

# The Systematic Review and Meta-analysis of Oral Sensory Challenges in Children and Adolescents with Autism Spectrum Disorder

Sachin Haribhau Chaware<sup>1</sup>, Surekha Godbole Dubey<sup>1</sup>, Vinay Kakatkar<sup>2</sup>, Ajit Jankar<sup>3</sup>, Swati Pustake<sup>4</sup>, Abhishek Darekar<sup>3</sup>

<sup>1</sup>Department of Prosthodontics and Crown and Bridge, Sharad Pawar Dental College, DMIMS, Swangi (M), Wardha, <sup>2</sup>Department of Prosthodontics and Crown and Bridge, SMBT IDSR Dental College Dhamangaon, Nashik, <sup>3</sup>Department of Prosthodontics and Crown and Bridge, MIDSR Dental College and Hospital, Latur, <sup>4</sup>Department of Prosthodontics and Crown and Bridge, MGV KBH Dental College and Hospital, Nashik, Maharashtra, India

Received : 22-04-21  
 Revised : 28-04-21  
 Accepted : 01-05-21  
 Published : 13-08-21

ABSTRACT

**Objectives:** The purpose of the systematic review was to provide a summary and evaluation of oral sensory challenges in children and adolescents with autism spectrum disorder (ASD). **Materials and Methods:** The review evaluated 19 studies that met the inclusion and search criteria. The review is registered in Prospero Database (CRD42020179852). The 14 studies (8 case-control, 4 cohort, 1 observational, and 1 randomized clinical trial) were related to speech disorders and five studies (case-control studies) were associated with feeding and eating behavior in ASD. The meta-analysis of speech and feeding behavior was analyzed by using risk ratios (RRs) and standardized mean difference (SMD), with 95% confidence interval (CI). **Results:** The meta-analysis found a statistically significant difference of speech disorder between children and adolescents of ASD when compared with typically developed or other neurotypical children of similar age [0.4891 (95% CI = -2.4580; 1.4799), fixed effect; -0.1726 (95% CI = -14.2925; 7.5697), random effect]. Feeding and eating behavior reported a statistically significant difference between ASD children and adolescents with similar age group of typically developed controls [0.0433 (95% CI = -0.3531; 0.4398), fixed-effect; 0.3711 (95% CI = -3.0751; 3.8172), random effect]. **Conclusion:** The speech errors and feeding behavior were more consistent in ASD than in typically developed controls. The oral sensory challenges such as speech disorder and feeding behavior were more prevalent in ASD children and adolescents than in typically developed children and adolescents of the same age group. There was a significant lack in oral sensory-motor synchronization, incomplete motor planning, and poor oral neuromuscular coordination.

**KEYWORDS:** Autism, autism spectrum disorder, dental specialty, feeding difficulty, language, oral receptors, speech

## INTRODUCTION

Autism spectrum disorder (ASD) is the most prevalent neurodevelopmental condition of unknown etiology. The prevalence ratio of ASD was thought to be 1 in 5000 in 1975; however, it had risen to 1 in 150 in 2002 to 1 in 68 in 2008 (around 50-fold in 40 years).<sup>[1-4]</sup> In India, the prevalence rate of ASD is 1 in 500 (2/1000) to 1 in 166 children (6/1000).<sup>[5,6]</sup>

The oral sensory challenges as part of a generalized sensory processing disorder in ASD has a major

impact on day-to-day activities of children with ASD. The speech disorder and feeding behavior are the two major oral sensory challenges associated with ASD. The ASD children show complete or partial lack of speech, delayed speech, speech inadequacy, and deficient

**Address for correspondence:** Dr. Sachin Haribhau Chaware, Department of Prosthodontics and Crown and Bridge, Sharad Pawar Dental College, DMIMS, Swangi (M), Wardha, Maharashtra, India.  
 E-mail: Sac32in@yahoo.in  
<https://orcid.org/0000-0002-8375-4494>

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**How to cite this article:** Chaware SH, Dubey SG, Kakatkar V, Jankar A, Pustake S, Darekar A. The systematic review and meta-analysis of oral sensory challenges in children and adolescents with autism spectrum disorder. J Int Soc Prevent Communit Dent 2021;11:469-80.

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in receptive and expressive speech and language impairment.<sup>[7,8]</sup> The speech disorder in ASD children is related to oral motor disorder, which further simplified as a lack in synchronization of oral sensory and motor receptors and their pathways, i.e., impairment in motor programming and planning.<sup>[7,8]</sup> The speech disorder is commonly referred to as a speech sound disorder (SSD). The SSD mainly comprises three types, i.e., articulation errors, phonological errors, and motor-speech disorder, which further divided into childhood apraxia of speech (CAS) and prosody.<sup>[8]</sup> Articulation errors are mainly due to inadequate motor learning, and these errors appear to be persistent, continuing into adolescence and adulthood.<sup>[9,10]</sup> The phonological errors are due to imperfection in the structuring of word or phrase.<sup>[9]</sup> The motor-speech disorder (MSD) includes speakers of all ages whose significant intelligibility deficits are associated with motor speech impairment. MSD includes dysarthria and CAS. It is a disorder of impaired speech production due to difficulties in oral muscular control of speech mechanism and speech motor planning and programming.<sup>[11]</sup> The significant features of MSD are speech delay, vowel error, unspecific phonetic distortion, and slow speech rate.<sup>[8]</sup> The third significant speech error is prosody, which described the speech sound parameters such as pitch, rate, intonation, and loudness.<sup>[12]</sup> Children and adolescents of ASD have higher rates of inappropriate prosody, which is distinguished by repetition of words (echolia), high pitched words and phrases, and misplaced stress.<sup>[11]</sup>

Atypical feeding behavior is the second major oral sensory problem. ASD children usually show a limited selection of food, often they are referred to as “picky eaters.” These children are reluctant to try new food or experienced difficulty in selection of new food.<sup>[13,14]</sup> An atypical feeding behavior is mainly associated with oral sensitivity or psychological behavior toward the food. The limited selection in food often shows nutritional deficiency with ASD children.<sup>[15]</sup>

ASD is a lifelong condition<sup>[16]</sup> because it does not have a complete core treatment and mostly depends on various therapies such as occupational therapy,<sup>[17]</sup> sensory integration therapy,<sup>[18]</sup> and applied-based analysis therapy<sup>[19]</sup> used for generalized sensory processing disorder in ASD. In the oral therapies, speech therapy<sup>[20]</sup> is the central therapy used for speech recognition and stimulation. However, it has been observed from the literature studies that oral sensory processing disorder in ASD was majorly associated with oral sensory and motor receptors. There is significant lack of synchronization between oral sensory and motor receptors and hyperactivity or hypoactivity (sensory seeking) associated with oral receptors. However,

previous systematic review does not mention any such causal relation.<sup>[8,21]</sup> Hence, the objective of the present review is to evaluate the cause-to-effect relationship between local oral sensory-motor disturbance and SSD and feeding behavior in children and adolescents with ASD.

## MATERIALS AND METHODS

This systematic review was designed according to the guidelines of the Preferred Reporting Item for Systematic Review and Meta-analysis Guidelines (PRISMA).<sup>[22,23]</sup> The review is registered in Prospero Database (CRD420201179852, <https://www.crd.york.ac.uk/PROSPERO>).

### SYSTEMATIC SEARCH

#### Identification

A systematic search was conducted from January 2000 to December 2018. Peer-reviewed journal articles were identified using the following electronic databases: Cumulative Index to Nursing and Allied Health Literature (CINHAL), MEDLINE (PubMed), Cochrane Library, Education Resources Information Center (ERIC), pscINFO, Scopus speechBITE, Web of Science, and Google Scholar. Keywords used are: Autism; speech; language; neuroimaging; first word; language development; autism spectrum disorder; sensory processing disorder; sensory integration; speech in noise; food selectivity; sensory sensitivity; food; taste; feeding assessment; mealtime behavior; selective eating; picky eater; articulation disorder; phonetics oral receptors; somatosensory awareness. Related articles were identified from the existing reviews and study design. The PICOS protocol is mentioned in Table 1.

#### Screening

The initial phase is the primary screening of the identified articles. Due to the broad nature of the initial search, references were further filtered according to title, abstract, and keyword. Following the initial search, a reference list of the retrieved articles was obtained manually. Additionally, authors and keywords were searched again in Google Scholar to ensure all relevant articles. Search included only those studies that discuss an oral sensory-motor relationship with oral sensory challenge in ASD. The studies associated with psychological behavior with ASD were excluded.

### QUALITY ASSESSMENT

The risk of bias was assessed using the Cochrane Collaboration tool. All the selected articles were assessed by the first and second authors, and any variant view of the selected articles was further assessed by the third and fourth authors. The studies were evaluated using the following domains: random

sequence generation, allocation concealment, blinding of participant and personal blinding of the outcome assessment, incomplete outcome data, selective outcome reporting, and other bias. The studies were rated further as a risk of bias (low, medium, and high) by the reviewers.

**DATA MANAGEMENT**

Data extraction was independently done by two reviewers using the specific format. The specific important information was as follows: year of publication, ASD diagnosis with sensory processing disorder, study population, diagnostic tool, age and IQ of the ASD children, and follow-up period.

Tools used for measuring outcomes were categorized as speech assessment: articulation disorder, phonological

errors, CAS, and prosody; feeding behavior: selection of the food in relation to oral sensitivity.

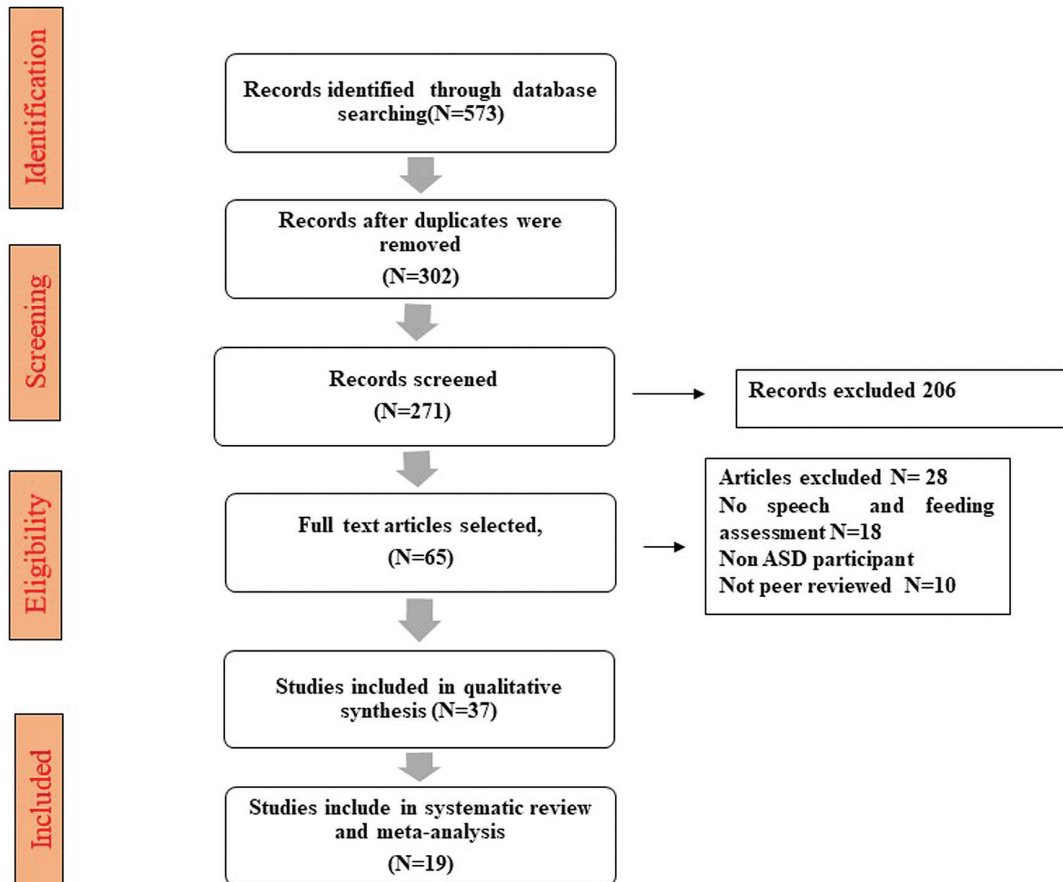
The outcomes were presented for relevant studies in a graphical format where possible. The studies were graphed according to the mean difference with the level of significance being  $P \leq 0.01$ . In the meta-analysis, heterogeneity was measured as a final calculation of effect size and CI around that effect size by using a random-effects and fixed-effects model in the forest plot.

**RESULTS**

The review identified 573 articles. A review of 65 full-text articles identified 37 articles for qualitative synthesis and 19 articles that met the inclusion criteria, search criteria, and confidence in ASD diagnosis [Figure 1].

**Table 1: PICOS table**

PICOS		
P	Participants	Children and adolescents of ASD
I	Interventions	Speech disorder, feeding, and eating behavior
C	Comparison	ASD children and adolescents vs. typically developed children or neurotypical children of similar age
O	Outcomes	Speech assessment and feeding behavior evaluation
S	Study design	Net-working meta-analysis



**Figure 1: PRISMA flow chart**

Twenty-eight articles were excluded from the study with subsequent reasons: no speech and feeding assessment, non-ASD participant, not peer-reviewed, and outcome assessment in relation to speech therapy and oral stimulation. The articles were distributed according to the assessment of speech in relation to phonological disorder, speech articulation, speech motor disorder, and prosody: There are a total of 14 studies that were evaluated, out of which 8 are prospective case-control studies and 4 are prospective cohort studies. There is a single observational study and a single randomized clinical trial [Table 2]. There are a total of five studies on associated sensory oral issues, and all were prospective case-control studies on feeding behavior in relation to oral sensitivity [Table 3].

#### RISK OF BIAS ASSESSMENT

There were 19 studies included for the assessment of risk of bias. The majority of the studies showed a moderate risk for selection bias as the less number of sample sizes and comparative group for sample size were for typically developed children but the criteria for typically developed children were not mentioned in many studies and a few studies included sample of other neurological disorders along with typically developed children. Selective reporting bias was higher for the studies of feeding behavior. The studies selectively reported that oral sensitivity, psychological behavior (mealtime behavior), and inferior muscle action may be the cause for feeding and eating behavior in ASD. There was a mild risk for detection bias and attrition bias, due to involvement of other neurological disorders. Publication bias of speech disorder was determined using funnel plot [Figure 2].

#### META-ANALYSIS

The meta-analysis was performed by using a fixed- and random-effects model. The overall acceptable heterogeneity is to confirm the homogeneity among the studies ( $i^2=96\%$ ). The result of speech assessment reported statistically significant heterogeneity ( $Q = 235.8259$ ,  $df = 8$ , and  $P < 0.0001$ ). The statistics of the fixed-effect model reported the mean difference (MD) to be  $-0.4891$  (95% confidence interval (CI) =  $-2.4580$ ;  $1.4799$ ). The random-effects model reported the MD to be  $-0.1726$  (95% CI =  $-14.2925$ ;  $7.5697$ ) (Table 4 and Figure 3). The meta-analysis reported a statistically significant difference between the typically developing or related neurotypical control group and children and adolescents of the ASD group with varying ages.

The meta-analysis of feeding behavior reported an overall acceptable heterogeneity among the studies ( $i^2=95\%$ ). The result of feeding reported statistically

significant heterogeneity ( $Q = 29.0677$ ,  $df = 4$ , and  $P < 0.0001$ ). The statistics of fixed-effects model reported the MD to be  $0.0433$  (95% CI =  $-0.3531$ ;  $0.4398$ ). The random-effects model reported the MD to be  $0.3711$  (95% CI =  $-3.0751$ ;  $3.8172$ ) (Table 5 and Figure 4). There was a statistically significant difference of feeding behavior between ASD children and adolescents than typically developed children and adolescents of the same age group.

## DISCUSSION

The purpose of the systematic review was to determine the oral sensory challenges and its relation with oral sensory motor synchronization in ASD children and adolescents. The review has taken 20 studies for meta-analysis and synthesized the following information.

#### SPEECH ASSESSMENT

A failure in speech development and language impairment is considered being a significant social stigma for ASD children.<sup>[8]</sup> Speech evaluation in ASD is an important diagnostic sign for pediatric psychologists and psychotherapists. Speech evaluation is also an important parameter to determine the outcome of the ASD.<sup>[8]</sup> The development of some amount of speech before the age of 5 years is a strong predictor of a better outcome in ASD. The retrospective study was conducted by Mayo *et al.*<sup>[24]</sup> on 119 ASD children, between the age group of 3 and 7 years. This study suggested that children who have not spoken their first words by age 2 may be at risk for a host of later functional deficits.

The speech errors in ASD are mainly due to oral speech motor disorder, which is commonly described as an SSD. It is a group of disorders that encompass various types of speech errors that are further divided into three types: (1) articulation disorder: improper articulation of oral component (fricative sound); (2) phonological disorder (lack in synchronization between oral sensory and motor receptors); and (3) motor-speech disorder<sup>[4]</sup> (poor oral muscular coordination while speech production). The prevalence of SSD is mentioned in two forms, initially, it was mentioned that younger ASD children show a higher prevalence than the older one. The prevalence of SSD for preschool children is 5–15% when compared with 1–6% for older ASD children. However, the current research observed that there is an increase in the concomitant articulation and phonological speech disorder.<sup>[25]</sup>

About 60% of the ASD children reported moderate-to-severe language problems and 21% reported major phonological problems. Shriburg *et al.*<sup>[11,26]</sup> have conducted analytical studies on ASD subjects to



**Table 2: Methodological description of the comparative studies of speech disorder**

Author and year	Type of study	Sample	Speech error assessment	Analysis
Shriburg <i>et al.</i> (2011)	Prospective case-control study	46 ASD children of 4–6 years age. Control: 40 TD children, 13 pre-school children with speech delay and 15 participants of age between 5 and 49 years with CAS in neurogenic disorder	Delayed speech, articulation, CAS, and prosody	Higher prevalence (15.9%) of speech delay, higher rates of speech errors in ASD children. Articulation errors reported into one-third of HFA
Cleland <i>et al.</i> (2010)	Qualitative analysis of speech errors	30 children of high functioning autism and 39 children of Asperger's syndrome between the age group of 5 and 13 years	Goldman Fristoe Test of Articulation (GFTA-2)	12% ASD children show higher speech errors and 41% children show small number of errors
Belmonte <i>et al.</i> (2013)	Prospective cohort study	31 ASD children of 22–65 months of age selected from intervention clinic. Subjects attended at least 1 year of daily intervention with consistent monitoring at an early intervention center and were assessed thrice (pre/mid/post-intervention) within the year	Two assessment instruments developed in India and normed for Indian populations were applied: (1) the com Dell Developmental Checklist (CDDC). (2) The com Dell Oral Motor assessment	11 out of 31 children show disparity between receptive language skill and expressive speech impairment and is associated with oral and other motor impairments. Clinical impression shows that many people with autism experience substantial motor difficulties including deficits in gross motor, fine motor, and oral motor skills
Newmeyer <i>et al.</i> (2007)	Prospective cohort study	Thirty-two children with sound speech disorder with the age of 25–72 months from Cincinnati Children's Hospital Medical Centre between July 2003 and July 2005 were included in this study	Preschool Language Scale (PLS) and the Kaufman Speech Praxis Test for Children (KSPT) for language assessment. Fine motor skills were assessed using the Peabody Developmental Motor Scales (PDMS-2)	The study result reported abnormal imitation of oral-motor movements. These impairments in motor planning can broadly affect speech and motor development, including impairment in daily functioning in home and school settings
Chenausky <i>et al.</i> (2018)	Experimental randomized clinical trial	38 minimally verbal children of ASD between the ages of 3;5 and 10;8	A comparison of auditory motor mapping training (AMMT) vs. speech repetition therapy (SRT)	The study analyzed that AMMT participants improved significantly more than SRT participants. However, the authors claimed that there may still be the possibility of improvement even for minimally verbal children of ASD
Williams (2008)	Prospective case-control study	Twenty-five children with ASD and 20 children with moderate learning disabilities	Picture stimulation	A clinical impression of the study shows that people with ASD actually do implement inner speech in their everyday lives but have difficulty in representing
Paul <i>et al.</i> (2005)	Prospective cohort study	Twenty-seven high functioning adult speakers, age group of 14–27 years, from Yale Child Study Centre	Prosody protocol	Qualitative and quantitative analyses of the study show that ASD speaker develops stress while making communicative and meaningful words and phrases
Shriburg <i>et al.</i> (2001)	Prospective case-control study	A comparison of 30 male speakers of ASD with 53 typically developing male speakers	Phonetic transcription and prosody-voice coding	ASD speakers show high percentage of residual articulation distortion errors and inappropriate stress during pronunciation of various communicative words and phrases

Table 2: Continued

Author and year	Type of study	Sample	Speech error assessment	Analysis
Kjellmer <i>et al.</i> (2018)	Observational study	The two experienced speech research pathologists evaluated 83 ASD children for sentence comprehension, grammar, and phonological process	The speech and language data	Results revealed that almost 60% had moderate–severe language problems. Nearly half exhibited combined expressive and receptive language problems, of which a majority also had phonology problems. Phonological speech problems were found in 21% of the total group.
McAlpine <i>et al.</i> (2014)	Prospective case–control study	Seven children of ASD and seven TD children with the age group of 24–68 months	Assessment of prosody in young verbal ASD children by Mullen Scales of Early Learning (MSEL)	The results of this study indicate that the prosodic patterns of young children with ASD do not differ significantly from those of TD children, with the exception of grammatical and pragmatic stress
Nadig <i>et al.</i> (2011)	Prospective case–control study	Fifteen children of HFA and 13 TD children with the age group of 8–14 years	Face-to-face conversation with HFA children about their special interests or hobbies and subsequent conversation recording for further evaluation	The significant observation is the high pitch (200 Hz) with HFA than with TD (124 Hz). Atypical prosody is more with HFA than with TD
McCann <i>et al.</i> (2007)	Analytical study	31 HFA children and 72 are typically developed controls	Language skills	The HFA children have deficit in expressive language prosody. The poor prosodic skills than controls
Diehl <i>et al.</i> (2009)	Analytical study	21 participants of HFA and 22 participants of TD control between the age group of 11–19 years	Prosody + Syntax (Congruent) condition	The HFA adolescents have a difficulty using prosody to disambiguate syntax in comparison to typically developing controls, even when matched on chronological age, IQ, and receptive language
Rapin <i>et al.</i> (2009)	Prospective cohort study	62 preschool ASD children from special school evaluated at age 7 and 9 years for expressive phonology and comprehension of word and sentence	Photo articulation test (PAT), and clinical evaluation of language fundamentals	The result shows mixed phonological errors. Clusters 1 and 2 show maximum errors than clusters 3 and 4.

HFA = high functioning autism, AS = Asperger's syndrome, TD = typically developing

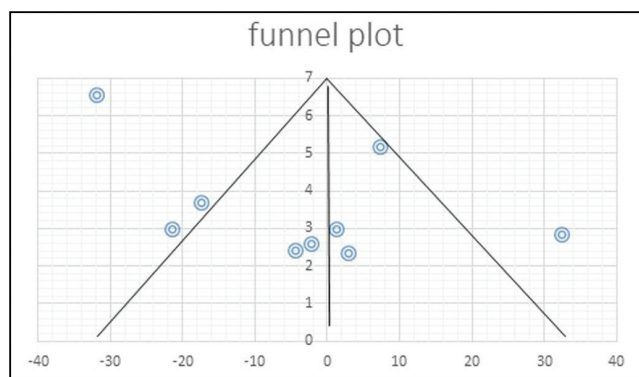
evaluate features SSD. The study reported that there is speech delay in almost 15.2% of 46 ASD subjects in the age group of 4–7 years. The percentage of speech errors is 31.8% at the age group of 6–7 years; however, the previous estimated prevalence is 7.9% at 8 years of age. The authors claimed that difference of prevalence cannot be directly compared due to normalization of prevalence, which is not possible by chance in one year.<sup>[11]</sup> The study explained that the articulation errors are often due to inaccurate motor learning and the inability to execute correct motor learning for the phonetic production of the speech sound. Articulation refers to a fricative sound produced by motor movements of the tongue to various parts of the hard and soft palate. Errors in fricative sounds are due to inaccurate motor learning. Articulation errors have been reported in approximately one-third of high

functioning autism, with difficulty in producing “s” and “r” sound.<sup>[15]</sup> Shriburg *et al.*<sup>[26]</sup> claimed that speech errors appear to be persistent, continuing into adolescence and adulthood. More percentage of residual speech errors are associated with high functioning autism and Asperger's syndrome.

About 12% higher phonological speech errors and 41% of minor speech errors in ASD subjects are reported by Cleland *et al.*<sup>[9]</sup> Asperger's syndrome has fewer errors than high functioning autism.<sup>[9]</sup> However, Rapin *et al.*<sup>[10]</sup> demonstrated a 24% percentage of higher phonological errors and 76% of borderline expressive phonology in ASD subjects. The significant observation of the Rapin study is that it disagrees with the previous hypothesis that minor phonological errors are present in school-aged children of ASD, as the authors claimed that only verbal children were mentioned with the previous

**Table 3: Methodological description of the comparative studies of feeding and eating behavior**

Study author year	Study design	Sample size	Intervention	Primary endpoint	Outcome
Kuschner <i>et al.</i> (2015)	Case-control study	65/ASD adult/adolescent (12–28 years); 59 neurotypical control (12–23)	Adult/Adolescent Sensory Profile, Food Neophobia Status	Food Neophobia Scoring (1–5: 1=less and 5= high)	ASD records high score, dislike textured food, and strong tastes
Chistol <i>et al.</i> (2018), ASD	Case-control study	53 ASD children and 58 without (3–11 years)	The Vineland Adaptive (VABS) Adaptive Skill, Differential (DAS) Food Frequency Questionnaire	Adaptive skills, cognitive skills, oral sensitivity	ASD children record significant higher food refusal. Atypical oral sensitivity (5.3 vs. 8.2, $P=0.003$ ) associated with ASD than without ASD
Proves <i>et al.</i> (2010)	Case-control study	24 ASD children and 24 TD (3–6 years)	Mealtime history, mealtime location, eating problem	Food preference, meal time location, mealtime behaviors	ASD children have a significant problem in cafeteria. Difficulty in eating new food and problem of gagging
Bandini <i>et al.</i> (2010) intake (HFSFI)	Case-control study	53 ASD children 58 TD children (3–11 years)	Youth/Adolescent Food Frequency Questionnaire (YAQ)	Food refusal, food repertoire, high frequency single food	ASD refuse more foods. No difference of HFSFI between ASD and TD, nutritional deficient reported with ASD and limited food selection
Cattaneo <i>et al.</i> (2007)	Case-control study	8 ASD and 7 TD children	Electromyography	Recording of mylohyoid muscle	Mylohyoid muscle reported inferior action during food grasp stage in ASD

**Figure 2: Funnel plot of studies distribution of speech disorder**

studies. The limitation of the study is that as no control is used it is difficult to analyze actual errors made by the ASD children. The phonological errors are difficulty in the construction of the expressive sentence and dysfluent speech.

There are two prospective studies on motor-speech disorders that reported that many people with autism experience substantial motor difficulties including deficits in gross motor, fine motor, and oral motor skills, and abnormal imitation of oral-motor movements can broadly affect speech and motor development, including impairment in daily functioning in the home and school settings.

The motor-speech disorder has two subtypes: (1) CAS: it is an impaired speech production due to difficulty

in the muscular control of the speech mechanism; (2) prosody: it is the type MSD of suprasegmental features of speech which include the use of stress, pitch, rate, intonation, and loudness.<sup>[11,27]</sup> These features enhance communication by adding a grammatical, pragmatic, and affective meaning of linguistic information.<sup>[4]</sup> The CAS is usually associated with ASD children but it has very low prevalence, and prosody is the disorder of adolescent and adult speaker of ASD.<sup>[11,27]</sup>

The prosody is the feature of speech expression associated with stress, pitch, rate intonation, and loudness. The prosody dilutes the communication by adding grammatical, pragmatic, and affective meaning to linguistic information. The prevalence of different features of prosody is mentioned in Figure 3. There are a total of six analytical studies including Shriburg *et al.* which evaluated the CAS and prosody. The three studies, Paul *et al.*,<sup>[27]</sup> Shriburg *et al.*,<sup>[26]</sup> and Diehl *et al.*,<sup>[28]</sup> were conducted on adolescents and adults. The study by Paul *et al.*<sup>[27]</sup> is a prospective study on the adult male speaker of ASD. The rest of the three studies are McAlpine *et al.*,<sup>[29]</sup> Nadig and Shaw,<sup>[30]</sup> and McCann *et al.*,<sup>[31]</sup> conducted on ASD children. The significant findings of the studies show that the ASD speaker develops stress while making communicative and meaningful words and phrases. ASD speakers show a high percentage of residual articulation distortion errors. ASD children show high pitch sound, high frequency stress vowels, a higher percentage of spontaneous speech than repeated

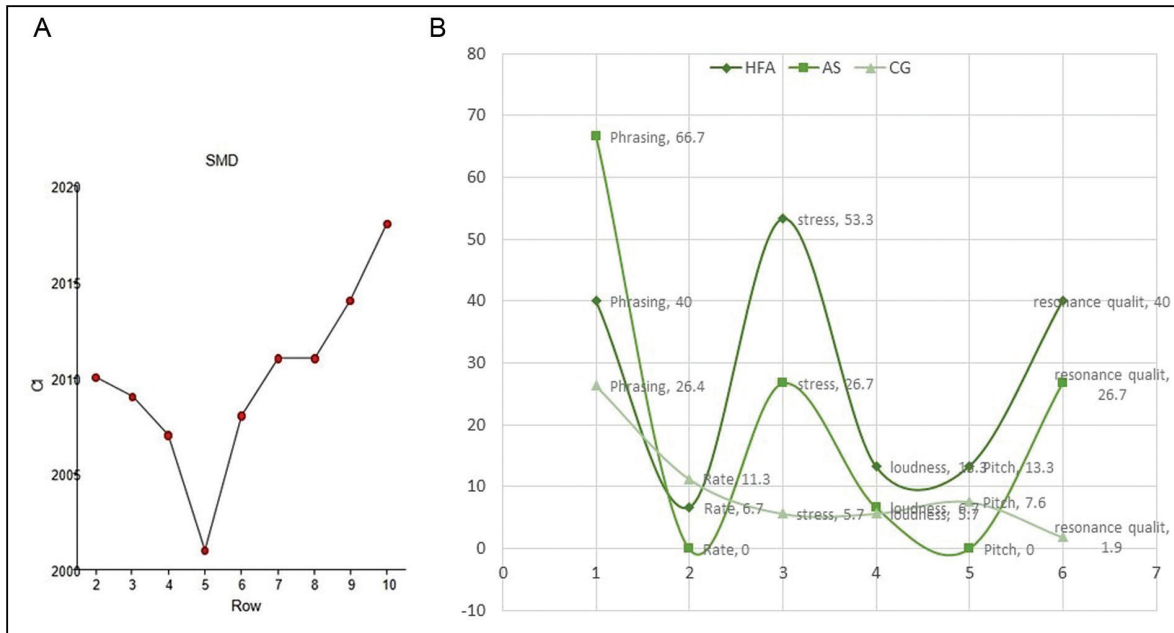
words, misinterpreted spoken language, and poor prosodic skills. A randomized clinical trial by Chenausky et al.<sup>[32]</sup> experienced that auditory motor mapping training (AMMT; speech therapy technique) showed improvement in speech outcome when compared with

speech repetition therapy (SRT: rhythmic hand tapping to facilitate sound-motor mapping) of minimally verbal ASD participant. The authors further stated that age is not predictive of response to treatment. The younger children possess more latent ability to learn

**Table 4: Forest plot of speech disorder**

	Year	Mean difference	Standard error	95% CI		Random effect	Fixed effect
				Upper	Lower		
	2010	-17.3000	3.6997	-9.9154	-24.6846	11.1079	7.3729
	2009	1.2300	2.9685	7.2250	-4.7650	11.3048	11.4525
	2007	-4.3500	2.4159	0.4424	-9.1424	11.4283	17.2912
	2001	-2.1400	2.5831	2.9996	-7.2196	11.3933	15.1245
	2008	7.2800	5.1534	17.6727	-3.1127	10.6199	3.8001
	2011	32.4000	2.8270	38.0013	26.7987	11.3385	12.6278
	2011	-21.3300	2.9722	-15.1957	-27.4643	11.3039	11.4241
	2014	2.9100	2.3322	7.9913	-2.1713	11.4451	18.5549
	2018	-31.8800	6.5504	-18.7356	-45.0244	10.0584	2.3520

Fixed-effects model and random-effects model, Cochran's  $Q$  235.8259; DF 8;  $P = 0.0000$



**Figure 3: A: Standardized mean difference (SMD) of comparative studies of speech disorder. B: Percentage difference of types of speech errors between high functioning autism (HA), Asperger's syndrome (AS), and control group (CG)**

**Table 5: Forest plot of feeding behavior**

	Year	Mean difference	Standard error	95% CI		Random effect	Fixed effect
				Upper	Lower		
	2018	4.3700	1.4753	7.2941	1.4459	22.3258	1.8797
	2016	-10.6200	2.9150	-4.8495	-16.3905	15.3290	0.4815
	2010	-0.7100	1.5119	-4.8495	-16.3905	22.1513	1.7900
	2010	8.5700	3.2757	15.0623	2.0777	13.8009	0.3813
	2007	-0.0080	0.2070	0.4592	-0.4552	26.3830	95.4675
	Average		-0.0080				

Fixed-effects model and random-effects model: Cochran's  $Q$  29.0667; DF 4;  $P = 0.0000$



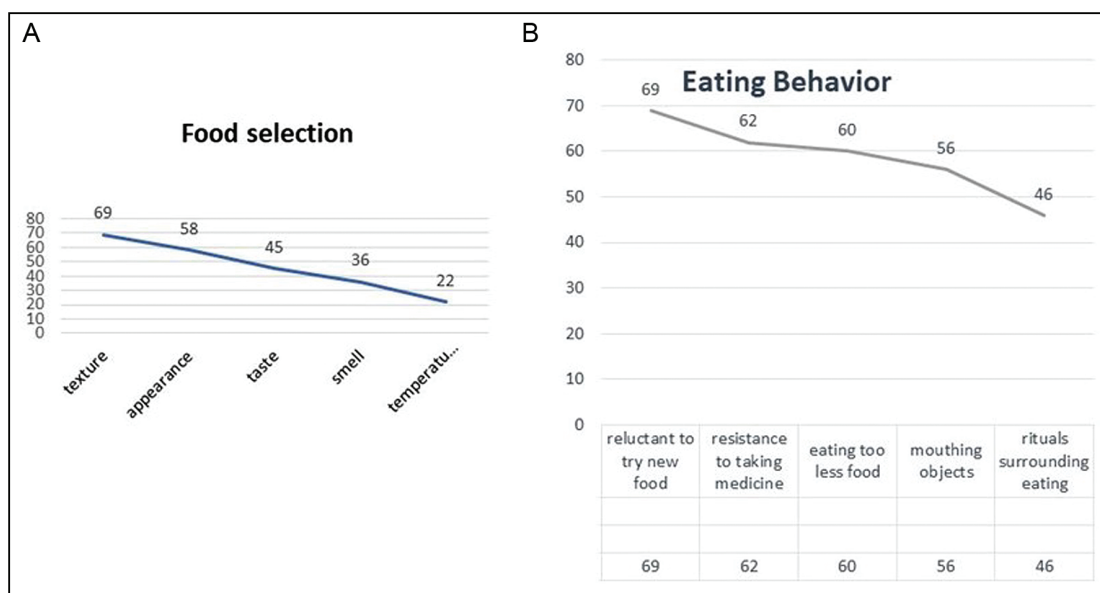


Figure 4: A: Percentage differences of food selection by ASD sample. B: Percentage differences of eating behavior

speech, joint attention and ability to tolerate pedagogic activities for extended period of time when compared with older children.

Recently, Chenausky *et al.*<sup>[33]</sup> examined 54 low-verbal and minimally verbal ASD individuals (ages: 4.4–18) for motor-speech impermanent. The study observed that very few individuals experienced occasional speech, mute speech, and disordered speech. However, the authors claimed that there was considerable heterogeneity among the 54 participants of ASD with respect to language and speech production ability. In addition, the authors suggested that therapy should follow the sensory profile of ASD subjects. If the selected therapy does not give measurable benefits, then alternative therapy should be chosen other than speech-language pathology, and frequent follow-up is essential to evaluate benefit of new therapy. Similarly, Shriburg *et al.*<sup>[34]</sup> investigated a group of subjects of complex neurodevelopmental disorder ( $n = 346$ , 13.3 average chronological age), including autism ( $n = 42$ ) for the prevalence of speech-motor delay. About 47.7% of the total subjects met the criteria of MSD, and the autism group showed 15.4% of the subjects with speech-motor delay. Namasivayam *et al.*<sup>[35]</sup> documented the dynamics of oral and laryngeal component of speech. The authors claimed that speech errors in SSD may potentially arise as a disarticulation of speech component, an immature speech motor system with limited speech motor skills, and restricted speech among the physical, physiological, and functional areas of tongue, palate, and lips.

#### FEEDING BEHAVIOR

ASD children have significantly more feeding problems than typically developing children. The estimated prevalence of feeding problems in ASD children is as high as 90%.<sup>[33]</sup> The major parental survey on food selection reported that the selection of the food depends on oral sensitivity and behavior.<sup>[36,37]</sup> The selection of the food and eating habits majorly depend up oral sensitivity, as a part of overall generalized sensitivity.

The ASD children and adolescents show a high percentage of food neophobia when compared with typically developing controls.<sup>[38]</sup> They have a preference for familiar food and dislike textured food and strong taste.<sup>[39]</sup> The children with ASD exhibited more food refusal and were limited in the selection of food and ate fewer vegetables and often have the problem of gag.<sup>[13]</sup> The significant experimental finding shows that the mylohyoid muscle action during the food grasp stage was much inferior to typically developing children.<sup>[40]</sup>

ASD children with oral hypersensitivity show a limited range of food selections; often they are referred to as “picky eaters.” ASD children are reluctant to select new food and whatever the selection of the food will be based on type, texture, consistency, smell, the sight of food, and gastrointestinal problems.<sup>[41]</sup> The presence of pickiness is most common in young ASD children and creates more restrictions in the selection of food patterns and may be extended to the adolescent age.<sup>[40]</sup> In contrast, oral hyposensitive children often related to unaware of sound during mealtime (auditory), changing visual input in the environment (visual), love and crave for intense flavors, i.e., sweet, sour, salty, spicy, and usually become

“condiment kids” (gustatory), unaware of even strong environmental odors (olfactory). Oral hyposensitive children are messy eaters; getting food all over their face and/or leaving bits of food in their mouth at the end of a meal. Children drool excessively beyond the teething stage. They always seem to have something in their mouth such as toys, pens, pencil tips, gum, candy, or inedible object.<sup>[42]</sup> The feeding problem in ASD children has a major impact on nutritional values as there is a lack of fruits, vegetables, and various other nutritional foods that affect the growth of ASD children.<sup>[43]</sup>

## CONCLUSION AND RECOMMENDATION

The review investigated 19 studies of speech disorder and feeding behavior in children and adolescents of ASD. It has been observed that ASD subjects experienced more speech problems when compared with typically developed children. The significant speech errors noticed with the ASD subjects are articulation error, phonological error, expressive language error, and receptive language error. However, the adolescent group experienced mild-to-moderate prosody. The significant observation of the review is that the majority of the speech errors in ASD are mainly due to impairment of local oral sensory-motor disturbance, incomplete motor planning, and poor oral neuromuscular coordination. In addition, limited number of subjects experienced major speech errors such as CAS and childhood dysarthria, which are related to central disturbance. With regard to feeding and eating behavior, ASD subjects have difficulty in selection or resistance to try new food, often they are referred to as “picky eaters.” The range of oral sensitivity (hypersensitive or hyposensitive) may be the major factor for the selection of food.

The review observed that oral sensory-motor disturbances and its effect on speech and feeding behavior in ASD subjects may focus the attention on precise oral stimulation. Hence, the review recommends that there may be significant need of oral stimulation by using speech-sensory tools. The stimulation articulating surface of speech component (articulation errors) and control of laryngeal air sound passage (phonological error) enhance the muscle coordination for tone, pitch, and loudness of speech sound (prosody) and may have a significant impact on speech. The oral stimulation may fulfill the sensory demands of oral tissue (sensory seeking) or decrease the sensory overload, which may control the feeding and eating behavior. The therapeutic role of oral stimulation has been already proved in subjects with cleft lip and palate and oral motor disorder such as Down syndrome.<sup>[44,45]</sup> Hence, oral stimulation may act as a single therapy or may

assist the speech therapy for the betterment of speech and feeding behavior in ASD.

## ACKNOWLEDGEMENTS

Not applicable.

## FINANCIAL SUPPORT AND SPONSORSHIP

Nil.

## CONFLICTS OF INTEREST

There are no conflicts of interest.

## AUTHORS CONTRIBUTIONS

Chaware contributed to the research question, search strategy, concept statement, eligibility criteria, screening of the articles, and meta-analysis. Dubey contributed to data acquisition, eligibility criteria, screening of the article, and evidence summary. Kakatkar and Jankar contributed for screening of article literature, search quality assessment, and meta-analysis. Pustake and Darekar contributed for risk of bias and software management.

## ETHICAL POLICY AND INSTITUTIONAL REVIEW BOARD STATEMENT

Not applicable.

## PATIENT DECLARATION OF CONSENT

Not applicable.

## DATA AVAILABILITY STATEMENT

Electronic databases has been sourced from Cumulative Index to Nursing and Allied Health Literature (CINHAL), MEDLINE (PubMed), Cochrane Library, Education Resources Information Center (ERIC), pscINFO, Scopus speechBITE, Web of Science, and Google Scholar.

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