic mannerisms after SI.

Notes: Short Sensory Profile (SSP) Movement Assessment Battery for Children-2 (MABC-2). Aberrant Behaviour Checklist-Community (ABC-C) Social Responsiveness Scale (SRS) Sensory Profile-Caregiver Questionnaire (SP-CQ) Peabody Developmental Motor Scale (PDMS-2) Developmental Disabilities (DD). VABS (Vcom: Communication, Vdls: Daily Living Skills, Vsoc: Socialisation and Vms: Motor Skills), Sensory Experiences Questionnaire (SEQ) Gross Motor Development-3 (TGMID-3) General Motor Quotient (GMQ) Equine-Assisted Interventions (EAIs) Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery-VMI) Inter-Observer Agreement (IOA) Centre of Pressure (COP) Root Mean Square Displacement (RMS) Immersive Virtual Realities (IVR) Head-Mounted Displays (HMDs) Motor Stereotypy (MS) interobserver agreement (IOA) Vineland Adaptive Behaviour Scales, (The VABS-2) Goal Attainment Scaling (GAS) Social Responsiveness Scale (SRS) Sensory Processing Measure (SPM) Oseretsky of Motor Proficiency (OMP).

Table 3 The procession of CCTA

<i>Author</i>	<i>Preliminaries (0–5)</i>	<i>Introduction (0–5)</i>	<i>Design (0–5)</i>	<i>Sampling (0–5)</i>	<i>Data Collection (0–5)</i>	<i>Ethical Matters (0–5)</i>	<i>Results (0–5)</i>	<i>Discussion (0–5)</i>	<i>Total scoren (%)</i>
1 (Ting, 2013)	5	4	5	4	4	3	5	5	35(88%)
2 (Holm et al., 2014)	5	4	4	3	4	0	4	4	28(70%)
3 (Karim and Mohammed, 2015)	5	4	5	3	4	3	5	5	34(85%)
4 (Afzal and Manzoor, 2017)	4	4	4	3	3	3	4	4	29(73%)
5 (Borgi, et al., 2016)	4	5	4	4	4	1	4	4	30(75%)
6 (Cascio et al., 2016)	4	5	4	4	4	2	4	4	31(78%)
7 (Columna et al., 2021)	5	4	4	3	4	0	4	4	28(70%)
8 (Contalbrigo et al., 2021)	4	4	4	4	4	1	4	5	31(78%)
9 (Wuang et al., 2020)	5	5	3	5	3	4	4	4	33(83%)
10 (Kuliński and Nowicka, 2020)	5	5	3	4	3	4	4	4	32(80%)
11 (Randell et al., 2019)	3	4	4	3	3	3	4	5	29(79%)
12 (Lydon et al., 2017)	4	4	4	4	5	2	4	5	32(80%)
13 (Tse et al., 2021)	4	4	4	3	3	3	3	4	28(70%)
14 (Valori et al., 2020)	4	4	4	3	3	3	4	4	29(73%)
15 (Tomchek et al., 2015)	5	5	4	4	4	1	4	4	33(83%)
16 (LaFrance et al., 2015)	4	4	4	3	4	2	4	3	28(70%)
17 (Ghafar et al., 2022)	5	4	4	4	4	3	5	5	34(85%)
18 (Hocking et al., 2022)	5	4	5	4	4	3	5	5	35(88%)

2.6 Reliability analytical

The evaluation system for CCTA is compromised of the preliminaries, introduction, research design, sampling, data collection, ethics, results and discussion sections, each of which contributes one to five points to the total quality score, which ranges from 0 to 40. The articles in the current review demonstrated high inter-rater reliability of the total quality score (ICC = 78%).

3 Results

3.1 Assessment overview

Upon the screening and analysis of the retrieved articles, the articles were divided into three categories for further analysis. The first category consisting of articles 1, 3, 9, 10, 12, 15 and 17 discussed the quantitative relationship between sensory approaches, motor skills, and gross skills; the second category consisting of articles 2, 4, 5, 8 described the sensory approach as a form of sports such as equine-assisted interventions to complete the research; and the third category consisting of articles 6, 7, 11, 13, 14 and 18 discussed the effects of the training of a specific sensory approaches (e.g., vestibule and proprioception intervention) on a specific gross motor skill (e.g., balance).

3.2 Risk of bias

Two authors (Saiful and Li) assessed the methodological quality and bias risk of the articles included in this systematic review. Review Manager 5.4 was used to evaluate the quality of the articles, which included random sequence generation (selection bias), allocation concealment (selection bias), blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data (attrition bias), selective reporting (reporting bias) and other biases.

3.3 Quantitative analysis of possibilities

The fundamental purpose of utilising meta-analysis (quantitative analysis) is to explain the different findings in different articles. Conversely, there would be no need for the review if varied results were not obtained in a research field (Cochran and William, 1994). Despite the fact that the goal of this article was to identify the interventional effect of sensory integration therapy techniques on gross motor, none of the articles reviewed directly established the association. Therefore, this review commenced with a portion of the data in the articles. Also, the data were not totally consistent due to inconsistencies in sensory approaches measurement (e.g., Article 1 utilised SSP Short Sensory Profile while Article 2 utilised Sensory Profile-Caregiver Questionnaire (SP-CQ)), and inconsistencies in gross motion measurement scales (e.g., Article 1 utilised MABC-2 (Movement Assessment Battery for Children-2) while Article 3 developed own testing procedure). Furthermore, significant study gaps, particularly in terms of data, were found.

3.4 Thematic analysis

Quantitative data analysis, in particular a thematic analysis, was utilised in the current review to establish the effectiveness of sensory integration therapy on gross motor skills. The data was sorted under the following themes:

Theme 1 (Sensory Approaches): The sensory theory emphasises that tactile, proprioceptive and vestibular systems improve muscle tone, automatic reactions and emotional welfare (Karim and Mohammed, 2015). In comparison to normative data, articles generally show that 50% to 73% of children with ASD have significant motor deficits (Berkeley et al., 2001). Early articles discovered variations in gait between TD children and children with ASD (Vilensky et al., 1981).

- 1 *Visual sensitivity:* The visual and auditory systems were equally important to the other sensory systems as children mature and interact more with their surroundings (Karim and Mohammed, 2015). However, different effects of visual perceptual load on awareness of a task-relevant aural stimulation were observed in TD children and children with ASD (Tillmann et al., 2015; Diener et al., 2014; Norcia et al., 2021; Pierce et al., 2013).
- 2 *Auditory integration training:* The effectiveness of Auditory Integration Training (AIT) as a treatment for stereotypy was not established. In fact, AIT was inappropriate for a variety of reasons (LaFrance et al., 2015). Nevertheless, the degree of complexity needed to complete auditory activities, such as while completing auditory tasks, helped explain the pattern of performance and activity seen in children with ASD (Sokhadze et al., 2016).
- 3 *Tactile-perceptual skill:* Tactile-perceptual skill therapies include a variety of sensory training and manipulation games and exercises that emphasise speed and precision (Abu-Dahab et al., 2013). By modifying the child's tactile sensitivity, children with ASD could walk on various surfaces and stamp their feet to enhance their performance in gross motor skills (Ting, 2013). In comparison to proprioceptive and vestibular stimulations, tactile stimulation exhibits the most clinical evidence for reducing behavioural issues in children, including decreasing inattention and participation in the classroom and enhancing social skills (Yunus et al., 2015).
- 4 *Vestibular sensitivity:* The effects of sensory-based vestibular swing therapy were evaluated using posturography (Reinert et al., 2015; Travers et al., 2013). Changes were most obvious in the condition where sensory processing and integration of all inputs were maximised, as well as in the state where the targeted vestibular system was the most dependable (Reinert et al., 2015). A brief and sparse quantity of vestibular practice was utilised in the reviewed articles, but it was nevertheless helpful in enhancing skill learning in children with severe ASD (Katz-Nave et al., 2020; Zimmer and Desch, 2012; Ghafar et al., 2022). According to empirical research, the defective integration of vestibular, somatosensory and visual signals contributed to the increased postural sway seen in children with ASD (Ghafar et al., 2022).
- 5 *Proprioceptive sensitivity:* A probable interhemispheric disease is caused by proprioceptive impairment brought on by visual fixation issues that are influenced

by the muscular tone in connection to the subcortical and cortical regions. As a result, neuropsychomotor processes that supported a variety of motor skills and gestures were compromised in a number of articles (Paquet et al., 2019; Cappagli et al., 2017; Yunus et al., 2015). The proprioceptive system uses sensors in the joints, tendons, ligaments, connective tissue and muscles to interpret information on the position and movement of a body (Karim and Mohammed, 2015; Ghafar et al., 2022).

- 6) *ELAS*: Equine-Assisted Treatments (EATs) are complementary techniques for children with ASD because the techniques bring physical and psychological enrichment to them. The review discovered insufficient evidence to support the use of AIT as a treatment for stereotypy in children with ASD (Borgi et al., 2021a, 2021b; Holm et al., 2014; Borgi et al., 2016).

Theme 2 (Motor Skill): Motor skills are divided into perceptual skills, cognitive skills and linguistic abilities (Ozonoff et al., 2008; Thompson et al., 2017; Mache and Todd, 2016). Deficits in the development of motor skills and difficulties in sensory processing are not necessary features for the diagnosis of ASD. However, the delays, especially in early development, were the cause of concern (Travers et al., 2013; Alsaedi, 2020). The Total Motor Quotient (TMQ), which was regarded as the most accurate estimate of overall motor ability (Karim and Mohammed, 2015), was determined by adding the scores from the gross and fine motor subtests.

- 1) *Fine motor*: Children with ASD have poor fine motor skills that lower their quality of life (Thompson et al., 2017; Ruiz-Rodriguez et al., 2019; Cai et al., 2018; Liu et al., 2021). The findings of the two subtests that assess muscle systems that make up the Fine Motor (FM) such as grasping and visual motor integration (Seiverling et al., 2018; Reinert et al., 2015).

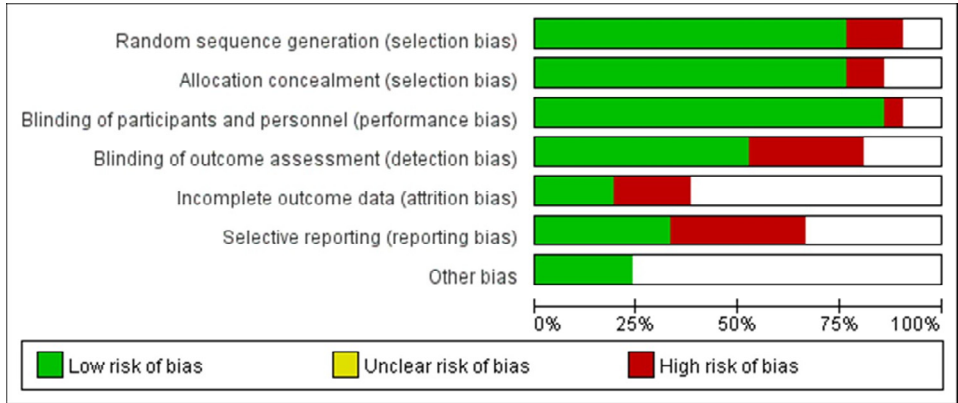
Theme 3 (Gross Motor Skills): The Gross Motor Quotient (GMQ) is a composite of the subtests that measure the utilisation of the big muscle systems (stationary, locomotion and object manipulation) (Karim and Mohammed, 2015). Evidence demonstrated that individuals with high-functioning ASD have delays or disorders in the acquisition of gross motor skills, including locomotor and object control, ball skills and balance (Berkeley et al., 2001; Home, 2016). To identify the uniqueness and provide customised treatment plans for each child, therapists must screen children with ASD separately.

- 1) *Balance and posture*: The integration of many sensory inputs is necessary for eye-hand coordination in order to direct movement in the direction of the objective (Karim and Mohammed, 2015). The integration of vestibular (inner ear), somatosensory (foot pressure) and visual input has been assumed necessary for successful postural stability and symmetry during static balance postures (Travers et al., 2013).
- 2) *Automatic reactions*: Muscle tone, instinctive responses and emotional wellbeing are improved by tactile, proprioceptive and vestibular systems (Karim and Mohammed, 2015).

Literature guide map: Prior to thematic analysis, a logical mind map of the relevant literature was produced in the current review, combining the objective of the article and the logical relationship between keywords in the literature, as well as the results being

argued, where serial numbers 1 to 18 refer to the literature from 1 to 18. Table 4 displays the visual representation, with red representing proof of a positive effect, blue representing proof of a negative effect and grey representing the inability to extract directly relevant data.

Table 4 The assessment of bias (see online version for colours)



Checklist of sensory approaches to improve gross skills of children with ASD

After a thorough review of 18 articles, taking into account methods of sensory approaches and the accompanying implementations, the themes were identified. Next, a checklist was developed. The checklist consisted of 13 items that improve gross motor skills and 1 item was reported to have insufficient evidence.

Table 5 Checklist of sensory approaches to improve gross-motor skills

Item criteria
<i>Sensory integration</i>
1) The poor performance of the children’s fine and gross motor skills is attributable to their atypical sensory processing.
2) Significant association between body functions and measures of activity participation strongly supports the potential contribution of sensory-perceptual-motor functions to children with ASD. ⑩
3) Sensory integration enhances motor skills such as ball tossing and catching and bouncing on two feet). ⑪
4) Improvements in motor function in children with ASD are contingent on early initiation of therapy. ⑪
5) Implementation requires a special emphasis on sensory seeking and distractibility for children with ASD. ⑱
6) The Biodex balance system can digitally analyse the interaction between the sensory systems responsible for postural control and the smallest body sway. ⑰
<i>Visual sensitivity</i>
7) Children with ASD have postural instability because they have trouble integrating visual sensory information. ⑯

Table 5 Checklist of sensory approaches to improve gross-motor skills (continued)*Auditory sensitivity*

- 8) As children grow and increase their interactions with the environment, the visual and auditory systems become more essential. ③

Tactile sensitivity

- 9) The assessment of tactile-perceptual impairments is important for higher and complex tactile processing. ④
- 10) The integration of inappropriate tactile-perceptual skills is correlated with behavioural rigidities in children with ASD. ④

Vestibular sensitivity

- 11) Movements of swing combined with additional interactions of sensory integration-based protocol influence overall sensory processing integration and specific vestibular function. ⑮

Proprioceptive sensitivity

- 12) Tactile proprioceptive and vestibular systems improve muscle tone, automatic reactions and emotional welfare. ③

Parent-Mediated

- 13) The activity books and text message encouragement provided to the families facilitate physical activities among children with ASD ⑧

EIAS

- 14) There is insufficient evidence to support the use of AIT as a treatment for stereotypy in children with ASD.⑥

VR intervention

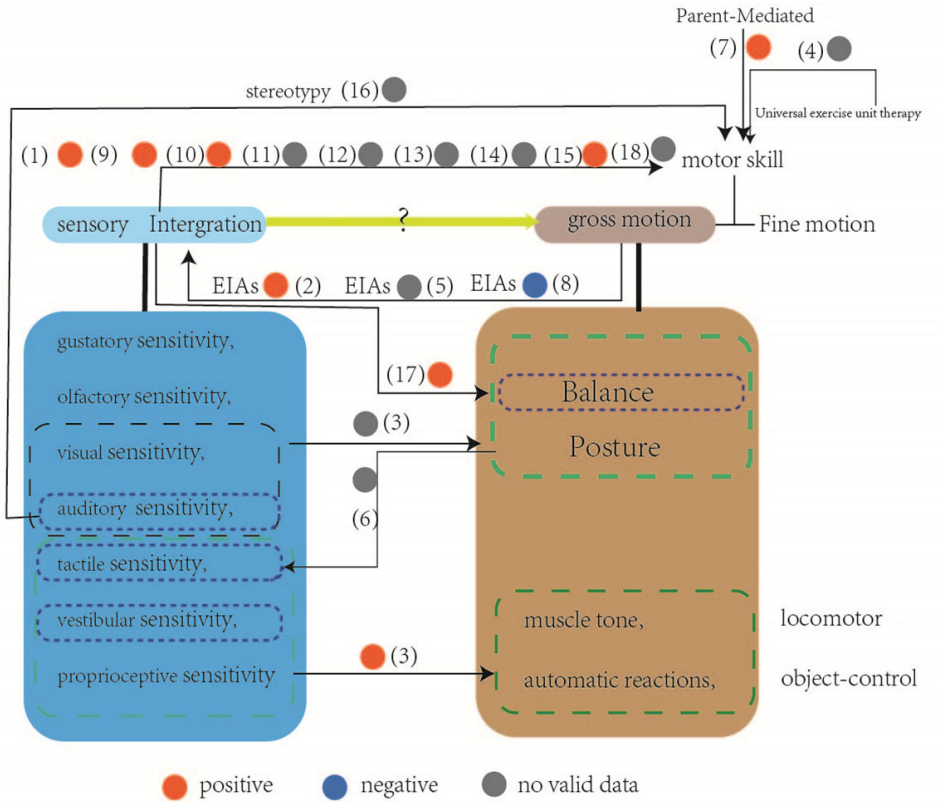
- 15) There are several positive relationships between our efficient, symmetrical and synchronous motion capture assessments and the standardised measurements of gross motor skills in ASD. ⑮

4 Discussion

4.1 Overall finding

The current review focused on the methods and effects of sensory approaches in improving the gross motor performance of children with ASD. Because research directions differ, qualitative research methods were adopted and written summary content was formed instead of employing quantitative research. Thematic analysis in the current review identified sensory approaches as a strategy for assisting children with ASD with their gross motor skills. This review provided four (4) analytical themes and nine (9) sub-themes. Figure 1 displays the logical connections between the themes and sub-themes in the most recent literature. The significance of each sub-theme was stated by analysing and arranging descriptive language according to the procedure. As a result, a total of three (3) perspectives were identified.

Figure 1 The relation map of literature (see online version for colours)



First, the standard scores of children with ASD revealed significant motor delays in both fine and gross motor skills when compared to TD children (Provost et al., 2007). Moreover, children with ASD display abnormal sensory processing and motor deficits, including gross motor behaviour (Ting, 2013). Furthermore, children with ASD have unique sensory traits that vary in severity and degree. Early motor skill acquisition in children depends on their sensory processing. Therefore, children with ASD may benefit from sensory integration therapy that integrates basic postural response and balance reflex practice, spatial orientation and lateralisation of superficial and deep senses (Kuliński and Nowicka, 2020). From the current review, it is demonstrated that gross motor skills, such as grabbing a ball, leaping on two legs and throwing a ball, improve with sensory-integrated treatment (Kuliński and Nowicka, 2020). Considering motor skill performance requires sensory processing, it is expected that sensory processing in children with ASD interferes with their motor skill performance (Ting, 2013). According to this line of reasoning, it has been established that postural instability in ASD children is caused by a failure in the integration of sensory input from the ocular and somatosensory afferent systems. Moreover, decreased stability is linked to lower IQs and, in some ways, earlier ages. Ghafar et al. (2022) supported the notion that early intervention in balance training may help prevent deficiencies in other motor skills, even if only minor body swings are found.

Second, since the last decade, researchers have been researching the motor performance of children with ASD and they discover deficiencies in a variety of areas of function, including motor anticipation, dyspraxia and postural control. For example, Mache and Todd (2016) and Randell et al. (2019) shown that sensory integration therapy aids in sensory processing to enhance gross motor skills in children with ASD. (Tse et al., 2021) further establish that the link between exercise and behaviour is mostly responsible for the behavioural advantages of physical activity in children with ASD. Moreover, motor skill deficiencies are noticeable in IHFA throughout childhood and continue throughout puberty (Abu-Dahab et al., 2013). Gross motor skills curriculum includes running, horizontal jumping, galloping, sliding, skipping and hopping. The curriculum also includes ball skills such as overhand throw, underhand throw, two-hand catch, two-hand strike, one-hand strike, dribble and kick (Columna et al., 2021). In addition, activity booklets, adapted equipment and encouragement via text messages which are provided to families with children with ASD have helped facilitate the participation of children with ASD in physical activity (Columna et al., 2021). The precise mechanisms by which exercise lessens SB in children with ASD should be the subject of further research.

Lastly, Articles 2, 6 and 9 supported the effectiveness of equine-assisted therapy for children with ASD from a different angle. For instance, Ting (2013) examined how well elementary school children with ASD processed sensory information and used their motor skills. In the article, multivariate regression analysis was used to identify the impact of sensory training on fine and gross motor skills in children with ASD. It is crucial to note that these interventions are complementary; thus, must be logically included in the child's overall rehabilitation plan, and must satisfy the needs of the family (Borgi et al., 2016). It reflects an endeavour to better characterise equine-assisted therapy programmes and the establishment of reproducible protocols that can make AAI an evidence-based intervention for children with ASD, in addition to providing a thorough description of the activities involving horses and the 'riding centre' variable (Borgi et al., 2016). When compared to TD children of the same age and experience, short EAI sessions with children with ASD have no deleterious impact on stress responses. Nevertheless, sessions with ASD children are expected to have a lower sympathetic tone since there is less novelty anticipation compared to sessions with TD children. This observation needs to be further investigated for any potential ramifications on the welfare of horses (Borgi et al., 2021a). Moreover, another finding is that therapeutic riding dosage strongly correlates with the magnitude of changes in target behaviours but not with the number of changes (Holm et al., 2014).

According to Ghafar et al. (2022), the inability of the eye and somatosensory afferent systems to integrate sensory input leads to sensory processing instability, which also affects the execution of motor abilities (Ting, 2013). Also, spatial orientation and lateralisation of shallow and deep sensations exercises, as well as sensory integration treatments, will help patients' basic postural reactions and balancing reflexes to be better integrated (Kuliński and Nowicka, 2020). For example, sensory integration therapy helps to improve the sensory processing ability of children with ASD (Randell et al., 2019).

Moreover, coarse motor skill programmes including running, horizontal jumping, galloping, sliding, jumping and jumping, ball skills including upper hand throwing, lower hand throwing, two-handed catching, two-handed hitting, one-handed hitting, dribbling and kicking (Columna et al., 2021) combined with manual activities are helpful for children with ASD (Columna et al., 2021). Borgi et al. (2016) demonstrated efforts to

better define equine adjuvant treatment regimens and to build repeatable regimens that make AAI an evidence-based intervention for children with ASD by thoroughly characterising horse-related activities and 'riding centre' variable. The article discovers that children with ASD who undergo brief EAI experiences had no negative effects on the stress levels of their horses. Also, ASD treatments are anticipated to have a decreased sympathetic tone (Borgi et al., 2021), besides that the therapeutic cycle dose and the magnitude of the desired behaviour change are highly connected (Holm et al., 2014).

5 Conclusions

Different symptoms of ASD require different treatment approaches. Therefore, the results should be presented in a diversified rather than integrated manner. The following are the results of the current systematic review which employed a thematic analysis approach.

Firstly, early sensory approaches to gross motor skills (e.g., throwing and catching a ball, jumping on two legs) should be introduced to children with ASD with a focus on sensory seeking and distractibility. The correlation between bodily processes and activity participation measures is compelling evidence that children with ASD may benefit from sensory-perceptual-motor functions. Hence, sensory-integrated approaches to supporting gross motion skills are a fundamental method for children with ASD with perceptual problems. Secondly, as the importance of visual and auditory systems increases as children age and engage with the world, children with ASD suffer from postural instability caused by inappropriate visual sensory input. Finally, higher and more complicated tactile processing is associated with the integration of improper tactile-perceptual skills among children with ASD.

Some literature still offers the idea that sensory approaches are unrelated to motor skills, as shown in Figure 1. However, theories that offer support would be more convincing. Future research could provide broader and more profound evidence demonstrating this. Also, more research on the role of sensory approaches training species visual, tactile, proprioceptive and vestibular on object control of movement.

The research limitations of this review are reflected in two aspects. First, in most of the literature, it is difficult to completely separate fine motor and gross motor skills. The demonstrating requires specialised clinical treatment experience and knowledge as well as more primary data. Second, this review employed a thematic approach that relies on descriptive content to analyse data based on the absence of adequate and uniform quantitative data, despite that most of the articles selected for this article used an experimental approach, such as pre and post testing of samples or control samples. As a result, the analysis process was prone to introducing bias that may occur from each piece of literature. This systematic review summarises the current pathways and roles of sensory approaches in enhancing gross motor movements in children with autism. Initially, it provides preliminary validation that sensory approaches have a positive effect on the enhancement of gross motor in children with autism and provides some theoretical basis for children with autism who currently have severe gross motor problems. Future research could further investigate the process of different sensory pathways on gross motor enhancement and the role of new interaction techniques on gross motor enhancement in children with autism.

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