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Review Article

Non-Medical Treatments of Drooling by Speech and Language Pathologists in Cerebral Palsy Children: A Systematic Review

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Abstract

Background: Drooling, commonly observed in cerebral palsy children, negatively impacts different aspects of their lives. There are several treatment options for drooling, with no consensus on a single method as the most effective one. The current systematic review provides an overview of the evidence of the different non-medical intervention methods used by speech and language pathologists to reduce drooling in cerebral palsy children.

Methods: A comprehensive and systematic search was conducted in the following electronic databases for publications from 2010-22: PubMed, Scopus, Science Direct, Web of Science, Cochrane Database of Systematic Reviews, and Google Scholar. The National Health and Medical Research Council (NHMRC)and the Physiotherapy Evidence Database (PEDro-P) scale were respectively used to determine the level of evidence and the methodological quality of articles.

Results: Out of 2740 articles identified, 15 records met the inclusion criteria and were included in the study. The studies considered in this systematic review differed in the following criteria: design, participant characteristics, types of assessments and treatments, and follow-up periods. Non-medical interventions for drooling were found to be effective in alleviating the severity and decreasing the frequency of drooling.

Conclusion: The results showed the effectiveness of nonmedical interventions for drooling in cerebral palsy children. The treatments provided by SLPs can be classified into three categories: oromotor and sensory interventions, behavioral interventions, and the use of Kinesio-tape. Among these, the use of oromotor interventions and oral sensory interventions, alone or combined with other approaches, was the most widely used method.

Keywords: Cerebral palsy, Drooling, Non-medical treatment, Salivation, Sialorrhea, Speech therapy, Systematic review

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Introduction

Drooling or involuntary loss of saliva from the oral cavity (1,2), is a natural phenomenon that occurs from early infancy to 15 to 18 months (3), and then saliva control is achieved by improving tongue control (4). Drooling after the age of four is abnormal (2,4) which persists in children with neurological disorders (2).

Drooling may result from many different factors, including muscle hypotension, macroglossia, dental malocclusion, abnormal posture, and nasal breathing disorders (5), with cerebral palsy being the most common cause, which is considered as a central etiology in children.

The term cerebral palsy refers to a group of developmental-motor and postural disorders with limited activity or motor disabilities resulting from abnormalities in or damage to the developing fetus or child's brain (6,7). Worldwide, 1 to 5 living children per 1000 are born with cerebral palsy (8). Factors that cause drooling in cerebral palsy children include incoordination in the oral phase of swallowing and inadequate closure of the lips (5). Also, in children with neurodisability, drooling can be due to reduced awareness of drooling (9), insufficient swallowing (10), and oral sensory issues (11), which can be exacerbated by postural problems or reflux (12). Medications such as anticonvulsants, which are essential for these children, also increase drooling (13,14). In cerebral palsy children, the prevalence of drooling can be as high as 30-53% (4), and the increase in the prevalence of drooling in these children correlates with increased functional involvement (4) so that, for example, drooling has been reported in 54% of quadriplegic cerebral palsy children (15).

The severity of drooling can be annoying for children, families, and caregivers (16). Chronic drooling can lead to problems such as dry skin, dehydration (4,16,17), wet and constantly dirty clothes, foul smell of child, sores around the mouth and chin, skin and mouth infections, swallowing and chewing problems, speech problems (16), weight loss (18), and damage to books, audio equipment and computers (16,17) which leads to significant social embarrassment and isolation for both the patient and their family (4,16). Also, it can result in a decrease in the child's self-esteem and affect the individual's success in society (19). In general, drooling reduces the quality of life of the affected children and their families (14).

Numerous interventions have been used to reduce or eliminate drooling, including botulinum injection, surgery, medication (20), and acupuncture (16), which are considered invasive treatments. The treatments also comprise less invasive treatments, like behavioral therapies for helping the child control their drooling, oromotor interventions, and the use of prostheses (20). There is no consensus on which interventions are safer and more effective in controling drooling in children with cerebral palsy, which complicates the selection of the appropriate intervention even more.

Speech and Language Pathologists (SLPs) are often involved in the treatment of drooling in children with neurological disorders. However, there is no comprehensive, evidence-based information on what SLPs should do (21). Despite the significant effects of drooling on a child's health, there is little research on reducing and treating it, likely because little research has been conducted to evaluate the effects of interventions such as sensory-motor treatments by speech and language pathologists (16). Therefore, due to the lack of sufficient evidence for identifying the various treatments used to manage the drooling by the speech and language pathologists, the present review study aims to identify and synthesize the evidence for non-medical interventions which speech and language therapists use in order to reduce or eliminate drooling in children with cerebral palsy. The findings of this review study can provide evidence to guide future exercise and research on the treatment of drooling in children with cerebral palsy.

Materials and Methods

Inclusion criteria

Studies were selected for analysis based on the following criteria: 1) studies involving cerebral palsy children between the ages of 0 and 18 years; 2) studies that clearly described types, procedures, and tools of evaluation; 3) studies that explicitly defined the types, procedures, and duration of intervention and treatment groups; 4) studies that provided non-medical treatments for drooling; 5) studies published in English from 2010 onwards (in order to identify the latest findings); and 6) studies that included outcome data (letters to the editor and reviews were excluded).

Search method

A comprehensive and systematic search was performed using the following keywords: "cerebral palsy", "drooling", "sialorrhea", and "intervention". To access articles on non-medical treatments for drooling, these queries were carried out in PubMed, Scopus, ScienceDirect, ISI (Web of Sciences), Cochrane Database of Systematic Reviews, The Cochrane Central Register of Controlled Trials (CENTRAL), and Google Scholar database, from January 2010 to December 2022. For obtaining more resources, all reference lists of the retrieved articles were searched manually.

Screening and collecting information

First, articles collected from the search process were imported into Endnote X9 software. In the initial screening, the first assessor removed duplicates, review articles, letters to the editor (editorials), and non-English articles. Then, the first and second assessors independently reviewed the titles, abstracts, and full texts of the articles in terms of eligibility and acceptance criteria. After this step, the two authors independently reviewed the articles to extract information according to the following criteria: study design, purpose and study population, number of participants (subjects) and diagnostic information, intervention, treatment results, the main findings, and the level of evidence. Any disagreements between the authors at this stage were resolved by discussion and consensus.

Methodological quality assessment

In this review article, the National Health and Medical Research Council (NHMRC) was used to determine the level of evidence (22). Two evaluators carefully reviewed the articles and then classified the articles into the appropriate level of evidence, based on the selected research method. Then, the methodological quality of the articles was determined using the Physiotherapy Evidence Database (PEDro-P) Scale (a reliable scale consisting of 11 items) (23,24). PEDro-P was created in order to assess the quality of controlled randomized and non-randomized clinical trial research methods. The usefulness of the PEDro-P scale for the field of speech therapy has also been confirmed (23). The two evaluators independently determined the methodological quality of the studies, and disagreements and possible contradictions between the two evaluators were resolved through consulting a third researcher.

Data analysis

The articles in this study were heterogeneous in the following variables: study design, characteristics of the participants, data collection methods, and the evaluations used in the selected studies and the results.

Results

In this study, the query resulted in 2740 articles (333 articles from ScienceDirect, 222 articles from Web of Science [ISI], 48 articles from Scopus, 17 from PubMed, 2057 from Google Scholar, and 63 articles from Cochrane database). After screening the titles and abstracts of the articles and eliminating the similar studies, 2692 articles were excluded. In the next step, 48 articles were reviewed, and 33 were excluded based on the inclusion criteria. Finally, 15 articles with inclusion criteria were included in this study. The diagram of the process of reviewing and inclusion of the studies into the research is presented in figure 1.

Characteristics of the participants

In 13 studies, the subjects were of both sexes (male and female), in 7 of which the number of males was more than females. One study included only a girl (case study) (25), and in one study, the gender of the subjects was not mentioned (26). The number of cerebral palsy patients participating in these studies varied from 1 to 80 children; their ages ranged from 12 months to 18 years; and only in one study, the age range of the participants was not mentioned (27). More details on the participants' profiles are provided in table 1.

Methodological quality assessment

Of the 15 final papers, 7 had evidence levels of II and III based on the NHMRC. Methodological quality evaluation of these studies indicated that 3 studies had high quality (28-30), 3 studies had medium quality (31-33), and 1 study had low quality (34). Further details are provided in table 2.

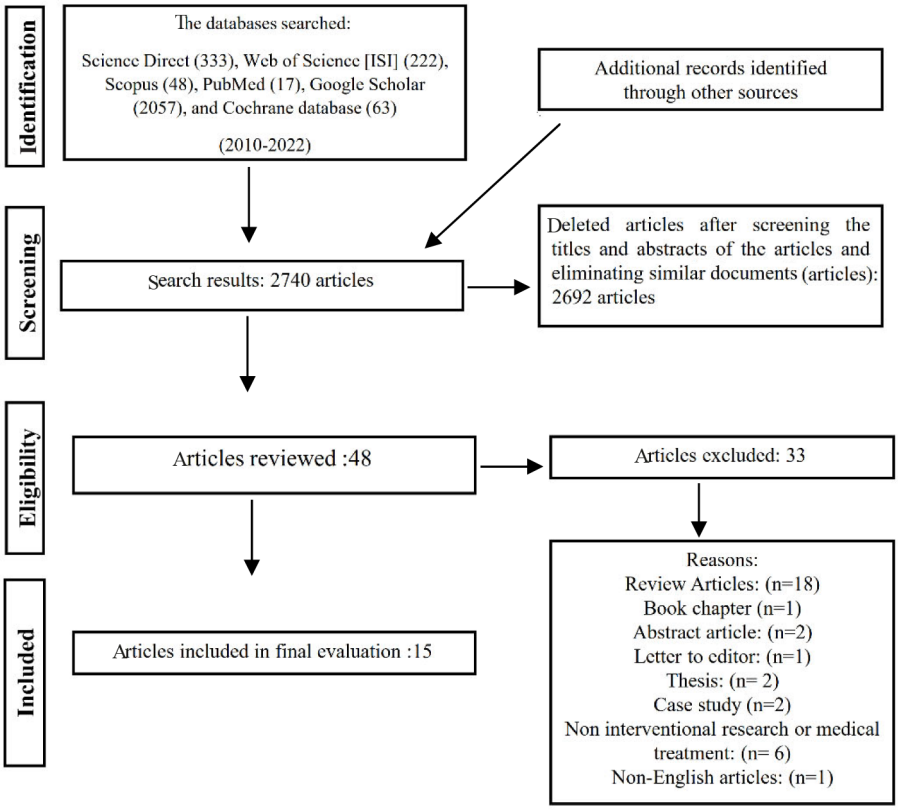

Figure 1. The process of reviewing and inclusion of the studies into the analysis.

Table 1. Characteristics of included studies

Study (Authors, Year, Aim)	Level of evidence type of study	Participants' diagnosis	Age/Gender	Total n
Mikami *et al* (2019), Effects of Kinesio Taping (KT) of the orbicularis oris muscles as an adjunct to standard therapy	- Level IV - Case series	Children with neurological disorders including cerebral palsy and drooling	4–18 years M: 7 F: 8	15
Russo *et al* (2019), Evaluation of the effectiveness of Repeated Muscle Vibration (rMV) in the treatment of drooling in cerebral palsy	- Level IV - Case series prospective experimental study	Cerebral palsy children affected by drooling	5–15 years M: 8 F: 14	22
Fatima *et al* (2019), Study of the effectiveness of oromotor exercises to reduce drooling in cerebral palsy children	- Level IV - Case series - Quasi-experimental study	Cerebral palsy cases with drooling	4-15 years M: 8 F: 7	15
Awan *et al* (2017), Determining the effectiveness of Kinesio taping (KT) with oromotor exercises (OME) in improving drooling in cerebral palsy children	- Level II - Randomized, single-center RCT	Cerebral palsy children had a good understanding of verbal commands and had good head control	4-8 years Group A: M: 8 F: 15 Group B: M:11 F:14	48

Contd. table 1.

Sethy and Mokashi (2011), Effect of conventional therapy along with behavioral therapy (token economy)	- Level II - Single-center RCT	Cerebral palsy and mild intellectual disability; drooling problems	5-12 years M: 15 F: 10 Experimental group: M: 9 F: 3 Group control: M: 6 F: 7	25
Inal *et al* (2017), Examined the effect of Functional Chewing Training (FuCT) on tongue thrust and drooling in children with cerebral palsy	- Level II - Single-center RCT	Cerebral palsy children with tongue thrust and drooling	4-6 Years Group A: M: 9 F: 7 Group B: M:10 F: 6	32
Mallick *et al* (2017), Determining the effectiveness of Sensorimotor stimulation in controlling drooling and improving feeding behavior and determining its relationship with feeding behavior in spastic cerebral palsy children	- Level III-2 - Comparative Study - Pretest-Posttest - Experimental design	Patients with a diagnosis of spastic Cerebral Palsy with Drooling	18 months to 12 years Group A: M: 9 F: 6 Group B: M:9 F: 6	30
Pervez *et al* (2014), Determining the effectiveness of Kinesio-taping intervention in cerebral palsy children with drooling	- Level IV - Pretest-posttest experimental study	Cerebral palsy children with moderate to severe drooling (rating of ≥3 on the Thomas-Stonells Drooling Scale)	2-6 years M: not mentioned F: not mentioned	30
Iram *et al* (2014), Identifying the most effective non-invasive intervention for drooling control in children with cerebral palsy	- Level III-2 - Interventional study design	Children with cerebral palsy	4-10 years M: 10 F: 5	15
Swati (2019), Determining the effect of Kinesio-taping as an adjunct to oromotor therapy in reducing drooling and enhancing mouth closure	- Level III-2 - Experimental trial with random allocation	Neurologically impaired children (including cerebral palsy) with drooling	1-9 years Group A: M: 9 F: 6 Group B: M:8 F: 7	30
Sığan *et al* (2013), The effects of oromotor therapy on cerebral palsy children with feeding problems	- Level III-1 - Single-center, randomized, prospective study	Cerebral palsy children with oromotor dysfunction	12-42 months Group A: M: 15 F: 25 Group B: M:20 F: 20	80
Kumar *et al* (2015), Determining the role of oromotor therapy in chronic drooling	- Level IV - Prospective study	Children with drooling (including cerebral palsy, Down's syndrome, mental retardation)	3-6 years M: 8 F: 7	15

Contd. table 1.

Muammer *et al* (2010), Investigating the effects of electrical stimulation, exercises, and proprioceptive neuromuscular facilitation (PNF) applied to the orofacial area on drooling in children with spastic cerebral palsy	Level IV	Children with spastic cerebral palsy with severe drooling	Age range: not mentioned Mean age: 9.9±3.6 years M: 5 F: 10	15
Caneschi *et al* (2014), The effectiveness of kinesiotaping along with speech therapy to control drooling	- Level IV - Longitudinal study	Children with chronic hypersalivation and neurological disorders: delayed global development, delayed neuropsychomotor development, cerebral paralysis, hydro encephalitis, poor congenital formation, encephalopathy	5-10 years M: 4 F: 7	11
Sousa *et al* (2019), The efficiency of Kinesio-taping in the control of saliva swallowing and drooling in children with cerebral palsy and evaluation of the improvement of the child's quality of life, motivation, and self-esteem	- Level IV - Case study	Cerebral palsy with spastic diplegia and chronic drooling	Seven-year-old female	1

KT= Kinesio Taping, M= Male, F= Female, rMV= Repeated Muscle Vibration, OME= Oromotor Exercises, RCT= Randomized Control Trials, FuCT= Functional Chewing Training, PNF= Proprioceptive Neuromuscular Facilitation.

Table 2. Findings of the methodological quality evaluations of included studies

Authors, Year	Level of evidence	PEDro-P score
Awan *et al* (2017)	II	4/10
Sethy and Mokashi (2011)	II	6/10
İnal *et al* (2017)	II	6/10
Mallick *et al* (2017)	III-2	5/10
Iram *et al* (2014)	III-2	2/10
Swati (2019)	III-2	5/10
Sığan *et al* (2013)	III-1	6/10

PEDro-P= Physiotherapy Evidence Database.

Types of treatments

The results of the present review showed that speech and language pathologists can use a range of methods (Table 3) in order to control drooling in children with cerebral palsy. However, the existence of heterogeneity within and between the interventions used is the most important limitation. In general, the treatments that speech and language pathologists can use may be classified into three categories: oromotor and sensory interventions, behavioral interventions, and the use of Kinesio tape.

In 7 of the 15 studies, only one treatment method was utilized to alleviate drooling in the study group or in the intervention and control groups separately (25,26,28,30,35-37), which consisted of muscle

Table 3. Interventions, Follow-Up, Outcomes, and Main Findings

Study (Authors, Year)	Interventions	Follow-UP	Outcomes	Main findings
Mikami *et al* (2019)	- Speech therapy for drooling plus application of KT: Speech therapy: - Passive therapy (tactile, thermal, and gustatory intraoral stimulation) - Active therapy (isotonic and isometric exercises of the lips, tongue, and cheeks) - Kinesio Taping: over the superior and inferior orbicularis muscles	-	Six parameters of drooling: a) Impact of drooling on the life of the child and caregiver, assessed by a 10-item questionnaire completed by the child's teacher; b) the severity of drooling, using data reported by teachers and family; c) frequency of drooling, using reported data; d) drooling estimated by the number of bibs used daily; e) drooling was estimated by pooling saliva on bibs, which was calculated by the difference between bib weight before and after oral motor skill evaluation; f) Inter-labial gap Seven markers of oral motor skills: a) lip closure; (b) lip closure on utensils; (c) lip closure during swallowing; (d) control of food during swallowing (solid/soft); (e) mastication; (f) straw-sucking; and (g) control of liquid during swallowing	Kinesio Taping of the orbicularis oris muscle reduced the interlabial gap. All markers of oromotor skills and almost all parameters of drooling improved after 15 days of treatment. Kinesiotaping the orbicularis oris region along with speech therapy techniques caused rapid improvement in oromotor skills and drooling. The Severity and frequency of drooling reduced during the intervention
Russo *et al* (2019)	The muscle vibration through Cro®System (low amplitude rMV at a fixed frequency of 100 Hz) on the submandibular muscles, behind mandibular symphysis, i.e., digastric, mylohyoid, hyoglossus, geniohyoid, genioglossus, and styloglossus muscles	At one month and three months after the treat-ment	The Drooling Impact Scale (DIS) The Drooling Frequency and Severity Scale (DFSS) Visual Analogue Scale (VAS) Drooling Quotient (DQ)	rMV might be a safe and effective tool in reducing drooling in cerebral palsy patients. There was a significant reduction in the frequency, intensity, and severity of drooling at rest and during activities. The vibrations can improve the swallowing mechanisms and favor the acquisition of the maturity of the oromotor control in children with cerebral palsy. Statistically, significant differences have been observed between baseline and post-treatment and the two follow-ups
Fatima *et al* (2019)	Use of oral motor exercises (OME) for drooling control, including sensory stimulation; face massage, tapping, stroking, brushing, and icing	-	Severity and frequency of drooling according to the Thomas-Stonell and Greenberg scale	Oromotor exercises (OME) are effective in the reduction of the frequency and severity of drooling among cerebral palsy patients. A Significant reduction in drooling occurred with a reduction in the drooling severity and drooling frequency
Awan *et al* (2017)	- Group A (n=24): taping of orbicularis oris muscle followed by oral motor exercises (including brushing on the tongue, upper and lower gums, inner cheeks, and vibration on chin and neck) - Group B (n=24): there was only application of Kinesio taping of the orbicularis oris muscle without oral motor exercises	-	Drooling severity scale (DSS), Drooling frequency scale (DFS) Drooling impact scale (DIS)	The KT along with OME and KT alone significantly improves drooling severity and impact on cerebral palsy children. The combination of KT and OME was more effective for drooling severity and its impact than KT alone

Contd. table 3.

Sethy and Mokashi (2011)	Group A: conventional therapy (oral motor stimulations and oral motor activities) along with behavioral therapy (token economy and Positive reinforcement) Group B: conventional therapy alone	Eight days after treatment	Drooling frequency: frequency of drooling episodes for 20 *min*	The token economy program was effective in controlling drooling in children with cerebral palsy associated with mild intellectual disability .Significant decrease in drooling frequency in the experimental group compared to the control group but this reduction is not maintained. There was an increase in the frequency of drooling after discontinuing the therapy. Despite this increase in the frequency of drooling, it did not reach the baseline in both groups
İnal *et al* (2017)	Group I, received the Functional Chewing Training (FuCT): providing optimal sitting posture to support oral sensorimotor functions, positioning the food to the molar area during every meal to stimulate lateral and rotational tongue movements, massaging the upper and lower gums through the front teeth to the molar area, chewing training with a chewing tube to stimulate lateral and rotational tongue movements, and gradually increasing the food consistency Group II, classical oral motor exercise program: including passive (passive range of motion exercises of lips and tongue with the assistance of the parents) and active lip and tongue exercises (an active range of motions and strength training of lips and tongue)	-	The Karaduman Chewing Performance Scale (KCPS): for evaluating the chewing performance level. Tongue Thrust Rating Scale (TTRS): for evaluating the tongue thrust severity The Drooling Severity and Frequency Scale (DSFS): for evaluating drooling severity and frequency	The FuCT is an effective approach to reducing tongue thrust and drooling severity in children with cerebral palsy. After the 12th week of intervention: The FuCT group showed improvement in chewing performance according to the KCPS, tongue thrust according to the TTRS, and drooling severity, but no improvement was found in terms of drooling frequency. The control group did not show any improvement in chewing performance, tongue thrust, drooling severity, and frequency
Mallick *et al* (2017)	The experimental group (A): oral sensorimotor stimulation along with conventional occupational therapy control group (B): conventional occupational therapy	-	Drooling Impact Scale (DIS) Behavioral Paediatric Feeding Assessment Scale (BPFAS)	Oral sensorimotor stimulation in combination with conventional therapy is more effective than conventional therapy alone and reduces drooling and improves feeding behavior. A moderate relationship was observed between drooling and feeding behavior in children with spastic cerebral palsy

Contd. table 3.

Pervez *et al* (2014)	Kinesio taping the orbicularis oris muscles	-	Drooling Frequency Scale (DFS) Drooling Severity Scale (DSS) Drooling Impact Scale (DIS)	KT plays an important role in reducing drooling in cerebral palsy children KT is one of the safest treatment options for the management of drooling in cerebral palsy children
Iram *et al* (2014)	Group A: oromotor therapy alone (neurodevelopmental techniques [NDT], and stroking techniques) Group B: behavioral therapy through reinforcement and feedback procedures Group C: a combination of both therapies	-	Thomas-Stonell & Greenberg scale for measuring the frequency and severity of drooling	Oromotor therapy takes the lead in the management of drooling among non-invasive therapies. Oromotor therapy was more efficient than behavioral therapy in decreasing the frequency of drooling
Swati (2019)	Group A: Oromotor therapy alone (active and passive exercises, and sensory stimulation). Group B: KT the orbicularis oris muscle and oromotor therapy	-	Drooling Impact Scale (DIS) Thomas-Stonell & Greenberg Drooling scale Lip closure measurement	Both interventions significantly reduced drooling, but the combination intervention group was more effective in enhancing mouth closure and reducing the frequency and severity of drooling. Time-efficient treatment for controlling drooling was statistically significant in the intervention using Kinesio-taping and oral motor therapy
Sığan *et al* (2013)	The training group (A): oral motor training The control group (B): routine physiotherapy	-	Oral motor assessment form Functional feeding assessment (FFA) subscale of the multidisciplinary feeding profile (MFP) The Bayley scales of infant development (BSID-II)	Oral motor therapy has a beneficial effect on feeding problems in children with cerebral palsy. The training group showed a significant reduction in drooling severity as compared to the control group
Kumar *et al* (2015)	Oromotor therapy (whistling, candle blowing, stretching, blowing thermocol balls through a straw, stroking, tapping, and massaging)	-	The severity of Drooling–Assessed by a 0-3 scoring scale Frequency of Drooling–Assessed by a 0-2 scoring scale for head control, jaw control, lip control, and tongue control Scoring for oral sensitivity, tongue thrust, and jaw thrust by a 0, 1 scoring scale	Oromotor exercise plays an effective role in the management of drooling in children A significant difference in frequency and severity of drooling, jaw, and lip control was seen pre and post -oromotor exercise
Muammer *et al* (2010)	Electrical stimulation lasted for 5 minutes on orbicularis oris and masseter muscles by skin electrodes Exercises and PNF technique: - Global stretching followed by resistance - Smiling with and without opening the mouth, pursing the lips, lifting the upper lip, lowering the lower lip, sticking out the tongue, sticking the tongue upward, downward, to the right and the left, and swallowing activity	-	The salivary flow rate was measured by the drooling quotient (DQ) assessment method	Interventions such as electrical stimulation and PNF may decrease the drooling level in patients with cerebral palsy. Significant decrease in the rate of salivary flow rate in the post-treatment period when compared with the pre-treatment period

Contd. table 3.

Caneschi *et al* (2014)	KT on the supra-hyoid muscle (anterior womb of the digastric muscle and mylohyoid muscle) The Speech therapy treatment: cryotherapy, inductive massages, oral motor sensory stimulus, and isometric and isotonic exercises	Three months after the removal of the KT	Speech-language pathologists' perception of the level of drooling. A quantitative evaluation through sialometry. The graveness and the number of mouth towels utilized per day	The KT has shown to be effective in controlling sialorrhea during its use period; the permanence of the results after three months of its removal was not observed
Sousa *et al* (2019)	Application of KT on the suprahyoid muscles (the anterior belly of the digastric muscle and mylohyoid muscle)	-	The perception of the mother or guardian regarding the social impact of sialorrhea. The number of towels/tissues used during a complete day for oral cavity cleaning was quantified. The severity and frequency of sialorrhea were verified through two scales: frequency scale (score from 1 to 4 points) and gravity scale (score from 1 to 5 points)	The KT was effective in: improving the control of swallowing saliva and sialorrhea reducing the number of towels used per day improving their self-esteem and quality of life

KT= Kinesio Taping, rMV= Repeated Muscle Vibration, Hz= hertz, DIS= Drooling Impact Scale, DFSS= Drooling Frequency and Severity Scale, VAS= Visual Analogue Scale, DQ= Drooling Quotient, OME= Oral Motor Exercises, DSS= Drooling severity scale, DFS= Drooling frequency scale, FuCT= Functional Chewing Training, KCPS = Karaduman Chewing Performance Scale, TTRS= Tongue Thrust Rating Scale, DSFS= Drooling Severity and Frequency Scale, BPFAS= Behavioral Paediatric Feeding Assessment Scale, DSS= Drooling Severity Scale, NDT= neurodevelopmental techniques, FFA= Functional feeding assessment, MFP= multidisciplinary feeding profile, BSID-II= Bayley scales of infant development.

vibration, Oromotor promotor Exercises (OME), muscle kinesiotape, orbicularis oris, suprahyoid muscle kinesiotaping, and Functional Chewing Training (FuCT).

Russo *et al* evaluated the effectiveness of Repeated Muscle Vibration (rMV) in the treatment of drooling in children with cerebral palsy at four-time intervals of baseline, 10 days, 1 month, and 3 months after treatment. The mentioned study showed that rMV stimulation below the chin symphysis improves drooling in children with cerebral palsy, and this method can affect the swallowing mechanisms and improve oromotor control (37). In a randomized, single-center clinical trial study by Inal *et al*, treatment of drooling in the treatment group focused on Functional Chewing Training (FuCT) and in the control group on OME (active and passive exercise) treatment (30). This study showed that FuCT is an effective method for improving chewing function, tongue thrust, and severity of drooling, but does not reduce the frequency of drooling, and the only significant difference between the two groups was in the severity of tongue thrust (30). In three studies, the effectiveness of OME intervention on drooling was investigated, and the results showed that OME intervention effectively reduced the frequency and severity of drooling (28,35,36).

In another study, Pervez *et al* (26) evaluated the effectiveness of Orbicularis oris muscle kinesiotaping on drooling. In this study, the patients received only kinesiotape on the orbicularis oris muscle for 45 *min per* session (5 days a week for two consecutive months). The results showed that kinesiotaping plays an important role in reducing drooling in children with cerebral palsy (26). Suprahyoid muscle kinesiotaping was another method used in a case study on a 7-year-old girl. Sousa *et al* used a kinesiotape on the anterior belly of the digastric muscle and mylohyoid muscle for five days with a two-day rest interval (60 days, overall); the results demonstrated the effectiveness of kinesiotaping in improving saliva swallowing, drooling control, the quality of life, and self-confidence (25).

The remaining eight studies had used a therapy method

in the intervention group or combination therapy for one group compared to a single therapy method in the control group, in most of which oromotor interventions (active and passive exercises, isometric and isotonic exercises) were used. Combination therapies in these studies can be divided as follows: combination therapy of kinesiotaping and oromotor intervention (speech therapy) (32,33,38,39); combination therapy of oromotor intervention and behavioral therapy (29,34); combination therapy of electrical stimulation and Proprioceptive Neuromuscular Facilitation (PNF) (27); and combination therapy of oromotor intervention and conventional occupational therapy (31).

Mikami *et al*, in order to control drooling, used speech therapy, including passive therapy (tactile, thermal, and gustatory intraoral stimulation) and active exercises (isotonic and isometric exercises of the lips, cheeks, and tongue) along with the kinesiotaping of the orbicularis oris muscle for 30 days (twice a week for 30 *min*) (38).

In a similar study, Caneschi *et al* used the suprahyoid muscle (anterior womb of the digastric muscle and mylohyoid muscle) kinesiotaping along with speech therapy (sensory-motor stimulation of the mouth, isotonic and isometric exercises, cryotherapy, inductive massages) for 30 days (39). In two studies, Awan *et al* (33) and Swati (32) used the combination of kinesiotaping and oromotor intervention, with the difference being that the control group in Awan *et al*'s study received only kinesiotaping intervention and in Swati, only oromotor intervention (32,33). These studies showed that combination intervention is more effective in reducing the severity and frequency of drooling than using a single treatment method.

The other two studies used a combination of oromotor intervention and behavioral therapy (29,34). Sethy and Mokashi used conventional therapy, including oromotor activities and stimulation along with the token economy, and positive reinforcement (29). Iram *et al* studied oromotor intervention, including Neurodevelopmental Techniques (NDT) and stroking along with the reinforcement and feedback methods (34). The results of Sethy and Mokashi's study indicated that combination intervention was more effective than the oromotor one alone, and the results of Iram *et al*'s study showed that oromotor intervention alone was more effective than combination intervention or behavioral therapy alone (29,34).

The use of electrical stimulation is another method used in combination with other methods to control drooling in children with cerebral palsy. Electrical stimulation is one of the electrotherapy methods used by physiotherapists to improve motor control and increase sensory awareness (27). Muammer investigated the effects of electrical stimulation and PNF exercises and techniques in the orofacial area on drooling in children with spastic cerebral palsy and showed that electrical stimulation and PNF techniques help in reducing drooling levels in these children (27). In their study, Mallick *et al* investigated the effects of oral sensorimotor stimulation combined with conventional occupational therapy (including positioning and providing children and families with some recommendations for awareness of and controlling drooling and maintaining oral hygiene) for controlling drooling and improving feeding behavior (31). Their results represented the effectiveness of this method on reducing drooling and improving feeding behavior (31).

Outcome measurement

In the present work, different measurements were used in the studies reviewed, to investigate the effects of the interventions on drooling. More than one technique or scale was utilized by most studies for evaluation, and only two studies used a single method to evaluate the effect of the intervention. Evaluation methods used in these two studies included measuring salivary flow rate through Drooling Quotient (DQs) (27) and measuring drooling frequency in 20-*min* periods (29).

Ten studies examined the target behavior through various scales, among which Drooling Impact Scale (DIS), the Thomas-Stonell and Greenberg Scale, and the Drooling Severity and Drooling Frequency Scale were the most widely used scales (26,28,30-37). In the other studies, however, the mentioned scales were not used, but various other methods were utilized such as the effect of drooling on life, daily counting of child's bibs and towels, drooling estimated by pooling of saliva on bibs, the speech and language pathologists' perception of the level of drooling, and sialometry assessment (25,28,39). More information

on outcome measurement is presented in table 3.

Treatment effects

In all studies, the treatments were observed to have positive effects on reducing drooling in children with cerebral palsy, and each study reported positive results associated with drooling and the related parameters after treatment (Table 3) with no adverse effects. In eight studies, it was reported that the frequency and severity of drooling after treatment dropped below the baseline level (4,26,32-37). Three other studies reported a decrease in drooling severity (28,30,31), and one study only reported a decrease in drooling frequency (29). In a randomized, single-center clinical trial study, the severity of drooling significantly decreased in the FuCT group after treatment, but this improvement was not observed for the frequency of drooling (30). In Sığan *et al*'s study, the participants in the intervention group received oromotor therapy once a week for six months (one hour per session), and the evaluations were performed in the initial examination and six months later, which showed a decrease in the severity of drooling and improvement in feeding problems (28). In another study, Mallick *et al* reported a reduction in the severity of drooling after combination treatment with oral sensorimotor therapy and conventional therapy (31).

In the remaining studies, post-treatment improvement in drooling was reported in parameters such as salivary flow rate (27), saliva control (39) and salivary swallowing, number of bibs used per day, and self-confidence and quality of life (25). More details of the treatment effects are reported in table 3.

Long-term results

Follow-up evaluations were reported only in three studies,. Russo *et al* performed follow-up evaluations one and three months after treatment, and their results showed a significant difference between baseline and the two follow-up time points (37). Sethy and Mokashi performed the follow-up evaluation eight days after treatment and concluded that despite the increase in drooling frequency after cessation of treatment, it was still different from the baseline rate (29). Caneschi *et al* performed the follow-up evaluations to assess the long-term outcomes three months after kinesiotape removal and concluded that treatment effects were not maintained after three months of treatment cessation (39).

Discussion

This review aimed to evaluate non-medical treatments for drooling in children with cerebral palsy, which can be performed by speech and language pathologists. This study was conducted on the works published between 2010 and 2022. The studies reviewed here had different designs. Overall, the results of the 15 studies indicated that non-medical treatments for drooling are effective in children with cerebral palsy. In the following section, we will discuss some important remaining issues.

Methodological quality assessment

In the present review study, most studies had a low level of evidence when assessed based on the NHMRC classification of evidence. In addition, methodological quality assessment based on the PEDro-P scale shows a low score for most of these studies. Random allocation, blinding (participants, evaluator, and therapist), and intention to treat were the criteria for which the lowest scores were obtained.

Types of treatments

In the present review study, it was shown that, in general, the treatment methods that speech and language pathologists can use to treat drooling in children with cerebral palsy can be classified into three broad categories: oromotor and oral sensory interventions, behavioral interventions, and kinesiotaping. Among these, the use of oromotor interventions and oral sensory interventions, alone or combined with other approaches, was the most wildly utilized method. These studies also demonstrated that no fixed single technique or method has been performed to control drooling, and researchers have used different methods with different treatment designs and frequencies. However, in all of the studies probed here, the positive results were reported after treatment, with a decrease in the frequency and severity of drooling being reported in most of these studies.

Evaluation of outcome measurement

Measuring target behavior before, during, and after

treatment is of great importance to keep the record of any changes resulting from the intervention (40). For accurate measurement of drooling, it is essential to have a practical definition and a measurement method that can effectively describe the data (41) and enable the researchers to examine treatment-related changes continuously beyond the point of intervention (40). In the studies reviewed here, there was variation in the methods used for measuring the outcomes. In general, the tools used to assess drooling in children with cerebral palsy include objective and subjective measurements. In the present review study, it was found that most of the used tools are subjective. Objective methods (such as drooling quotient [DQ], bib weight measurement, and sialometry) are utilized to measure saliva volume and saliva flow, which of course, are time-consuming and do not examine psychological damages. Drooling quotient (DQ) as an objective measurement method is a reliable method for measuring drooling severity (42), which has been used by only two studies in this work (27, 37). Subjective assessments used in the studies in the present work were validated tools for assessing drooling. For instance, the most widely used tool was the Drooling Effect Scale, which parents completed and had good test-retest reliability. Furthermore, it is sensitive to changes occurring during the treatment process (43). It is suggested that valid objective and subjective tools should simultaneously be utilized to study drooling.

Long-term results

The results of the studies in the present review indicated the short-term effectiveness of various interventions for drooling; more studies, then, are required to provide evidence for long-term recovery and efficacy after treatment. Prolonged follow-up is essential given that there is the possibility of recurrence and relapse after treatment. Long-term follow-up evaluations were performed only in 3 studies. In general, the results of two of the three studies demonstrated positive effects of treatment during the follow-up period (29,37). However, future studies should pay more attention to this issue.

Limitations

There are some limitations in the current review study which should be considered before generalizing the findings. The articles reviewed here were all in English, and studies in non-English languages, the gray literature such as study reports, conference papers, dissertations, and articles in obscure journals were excluded from the study, which means that some studies have not been reviewed. Another limitation of the present study was that, to ensure that only new articles are investigated, only articles published since 2010 were reviewed.

Conclusion

Various treatment methods with heterogeneous research designs have been used in studies on drooling in children with cerebral palsy. These studies also did not show a high level of evidence, and therefore this does not allow for any specific treatment method or protocol to be proposed. This review study does not specify any specific order for interventions but provides a range of treatment options with published evidence supporting each intervention. However, the results of many studies reviewed here indicated the favorable effect of non-medical treatments for drooling in cerebral palsy children. Finally, future studies should have higher levels of evidence (*i.e.*, RCTs), more accurate methodological quality, and more extended follow-up evaluations.

Statement of ethics

The authors have no ethical conflicts to enclose.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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