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OROMOTOR FUNCTION

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Introduction

The development of precise and synchronized oromotor movements provides the foundation for feeding and speech. Oromotor dysfunction (OMD), defined here as an impairment in the range, rate, strength and fine coordination of the jaw, lips, tongue, and cheeks, can disrupt the natural development of these crucial skills (Morgan 2011). The term OMD often encompasses sensory impairments; however, for this chapter, they will not be discussed. OMD in children with cerebral palsy (CP) may result from weakness, rigidity, in-coordination, or involuntary movements of the oral musculature. This chapter will focus on the various presentations of OMD in individuals with CP. Typical oromotor development is briefly discussed to provide a context for how it may deviate in children with CP (the anatomy and physiology of the larynx can be found in Chapter 35). The effect OMD has on associated functions is also summarized. The chapter concludes with an overview of assessment and treatment of OMD.

Clinical science

Typical oromotor development

Speaking and eating are complex functions that are dependent on the integrity of the oromotor system. Movement of the oral structures is achieved through the activation of nerve impulses arising from the motor areas of the cerebral cortex that then travel along the motor pathways (Murdoch 1998). Oral movements are primarily produced through the motor nuclei of cranial nerves V, VII, X, and XII (Table 25.1). The mandibular branch of the trigeminal nerve (V) supplies the muscles of mastication and is responsible for movements of the jaw. Facial expressions (including movement of the lips and cheeks) are controlled by the facial nerve (VII). The range and precision of tongue movements is directed by the hypoglossal nerve (XII), whereas the trigeminal (V) and vagus (X) nerves both function to elevate the soft palate.

The establishment of rapid and highly coordinated oromotor movements undergoes constant refinement during childhood. It is influenced by many factors including a child's exposure to various food consistencies (Gisel 1988), neural maturation, and musculoskeletal growth (Green et al. 1997). Stabilization of the head and trunk is essential as it provides the support needed to produce refined oral movements (Redstone and West 2004). The complex nature of oromotor development is perhaps highlighted by the fact that stability of motor control for speech is not achieved until adolescence (Walsh and Smith 2002).

During the neonatal period, precise and coordinated movements of the lips, jaw, tongue, cheeks, and palate are essential for sucking. As the child develops, optimal functioning of these structures provides the foundation for managing various food consistencies (Morgan and Reilly 2006) and producing clear speech. The introduction of solids at approximately 6 months of age initiates a rapid progression in oromotor development. Movement of the oral structures is initially involuntary and a result of reflexes (Stevenson and Allaire 1991). As discussed in Chapter 35, these reflexes function to assist neonates in the feeding process (Table 25.2; Wolf and Glass 1992). In children with CP, oromotor reflexes may be hyperactive or persist beyond the typical age of suppression, as discussed below in this chapter. To understand how oromotor development in children with CP can deviate from the norm, typical development is briefly summarized below and in Table 25.3.

Jaw

The jaw is one of the first oromotor structures to mature functionally (Green et al. 2002, Nip et al. 2009). Stability of the jaw provides the framework for precise and independent movements of the tongue and lips (Wolf and Glass 1992, Hayden and Square 1994). The range and speed of jaw movements undergoes considerable development during infancy. Initially, vertical jaw movements predominate (i.e. opening and closing; Gisel 1991, Wilson and Green 2009). As solids are introduced to the child's diet, children begin to acquire greater jaw control and lateral jaw movements emerge (Pinder and Faherty 1999). At 10 to 12 months, increased range of motion is achieved as rotary jaw movements emerge (Pinder and Faherty 1999). In conjunction with the movements of the tongue and cheeks, rotary jaw movements play an important role in preparing the bolus for swallowing (van der Bilt et al. 2006). The establishment of rotary jaw movements also signifies mature chewing

Ava

Ava is 5 years old and has bilateral spastic cerebral palsy (CP) (Gross Motor Function Classification System [GMFCS] level III, Manual Ability Classification System [MACS] level II, Communication Function Classification System [CFCS] level III, Eating and Drinking Ability Classification System [EDACS] level III).

Ava was referred for a speech motor assessment. She has normal vision and hearing, and age appropriate language and cognitive abilities. Ava's oromotor functioning was assessed using the Verbal Motor Production Assessment for Children (VMPAC).

Ava scored 50% on the global motor control subtest of the VMPAC, indicating severe deficits in this area. Areas of difficulty were postural control and muscle tone during ambulation, respiration for phonation, and coordination of chewing and swallowing. For the Focal Oromotor Control subtest, Ava achieved a score of 49%, indicating severe difficulties in controlling movements related to the jaw, face, lips, and tongue. She presented with reduced range of lip and tongue and movements, and jaw instability/sliding. Ava was able to produce all of the single phonemes although her motor control was poor. She demonstrated oromotor control difficulty on all of the double and triple oromotor–phoneme movements. Ava scored 63% on the sequencing subtest, indicating mild difficulties in sequencing non-speech and speech movements. Improvements in this area were noted for items involving words and sentences. Ava presented with a moderate dysarthria, which affected all of the motor speech subsystems (i.e. respiration, phonation, articulation, prosody, and resonance).

Ava's speech difficulties reflect her moderate dysarthria. She would benefit from multidisciplinary team management (e.g. speech and language, occupational and physical therapy) to assess and manage her overall posture to facilitate jaw stability. Motor speech intervention should involve meaningful speech tasks. Although Ava demonstrated some sequencing difficulties, her coordination and range of movements had a greater impact on her speech. Therapy could include a focus on facilitating jaw stability to enhance precision and selective control of tongue movements. This in turn will facilitate her production of consonants. Ava's breath support for speech should also be targeted to provide a solid foundation for speech as per recent evidence indicating improvements in the speech of children with CP after intervention focused at a respiratory–phonatory level.

Sam

Sam is an 8-year-old boy with bilateral spastic cerebral palsy (GMFCS level IV; MACS level III; CFCS level IV; EDACS level III). Sam was referred for a feeding review. He has mild intellectual disability and uses augmentative and alternative communication.

During the assessment Sam was seated in his wheelchair. He had some difficulty maintaining appropriate trunk and head alignment. He was able to feed himself although he required assistance at times. With semi-solid food textures, a lip seal was not maintained resulting in some anterior spillage. Sam demonstrated greater difficulty with solid food textures: mastication was prolonged and lateral tongue movements were minimal. While drinking from a cup, anterior spillage was noted and his head often tilted backwards. Signs of aspiration (e.g. coughing) were not observed.

Sam's positioning was modified through the use of a chest harness to facilitate trunk and head stability. This allowed greater control of jaw and lip movements. A nose cut out cup was introduced to limit Sam's head tilting backwards thereby decreasing the risk of aspiration. Sam would additionally benefit from multidisciplinary team management to facilitate positioning for feeding. To encourage lateral tongue movements, food was directly placed on the molars.

which starts between the ages of 24 to 30 months (Stevenson and Allaire 1991, Pinder and Faherty 1999). There is a broad age range for the development of this sophisticated skill, however, which may emerge much later in some children with typical development (Wilson and Green 2009).

Tongue

Chapter 35 describes the initial limitations in children's tongue movements. With increased jaw stability and through the introduction of solids, the tongue's range of movement expands to include lateral movements between 12 and 24 months of age

TABLE 25.1
Cranial nerves associated with oromotor function

Cranial nerve	*Motor function*
Trigeminal (V)	Muscles of mastication Movement of the lower jaw Elevation of the velum
Facial (VII)	Facial expressions
Vagus (X)	Elevation of the velum Posterior tongue elevation
Hypoglossal (XII)	Tongue movements

TABLE 25.2
Oromotor reflexes in children with typical development

Reflex	*Description*	*Age reflex diminishes*
Rooting	Touch to the lips or cheeks causes the head to turn toward the source and the mouth to open	3–6 mo
Suckling	Light touch to the tongue initiates a sucking response	4–7 mo
Gag	Elicited by touch to the middle area of the tongue in newborn infants	Persists, reduces in strength at 7 mo
Cough	Elicited by foreign material entering the airway	Persists

Source: McGowan et al. (1991), Wolf and Glass (1992).

TABLE 25.3
Oromotor milestones in children with typical development

Age (mo)	*Milestone*
4–6	Mouth opens in response to food
4	Lower lip lowers to remove food from the spoon
6	Lateral jaw movements emerge
6–8	Fat pads in the cheeks diminish
9	Tongue is able to elevate and depress
10–12	Rotary jaw movements emerge
12	Lips move inwards to remove food from the spoon
12–24	Lateral tongue movements emerge

Source: Stevenson and Allaire (1991), Reilly et al. (1995), Pinder and Faherty (1999), Carruth and Skinner (2002).

(Stevenson and Allaire 1991, Reilly et al. 1995). This enables children to move food particles from one side of the oral cavity to the other for efficient chewing (Stolovitz and Gisel 1991). Dissociation between jaw and tongue movements is also important for speech development. With an increasingly stable jaw, the tongue is able to achieve a broader range of articulatory postures (Hiiemae and Palmer 2003).

Lips

The ability of the lips to achieve various positions (i.e. retraction, rounding) is important for accurately producing speech sounds. The importance of adequate lip function during feeding is highlighted in Chapter 35. Lowering of the upper lip to remove food from a spoon can be seen at 4 months of age (Carruth and Skinner 2002). This skill undergoes a period of refinement until 24 months of age (Stolovitz and Gisel 1991). The tone of the lips progressively increases between the ages of 5 months to 3 years, and is further strengthened up until the age of 5 years (Chigira et al. 1994).

Soft palate

Elevation of the soft palate has the dual role of producing oral versus nasal sounds and preventing the bolus from entering the nasopharynx. An infant's soft palate differs from that of an adult as it is larger and rests in close proximity to the epiglottis (Wolf and Glass 1992; see chapter 35 for further discussion). In regard to soft palate function during speech, infants' vocalizations are predominately characterized by nasal resonance (Vorperian and Kent 2007). At 2 months of age children demonstrate the ability to accomplish inconsistent velopharyngeal closure (Thom et al. 2006). It is reported that by approximately 1 year of age, children demonstrate efficient velopharyngeal control during the production of vowels (Vorperian and Kent 2007).

Clinical presentation

Prevalence of oromotor dysfunction in cerebral palsy

OMD is considered a common symptom of CP. Yet its precise prevalence in this population remains relatively unclear. It is often difficult to compare findings across studies because of varying definitions of OMD, the use of wide age ranges, the inclusion of only certain types or severity of CP, and the method of recruitment (i.e. population versus convenience samples) (Table 25.4). As seen in Table 25.4, OMD often co-exists with drooling and disorders of speech and feeding, and its prevalence can vary according to the method used to identify abnormal functioning. For example, the prevalence of OMD ranges between 22% (associated with drooling; Sullivan et al. 2000), 36% (associated with motor speech impairment; Parkes et al. 2010), and 99% (associated with dysphagia; Calis et al. 2008).

Association between oromotor dysfunction and cerebral palsy type and severity

OMD occurs in all types of CP and across the spectrum of severity. It is however, reportedly more common in children diagnosed with dystonia or athetoid CP (also known as dyskinetic CP) (Thommessen et al. 1991, Dahl et al. 1996). Further, OMD is most prevalent in children demonstrating greater limb involvement (i.e. bilateral CP [quadriplegia]; Thommessen et al. 1991, Stallings et al. 1993, Reilly et al. 1996, Chen et al. 2010b, de Carvalho et al. 2011) and severe gross motor impairment (Reilly et al. 1996, Chen et al. 2010b, Erkin et al. 2010), particularly Gross Motor Function Classification System (GMFCS) levels IV and V (Parkes et al. 2010). Similarly, there is a greater chance of presenting with oropharyngeal dysphagia

TABLE 25.4
Prevalence of oromotor dysfunction (OMD) in children with cerebral palsy

Author	*Method of recruitment*	*Age*	*Sample size*	*Cerebral palsy type*	*Cerebral palsy severity*	*Prevalence of OMD, n (%)*	*OMD based on:*
Benfer et al. 2013	Population-based	18–36 mo	120	Spastic, dyskinesia, ataxia, hypotonia	Mild–severe	51 (43)	Feeding
Calis et al. 2008	Community	2–19 y	166	Not reported	Severe	164 (99)	Dysphagia
Erkin et al. 2010	Convenience	2–12 y	120	Spastic (hemi-, di-, quadriplegia)	Mild–severe	13 (11)	Chewing
Field et al. 2003	Chart review	1 mth–12 y	44	Not reported	Not reported	30 (68)	Problems with chewing, tongue movement, lip closure or other oromotor areas
Love et al. 1980	Convenience	3–23 y	60	Spastic, athetoid, mixed spastic-athetoid	Slight–severe	24 (40)	Feeding
Mirrett et al. 1994	Convenience	7 mo–19 y	22	Spastic (di-, quadriplegia), mixed spastic-athetoid	Severe	21 (95)	Feeding
Ortega et al. 2009	Convenience	3–13 y	53	Spastic, athetoid, ataxic	Mild–severe	44 (83)	Feeding
Parkes et al. 2010	Registry-based	3–9 y (interquartile range)	1268	Spastic (uni-, bilateral), mixed spastic-dyskinetic (bilateral), dyskinetic, ataxic	Mild–severe	419/1168 (36) 240/1168 (21) 258/1168 (22)	Motor speech Swallowing/ chewing Drooling
Pirila et al. 2007	Convenience	1;10–9;0 y	36	Spastic (hemi-, di-, quadriplegia)	Mild–severe	18 (50)	Swallowing and non-speech tasks
Reilly et al. 1996	Registry-based	12–72 mo	49	Spastic, mixed spastic-athetoid, ataxia, hypotonia, hemi-, di-, tetraplegia	Mild–profound	(92)	Feeding
Rogers et al. 1994	Chart review	1 wk–22 y	90	Not reported	Ambulatory–non-ambulatory	88 (98)	Feeding
Santoro et al. 2012	Not reported	4 mo–11 y	40	Spastic quadriplegia, dyskinetic, mixed	Moderate–severe	30 (75) 3 (8)	Drooling Sucking
Santos et al. 2009	Convenience	4–19 y	108	Spastic, dystonia with athetosis, mixed, hemi-, di-, quadriplegia	Not reported	50 (46)	Speech and non-speech tasks
Stallings et al. 1993	Convenience	2–18 y	142	Spastic quadriplegia, mixed spastic-dyskinetic quadriplegia	Walker required–wheelchair bound	122 (86)	Feeding
Sullivan et al. 2000	Registry-based	4–13 y	343	Spastic quadriplegia, hemiplegia, dyskinetic, ataxic	Mild–severe	145 (42) 77 (22)	Speech Drooling
Thommessen et al. 1991	Convenience	1–16 y	42	Athetoid, dystonia, hemi-, di-, tetraplegia	Mild–severe	22 (52)	Feeding
Waterman et al. 1992	Convenience	5–21 y	56	Spastic (di-, quadriplegia), mixed, other	Mild–severe	40/51 (78)	Drooling
Wilson and Hustad 2009	Community	11–58 mo	37	Not reported	Not reported	29 (78)	Motor speech

Hemiplegia, unilateral CP; diplegia, bilateral CP with greater lower limb involvement; quadriplegia, bilateral CP with lower and upper limbs equally involved; athetoid, dyskinesia.

with increasing (more impaired) GMFCS levels (Benfer et al. 2013). Although oropharyngeal dysphagia has been reported to occur in all GMFCS levels, children in levels III to V are seemingly most at risk (Benfer et al. 2013). In relation to tube feeding, children within GMFCS levels IV to V have been found to be most commonly gastrostomy fed (Shevell et al. 2009, Benfer et al. 2013). Instances of tube feeding have been identified in GMFCS level I (Shevell et al. 2009), demonstrating that there can be additional factors that affect oral feeding ability beyond gross motor functioning.

The association between OMD and gross motor impairment is thought to be due to the greater degree of brain damage associated with severe CP (Sullivan 2008). Limited information is currently available to conclude whether there is a link between

OMD and specific neural abnormalities in individuals with CP. However, in a study focusing on 50 adolescents with periventricular leukomalacia born at less than 33 weeks' gestation (four were diagnosed with CP), left-hemisphere abnormalities involving the corticospinal and corticobulbar tracts were found to be associated with subtle deficits in speech-oromotor control (Northam et al. 2012). Specifically, deficits in the focal oromotor control domain of the Verbal Motor Production Assessment for Children (VMPAC; Hayden and Square 1999) were associated with abnormal magnetic resonance imaging findings (Northam et al. 2012). This domain measures the coordination, excursion, and symmetry of the jaw, lips, face, and tongue during speech and non-speech tasks. Three of the four children with CP included in the study by Northam et al. (2012) demonstrated deficits within this area. In another study reporting brain imaging findings for 175 (89 with CP) term-born infants with hypoxic–ischaemic encephalopathy and basal ganglia and thalamic injury, the presence of feeding impairment was associated with the severity of basal ganglia, thalamic, and brainstem injury (Martinez-Biarge et al. 2012).

Perhaps unsurprisingly, an association between the severity of OMD and the type of CP has also been reported (Reilly et al. 1996, Santos et al. 2009, de Carvalho et al. 2011). More specifically, moderate to severe OMD is commonly associated with bilateral CP affecting the arms and legs equally (quadriplegia) (Reilly et al. 1996) (de Carvalho et al. 2011). By contrast, children with bilateral CP affecting the lower limbs greater than the upper (diplegia) are more likely to demonstrate mild (Reilly et al. 1996) or mild to moderate deficits (de Carvalho et al. 2011).

Chen et al. 2010b compared the oromotor abilities of 33 children aged 4 to 12 years with bilateral spastic CP affecting the upper and lower limbs equally (*n*=16), bilateral CP affecting the lower limbs greater than the upper (diplegia) (*n*=13) and unilateral spastic CP (hemiplegia) (*n*=4, also Children unable to communicate verbally were excluded from the study. Authors used a modified version of the VMPAC to detect OMD. Three subscales of the VMPAC were administered: global motor control (assessing the neuromotor innervation to peripheral muscles in the torso, neck, head, and orofacial region), focal oromotor control (measuring volitional oromotor control of the jaw, lips, and tongue), and sequencing (assessing the child's ability to correctly sequence speech and non-speech movements). Study results were in accordance with previous findings as children with bilateral spastic CP (quadriplegia) and severe gross motor impairment were more likely to demonstrate severely reduced performance on all three VMPAC subscales (Chen et al. 2010b).

Patterns of oromotor dysfunction in cerebral palsy

Children's global motor development plays a key role in producing sophisticated oral movements (Stevenson and Allaire 1991). Motor disturbances resulting from CP may extend to involve the lips, tongue, cheeks, jaw, and/or soft palate. The first signs of impaired oromotor functioning typically become apparent during feeding (e.g. difficulties in sucking, transitioning to solids). Children with athetoid (dyskinetic) CP for example, have been described as demonstrating significant OMD from birth (Workinger and Kent 1991). This group of children tend to face continuing oromotor control challenges during adulthood due to pervasive involuntary oral movements such as facial grimacing, spasms, blocking, tongue thrusting, and gagging (Neilson and O'Dwyer 1984). Additionally, OMD in individuals with athetoid (dyskinetic) CP has been characterized by abnormal control, timing, and coordination of the lips, tongue, jaw, and velum (Kent and Netsell 1978). In particular, dissociation of lip and tongue movements from the jaw is difficult and tongue movements during speech have been described as slow, imprecise, and reduced in range (Kent and Netsell 1978).

In terms of spastic CP, Chen et al. (2010a) reported that children with a mild form of the disorder demonstrated greater oromotor variability during speech compared with children with typical development. In a sample of 10 children aged 4 to 7 years, these authors found that, compared with aged-matched participants, children with mild spastic CP demonstrated deficits in the timing of muscle activation and grading of muscle movements. This was particularly apparent during complex articulatory tasks that required the child to sequence syllables (Chen et al. 2010a).

Another common pattern of OMD in children with CP is retaining oral reflexes that are typically inhibited by 8 months of age. The presence of abnormal oral reflexes in this population is reportedly more widespread in children under 10 years of age (Love et al. 1980), suggesting that there may be inhibition of these reflexes eventually into late childhood. Commonly occurring abnormal oral reflexes include the bite reflex (Love et al. 1980, Dos Santos and Nogueira 2005, de Carvalho et al. 2011), mouth opening reflex (Sheppard 1964), and the gag reflex (Love et al. 1980, Dos Santos and Nogueira 2005, Erkin et al. 2010). Children with bilateral spastic CP (quadriplegia) are reportedly more likely to demonstrate persistence of the bite, gag and suck-swallow reflexes compared with those with unilateral and bilateral spastic CP (hemiplegia and diplegia) (Dos Santos and Nogueira 2005). Of these studies, only Erkin et al. (2010) investigated the relationship between abnormal reflexes and GMFCS level, reporting that levels IV and V were more commonly associated with a hyperactive gag reflex. It can be assumed that other abnormal oral reflexes are associated with severe CP owing to the higher degree of neurological impairment. Specific features of OMD according to the oral structure are described below and are summarized in Table 25.5.

Jaw

Children having all CP types often demonstrate jaw instability resulting in reduced precision and independence of tongue and

TABLE 25.5
Features of oromotor dysfunction in children with cerebral palsy

Oral motor structure	*Features of oromotor dysfunction*
	Excessive drooling
Cheeks	Reduced/excessive tone
Lips	Poor/absent lip closure
	Anterior spillage of food/liquids
Tongue	Reduced/absent lateral tongue movements
	Reduced/absent tongue elevation and depression
	Excessive tongue thrusting and pumping
	Poor/absent bolus formation
	Poor/absent transportation of the bolus
Jaw	Poor/absent jaw closure
	Jaw thrusting
	Temperomandibular joint contracture
	Prolonged and exaggerated bite reflexes

Adapted from Morgan and Reilly (2006) and Reilly et al. (2010).

lip movements. Impaired trunk and head stabilities due to abnormal muscle tone or movements are likely to affect jaw stabilization. Children often compensate for reduced jaw stability by biting on the cup or spoon during feeding. In some cases, closure of the jaw can be difficult owing to malocclusions or fixed contractures of the jaw (Reilly et al. 2010). Lateral jaw movements can be absent, with subsequent negative effects on chewing (Reilly and Skuse 1992, de Carvalho et al. 2011). Increased tone in the jaw musculature may be associated with the tonic bite reflex. It has also been suggested that children with spastic CP demonstrate weakness in the jaw (Santos et al. 2010), further contributing to jaw instability in this group of children.

Tongue

Abnormal tongue function is often indicated by limited range of movement and reduced strength. Abnormal tone may affect the entire tongue or, in children with unilateral CP, only one side. Excessive tone will result in the tongue resting in a retracted position. In children with severe CP, tongue movements are often not independent of those of the jaw (Gisel and Alphonce 1995). Additionally, movement of the tongue away from the midline is often difficult or absent (Reilly and Skuse 1992, Gisel and Alphonce 1995, Waller 1998). This absence of lateral tongue movements reduces chewing efficiency and hence limits the variety of food textures a child is able to manage (Andrew et al. 2012). Limitations in tongue elevation and depression have been reported (Reilly and Skuse 1992). Involuntary tongue movements are associated with dyskinetic CP. Finally, the presence of tongue thrusting affects the child's ability to maintain the bolus within the oral cavity (Andrew et al. 2012).

Lips

Abnormal tone in the upper and lower lip muscles affects the range of lip movements. Excessive tone around the lips and cheeks, associated with spastic CP, will cause the lips to retract whereas reduced tone, associated with hypotonic CP, results in an open-mouth posture at rest. As children with dyskinetic CP demonstrate mixed muscle tone, either of these features can be observed. Restricted lip closure, rounding, and retraction often affect the production of speech sounds. Reduced lip closure during feeding is common (Reilly and Skuse 1992), resulting in anterior spillage of food and liquids (Waller 1998, Andrew et al. 2012). Reduced tone additionally effects the removal of food from the spoon (Reilly and Skuse 1992). The lips may have an asymmetric appearance at rest and during movement in children with unilateral CP.

Lip pressure in children with CP was examined by Chigira et al. (1994). The study consisted of three groups: children with CP (n=10; mean age 5y 0mo, only one child was ambulant, type of CP was not reported), children with a developmental delay (n=11; mean age 4y 5mo), and children with typical development (n=104; age range 5 months to 5y 11mo). Lip pressure was measured as children removed yoghurt from a spoon. Compared with children with typical development, the CP group demonstrated considerably reduced lip strength and greater variability in lip pressure. The mean lip pressure for children with CP was comparable to children with typical development between the ages of 5 months and 2 years. This finding was attributed to reduced control over lip movements, and in-coordinated movements of the lips and lower jaw (Chigira et al. 1994).

Soft palate

Netsell (1969) described the various presentations of velopharyngeal dysfunction in children with CP and dysarthria. This included gradual opening and closing of the velopharyngeal port, anticipatory opening, retentive opening, and premature opening. Individuals with athetoid (dyskinetic) CP have been found to demonstrate variable and insufficient velopharyngeal closure during speech (Kent and Netsell 1978). Reduced control over the velopharyngeal mechanism may lead to impaired resonance during speech (hyper- and/or hyponasality) and nasal regurgitation during feeding.

Conditions associated with oromotor dysfunction

The previous sections have discussed OMD deficits seen in children with CP specific to the oral motor structures and their effects on aspects of feeding and speaking. The overarching diagnoses for difficulties in these areas are dysphagia and dysarthria. The present section discusses the association between OMD and dysphagia, dysarthria, and drooling. As it is not within the scope of this chapter to describe these disorders in detail, references to other relevant chapters are provided below. The potential effect of OMD on oral hygiene is also discussed.

Dysphagia

OMD is one of numerous factors contributing to dysphagia in children with CP who may present with deficits across both the oral, pharyngeal and oesophageal phases of swallowing (Reilly et al. 2010; see chapter 35 for further discussion of pharyngeal and oesophageal deficits in CP). The oral stage of swallowing depends upon the skilled movements of the lips, tongue, cheeks, and jaw. Impaired control of these structures and the persistence of oral reflexes may result in difficulty acquiring the bolus from the spoon or cup, anterior spillage of food, diminished sucking, in-coordinated and lengthened duration of chewing, reduced anterior–posterior propulsion of the bolus, food remaining in the mouth post-swallow, and avoidance of certain food textures (Waterman et al. 1992, Rogers et al. 1994, Waller 1998, Yilmaz et al. 2004, Andrew et al. 2012). Furthermore, reduced tongue function may increase the risk of aspiration (Waterman et al. 1992) due to poor bolus control.

Children with significant OMD are more likely to demonstrate greater feeding difficulties, whereas some children with mild to moderate OMD may demonstrate adequate feeding skills (Clancy and Hustad 2011). Compared with children with CP with intact oral motor functioning, children with OMD are often introduced to solids at a later age (Wilson and Hustad 2009) and have difficulty transitioning to solid food textures (Gisel and Alphonce 1995). The consequences of OMD and dysphagia have been widely reported and include poor growth and nutritional status (Kirk and van Duyn 1984, Fung et al. 2002), tube feeding (Wilson and Hustad 2009), and lengthened (Gisel and Patrick 1988) or shortened (in children with severe OMD; Reilly et al. 1996) mealtime durations.

Dysarthria

As speech and feeding share common oral structures, the strong association between OMD, dysphagia, and dysarthria in CP is not surprising (Sullivan et al. 2000). Disruption to the range, speed, tone, and coordination of the oral musculature can have implications on a child's ability to produce clearly articulated speech. Dysarthria, an impairment in the neuromuscular control and execution of speech, is often associated with OMD. Children can show involvement in one or all motor speech subsystems (i.e. respiration, phonation, articulation, resonance, and prosody; expanded discussion of dysarthria and its features can be found in chapter 31).

Focusing solely on the oral cavity, speech production relies heavily on the stabilization of the jaw to enable dissociated movements, and increased mobility of, the tongue and lips to achieve the accurate placement for an intended sound. Reduced tongue function may result in inadequate force to produce plosives or affect lingual–palatal placement, resulting in imprecise articulation. Inadequate strength and mobility of the lips may lead to difficulties in producing sounds requiring lip closure, rounding, or retraction. Additionally, inadequate strength or coordination of the velopharyngeal valve will effect children's resonance (i.e. too much or too little air may escape through the nose). These impairments may have minimal effect on a child's speech intelligibility or in severe cases, might result in marked reductions in speech intelligibility whereby children may rely on other means to communicate (e.g. alternative and augmentative communication devices).

Drooling

Drooling occurs in approximately 40% to 58% of children with CP (Tahmassebi and Curzon 2003, Reid et al. 2012) and is a consequence of poor oromotor functioning (Erasmus et al. 2009, Reid et al. 2012). Saliva control requires adequate lip closure and tongue control, and the ability to frequently generate a swallow (Senner et al. 2004). These areas are frequently impaired in children with CP (Sochaniwskyj et al. 1986, Yilmaz et al. 2004) thus increasing the risk of poor saliva control. Other factors associated with the presence of drooling are poor head control, severe involvement of all four limbs, and no independent ambulation (Reid et al. 2012).

Oral hygiene

OMD can contribute to poor oral hygiene in individuals with CP. Maintaining oral health, particularly in individuals with bilateral CP (Dos Santos and Nogueira 2005), can be difficult owing to limited tongue movements, oral hypersensitivity, a hyperactive gag reflex, or the persistence of the bite reflex. Food can accumulate in the mouth because of inadequate clearance during the oral phase of swallowing, and limited tongue movements result in an inability to dislodge debris. The resulting debris within the mouth can lead to halitosis (bad breath). Food particles remaining in the oral cavity post-swallow should be removed by rinsing the mouth with water or sweeping the mouth with a clean finger. Gastroesophageal reflux into the mouth can further contribute to oral health problems due to dental erosion (Guare et al. 2012). Additionally, some medications may cause a dry mouth (xerostomia), which can increase the risk for dental caries (Norwood and Slayton 2013). Although evidence suggests that drooling does not increase the risk of dental caries, children who drool demonstrate poorer oral hygiene than children with adequate saliva control (Hegde et al. 2008). This is possibly due to a build-up of tartar resulting from the pooling of saliva (Hegde et al. 2008).

Natural history of oromotor dysfunction

Understanding the natural history of a given disorder is important for determining its course, possible improvements with age, and the need for continuing intervention. The progression of OMD in children with CP remains relatively unclear because of the lack of longitudinal studies. Emerging data, however, highlight the potentially ongoing nature of OMD associated with feeding (Wilson and Hustad 2009, Clancy and Hustad 2011).

Clancy and Hustad (2011) investigated longitudinal changes in feeding among 23 children with CP with varying oromotor abilities. Children's feeding ability was initially assessed at 4 years 6 months and then every 6 months until 7 years of age. The presence or absence of OMD was determined by a speech–language pathologist and feeding-related data were collected by parent questionnaires. Children were classified as having typical, mild–moderate, or severe OMD. The authors reported that all three groups demonstrated relatively stable feeding abilities over time (Clancy and Hustad 2011).

The persistence of feeding difficulties in children with OMD was also confirmed by Wilson and Hustad (2009). Authors investigated the feeding abilities of 37 children with CP aged between 1 and 5 years. Children's past and present feeding abilities were based on parent report, whereas the presence or absence of OMD was confirmed by a speech–language pathologist. Children with and without OMD reportedly demonstrated similar early feeding problems (e.g. difficulty drinking from a bottle and transitioning to solids). As children developed, differences between the two groups emerged. Feeding difficulties in the group of children without OMD tended to resolve, whereas they continued in children with OMD (Wilson and Hustad 2009).

Assessment of oromotor function

As for gross motor function and hand function, there is now a classification system for communication, the Communication Function Classification System (CFCS; Hidecker et al. 2011; see also Chapter 31 and Appendix 3), and for eating and drinking skills, the Eating Drinking Assessment Classification System (EDACS; Sellers et al. 2014; Appendix 4). The scale classifies eating and drinking ability in terms of efficiency and safety, with levels of assistance applied to EDACS levels I to III. The tool is currently valid for children with CP from the age of 3 years. The EDACS joins the growing family of classification systems for CP describing functional performance within daily life. Both the CFCS and EDACS provide a way of classifying aspects of oromotor functioning in a child with CP. To manage these impairments, however, a more detailed assessment is required. Hence the present section will focus on key aspects to consider during a clinical oromotor examination according to the International Classification of Functioning, Disability and Health (ICF; World Health Organization 2001) model. The relevance of each ICF component is highlighted below.

Body function and structure

Evaluation of oromotor functioning involves examining the oral structures at rest and during oral, speech and feeding tasks. At rest, the following should be noted: (1) overall body tone, postural control, head and trunk stability; (2) respiration (e.g. regular, shallow, clavicular); (3) presence of drooling; (4) asymmetry or abnormal tone of the oral musculature; (5) structural abnormalities of the oral cavity including malocclusion, tongue tie, and cleft.

After completing the above observations, assessment should focus on examining the oral structures during oral motor tasks that do not involve speaking or eating. At this stage, it is important to consider the symmetry, coordination, tone, and range of movement of the jaw, tongue, lips, and soft palate. The presence of involuntary movements should be noted. During the neonatal period and early infancy, assessment of the oromotor system relies heavily on observing the child at rest/during play, evaluating the quality of the child's vocalizations/speech, and observing the child during feeding. For older children and adults, more formal cranial nerve and oromotor assessments may be possible, but this will depend on the individual's compliance and level of cognitive functioning. Commonly used oral motor assessments include the Neonatal Oral-Motor Assessment Scale (Palmer et al. 1993; Zarem et al. 2013) for neonates, the Schedule for Oral Motor Assessment (Reilly et al. 2000) for young infants, and the VMPAC (Hayden and Square 1999) for older children.

Key areas to assess during an oromotor examination include the following: (1) jaw (cranial nerve V)—symmetry, range of motion (e.g. inadequate/excessive opening or closing), abnormal tone and reflexes (e.g. jaw clenching, extension); (2) tongue (cranial nerves X and XII)—symmetry, range of motion (elevation/depression, protrusion, lateral movements), abnormal tone and reflexes (e.g. tongue thrust); (3) lips (cranial nerve VII)—symmetry, range of motion (retraction/pursing, opening/closing), abnormal tone and reflexes (e.g. lip pursing, retraction); (4) soft palate (cranial nerves V and X)—symmetry and level of contraction (complete/incomplete/no movement).

The final component of an oromotor examination at a body function level involves assessing the child's speech and feeding abilities. In terms of speech, assessment involves consideration of all the motor speech subsystems (i.e. respiration, phonation, resonance, articulation, and prosody). Assessment of OMD in relation to feeding focuses on the oral phase of swallowing (e.g. the ability to form an adequate lip seal and movement of the tongue and jaw). Expanded discussion of assessments relating to speech and feeding can be found in chapters 31 and 35, respectively.

Activity and participation

This aspect of the ICF shifts the focus from oromotor functioning per se to the broader implications of OMD (i.e. speech and feeding). Assessment at this level involves evaluating the following: speech intelligibility, the individual's ability to communicate successfully in a range of everyday situations, and level of independence and participation during mealtimes and social situations. There is currently no standardized paediatric assessment that systematically assesses oromotor function at an activity and participation level. There are, however, general measures of activity and participation (i.e. the School Function Assessment; Coster et al. 1998) that contain items relating to mealtimes, eating, and drinking. In relation to activity, the School Function Assessment considers a child's ability to drink from a cup, pick up utensils, and bring food to the mouth. One item within the School Function Assessment directly addresses participation during mealtimes. This item requires the respondent to rate how actively the child participates during mealtimes on a scale of 1 (participation extremely limited) to 6 (full participation). Additionally, there are ordinal scales of feeding and drinking at an activity level; however, these lack robust psychometric properties (see the systematic review by Sellers et al. [2014]). For adults with dysphagia, the SWAL-QOL (McHorney et al. 2000) is a validated questionnaire measuring the effect of dysphagia on an individual's quality of life.

Contextual factors
Finally, it is important to determine whether the surrounding environment or the individual's own characteristics influence speech and feeding. Barriers and facilitators include the use of devices to assist with communication, the use of modified utensils, plates, cups, etc. during mealtimes, the familiarity of the setting, noisy environments, and the attitudes of others.

MANAGEMENT OF OROMOTOR DYSFUNCTION

The ultimate goals of oromotor therapy are to improve an individual's speech intelligibility and/or to enable the safe consumption of food and drinks for adequate growth and nutrition. The following management approaches are divided according to the components of the ICF.

Body function and structure
Before specifically addressing an individual's OMD, optimal positioning should be determined (in consultation with occupational therapists and physiotherapists) to facilitate postural control and stability of the head (Morgan 2011). In turn, this will enhance oromotor performance. OMD management approaches are discussed below in relation to speech and feeding. The recommended position for feeding is upright at a 90° angle (see Figure 25.1) although children with dystonic tetraplegia (i.e. bilateral CP) may benefit from a 30° reclining position with the neck flexed (Larnert and Ekberg 1995).

Speech. Oromotor exercises not involving speech are reportedly often used with children with CP; however, their use is not recommended because of the lack of evidence supporting their effectiveness (Hustad 2010). Therefore, intervention for speech disorders associated with OMD should focus on speech related tasks as discussed in chapter 31. In the case of velopharyngeal incompetency, evidence suggests that palatal lifts are an appropriate management strategy particularly for individuals with a flaccid soft palate, pharyngeal wall movement, and adequate articulation and respiratory support for speech (Yorkston et al. 2001).

Fig. 25.1. Positioning for feeding. Source: Starr (2006). Reproduced with permission from the Allowah Presbyterian Children's Hospital.

Feeding. Although oromotor techniques are often used to manage oral phase impairments, there is currently no high-level evidence to support the use of a particular type of oromotor treatment both for children (Morgan et al. 2012) and for adults with dysphagia (Lazarus et al. 2001). In the absence of this evidence, a specific oromotor treatment approach cannot be advocated. Management of OMD associated with feeding therefore relies on the clinician's clinical judgement of what works best in conjunction with the personal preferences of the patient (including parents). Below is a list of common management approaches for OMD associated with feeding. The reader should refer to chapter 35 for further details about the management of dysphagia.

- Texture and liquid modifications (e.g. the use of soft textures to compensate for reduced chewing efficiency and thickened fluids to increase oral transit times). Limited evidence is currently available about the effectiveness of these diet modifications for children with CP (Snider et al. 2011). Diet modifications should be made in consideration of the individuals nutritional requirements to prevent nutrient deficiencies.
- Altering the taste or temperature of the bolus (e.g. sour, cold). This heightens sensory awareness with the aim of triggering a more prompt swallow (Logemann et al. 1995). This strategy will depend on the individual's sensory tolerance and gradual increases in sensory stimulation may be required.

- Reducing the volume of food presented to the individual.
- Performing oromotor exercises aimed at increasing the strength and range of motion of the tongue, jaw, and lips, for example placing food in certain positions of the mouth to increase the tongue's range of movement. In children with CP with moderate to severe motor impairment, Gisel et al. (1996) found that these tasks significantly improved oromotor skills (spoon feeding, chewing and swallowing but not drinking) although they were not associated with catch-up growth (children were, however, able to maintain their weight).

These modifications can be used with children in all GMFCS levels and may particularly be required for levels III to V. Further discussion of feeding management can be found in Chapter 35.

Activities and participation

From childhood to adulthood, management of OMD in relation to speech and feeding focuses on increasing the individual's independence and participation in a range of social situations. This involves selecting appropriate augmentative and alternative communication systems that allow the individual to communicate successfully within the home, school, and community about a range of topics. For individuals with dysphagia, situations involving eating and drinking form a key aspect of an individual's social life. Therefore, impairment-focused techniques should be paired with participation-focused strategies to facilitate involvement during mealtimes and social events. For instance, during childhood the clinician may work with the child's parents and teachers to enable participation during mealtimes. This is particularly important for children who require non-oral feeds. From adolescence to adulthood, where social events increasingly revolve around eating and drinking, management focuses on consulting with the patient about strategies that will promote involvement during these situations.

Contextual factors

At an environmental level, management of OMD in relation to speech focuses on selecting the most appropriate device to facilitate communication (see Chapter 31). Environmental modifications that can facilitate speech and feeding include being in a familiar setting, being surrounded by familiar people, reducing noise levels, and adjusting the lighting of the room (e.g. reducing glare). Other environmental modifications for feeding include adapted feeding devices/utensils. In general, children classified in GMFCS levels I and II demonstrate less involvement of the oral musculature and may only require modifications at an environmental level (Gisel 2008). In terms of approaches that are more medical, the effectiveness of botulinum neurotoxin A and pharmacological interventions (benztropine and glycopyrrolate) in improving oromotor function for drooling is currently supported by low-level evidence (Walshe et al. 2012).

Conclusion

OMD is commonly experienced by children with CP and can significantly affect children's speech and feeding skills. Disruption to the development of these essential activities can lead to negative health and social consequences for the child. Identification of OMD in children requires an understanding of typical oromotor development to detect abnormal patterns. Before addressing specific oromotor deficits, it is important to consider the effect the child's abnormal tone and postural stability may have on their ability to produce controlled oral movements. Given that speech and feeding problems in children with CP often progress into adulthood, continual management of OMD may be warranted.

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