Oral Sensorimotor Functions in Typically Developing Children 3 to 8 Years Old, Assessed by the Nordic Orofacial Test, NOT-S

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Background: Oral senorimotor development is the basis for several vital functions for the child, hence orofacial dysfunction may be severely disabling. Recently, a comprehensive screening instrument assessing different aspects of orofacial function in adults and children age three and up was developed, the Nordic Orofacial Test-Screening (NOT-S). The aim of the present study was to establish developmental profiles of orofacial function for children 3 to 7:11 years old using NOT-S methods: A total of 231 typically developing children 3:0 to 7:11 years old were included. Data were compiled from previous investigations. Comparisons across ages and gender were made.
Results: The total NOT-S score was below two for 58% (133) of all children in the study. There was a clear trend of lower total NOT-S score with increased age according to a best linear fit regression, $R^2 = .81$, $p = .014$. The number of children without any score on NOT-S increases dramatically for the seven-year-old children, 44% compared to 20% or lower for the other age groups. Boys had statistically significant higher scores than girls on the total NOT-S score and also for the clinical examination according to a Mann-Whitney U-test, $p < .000$ for both cases.
Key Words: NOT-S, oral sensory motor functions, speech, developmental profiles, reference values

BACKGROUND

Motor development is a fundamental aspect of a child's maturity. Gross motor development is often assessed in terms of motor milestones (Wijnhoven, de Onis, Onyango, Wang, Bjoerneboe, Bhandari, Lartey, & Al Rashidi, 2004). Motor development involves the integration of several processes such as planning, decision-making, memory, intentions, motivation, and goals (Adolph & Berger, 2006). Regarding the motor development in the face and mouth, the orofacial functions include several vi-

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tal functions such as breathing and nutrition. The orofacial area also acts as the basis for social interaction, emotional communication, facial expression and speech communication. Developmental studies have focused on speech and language development largely disregarding aspects of motor development (Green & Nip, 2010). Well-established landmarks regarding the sensory motor development of orofacial functions are much needed in clinical work where decisions regarding typical or deviant development in children are the basis for decisions regarding intervention.

During the first years of life there is a rapid growth of the orofacial skeletal structures and a maturation of the neural system. However, this skeletal growth into a more adultlike orofacial configuration is not determined by growth alone. The skeletal shape and the orofacial functions interact and the structures are successively shaped by their use (Bresolin, Shapiro, Shapiro, Dassel, Furukava, Pierson, Chapko, & Bierman, 1984; Kent, 1999). After about four years of age, a refinement of oral movements occur (Robbins & Klee, 1987; Sharkey & Folkins, 1985) and the previous variability between typically developing children's performance decrease (Robbins & Klee, 1987). Previous studies have shown that young boys have a somewhat slower maturation than girls, but boys seem to catch up after five years of age (Cheng, Murdoch, Goozee, & Scott, 2007; Smith & Zelanik, 2004). By the age of five, typically developing children also master the fundamental structures of speech and language (Baird, 2008). However, there is a great variation in the rate of speech and language acquisition. This means that children assessed as being delayed at one point in time may be within normal limits later in life. The converse also applies. Not surprisingly, it is the children with the most severe delay that have the most persistent and stable problems (Baird, 1995). The process of phonological acquisition and speech development involves several aspects of organizing and learning the connection between auditory speech input and the gestural control of speech output (Snowling & Hulme, 1994). In the clinical assessment the linguistic representation must be inferred from overt motor behavior in speech. Thus, there is a need to identify, treat, and follow up, children with disorders involving speech and other orofacial sensory motor functions.

Orofacial dysfunction may be severely disabling (Bergendal, McAllister, & Stecksén-Blicks, 2009; Lundeborg, McAllister, Ericsson, Graf, & Hultcrantz, 2009a) and impair perceived quality of life (Cohen, Noone, Munoz-Furlong, & Sicherer, 2004; Ericsson, Lundeborg, & Hultcrantz, 2009; Karande, Bhosrekar, Kulkarni, & Thakker, 2009). Due to their complexity, several clinical professionals are needed to assess orofacial problems. A few years ago, a comprehensive screening instrument assessing different aspects of orofacial function was developed, the Nordic Orofacial Test-Screening (NOT-S) (Bakke, Bergendal, McAllister, Sjögreen, & Ågren, 2007). NOT-S consists of two parts: an interview and a clinical examination. The two parts are each dived into six different domains. The interview part assesses: (I) Sensory function, (II) Breathing, (III) Habits, (IV) Chewing and swallowing, (V) Drooling, and (VI) Dryness of the mouth and in the clinical examination the domains deal with: (1) The face at rest, (2) Nose breathing, (3) Facial expression, (4) Masticatory muscles and jaw function, (5) Oral motor function, and (6) Speech (Table 1).

Each domain contains one to five items, thus reflecting the complexity of the specific function. The maximum total score for each domain is one point with a maximum score for each part of 6 points and

TABLE 1. The Different Domains in the Interview (I–VI) and the Clinical Examination (1–6) of NOT-S

Interview	Clinical Examination
I Sensory function	1 The face at rest
II Breathing	2 Nose breathing
III Habits	3 Facial expression
IV Chewing and swallowing	4 Masticatory muscles and jaw function
V Drooling	5 Oral motor function
VI Dryness of the Mouth	6 Speech

a maximum total NOT-S score of 12 points, the higher the score the more severe oral sensory motor problems. NOT-S is developed from the age of three years old and up. From the age of five years old the demands on speech production increases with an added item of speech diadochokinesis in syllable repetition (pa-ta-ka × 3) and stricter criteria for articulatory precision. The test has been shown to identify areas of impaired function, to discriminate between individuals with various degrees of disability and healthy subjects, and to have good inter- and intraexaminer reliability (Bakke et al., 2007; Bakke, Larsen, Lautrup, & Karlsborg, 2011; Bergendal et al., 2009). It has also been used to evaluate treatment outcome after tonsil surgery (Lundeborg et al., 2009a; Lundeborg, McAllister, Samuelsson, Ericsson, & Hultcrantz, 2009b; Lundeborg, Hultcrantz, Ericsson, & McAllister, 2012). The NOT-S test form is available on-line in several languages through the Swedish National Competence Center for Orofacial disorders (http://mun-h-center.se/en/Mun-H-Center/Mun-H-Center-E/NOT-S/).

The aim of the present study was to compile data from two studies of typically developing children in order to establish developmental profiles of orofacial function in children 3 to 7:11 years old using NOT-S.

METHODS

The data are composed of two investigations of typically developing children made as student thesis within the program of speech and language pathology at Linköping University. For the age group 3 to 6 years old by Gustavsson, Skoglund, and Thelin (2007) and for 6 to 7:11-year-olds by Andersson and Nordin (2011). For the age group 6:0 to 6:11 years old, data from both these studies and the control group in the original development of NOT-S (Bakke et al., 2007) have been compiled to increase the number of participants in the age group.

Enquiries regarding participation in the studies were sent out to headmasters of schools and preschools in the south east region of Sweden. Through the participating schools and preschools, the children and their caretakers received a letter with information regarding the study and a consent form regarding participation for their child. All testings were done in a separate quiet room at the school or preschool (Andersson & Nordin, 2011; Gustavsson, Skoglund, & Thelin, 2007).

A total of 231 children participated in the studies. A presentation of gender and age distribution is shown in Table 2.

The Mann-Whitney U-test was used to analyze the difference between two samples and the Kruskal-Wallis test for three or more samples. To examine developmental trends across ages and total scores a best fit linear regression was calculated. p-values <0.05 were considered statistically significant. All statistical analyses were performed using SPSS© Windows, version 18.

RESULTS

The mean values were below two for the total NOT-S score in all age groups. The highest standard deviation was found at four years of age, SD ± 1,37. There was a clear trend of lower total NOT-S scores with increased age according to a linear best fit regression, $R^2 = .80$. $p = .014$. The total score for all children and age groups is shown in Figure 1.

The mean scores for the interview and examination parts are shown in Figures 2 and 3, respectively. For the clinical examination a trend of lower scores with increased age was observed according

TABLE 2. Age and Gender Distribution of Participants

	Age groups					
Gender	**3:0–3:11**	**4:0–4:11**	**5:0–5:11**	**6:0–6:11**	**7:0–7:11**	**All**
Girls	27	24	22	28	32	130
Boys	26	25	19	10	18	90
All	53	49	41	38	50	231

Data compiled from Bakke et al., 2007, Gustavsson, Skoglund, & Thelin, 2007, and Andersson, & Nordin, 2011.

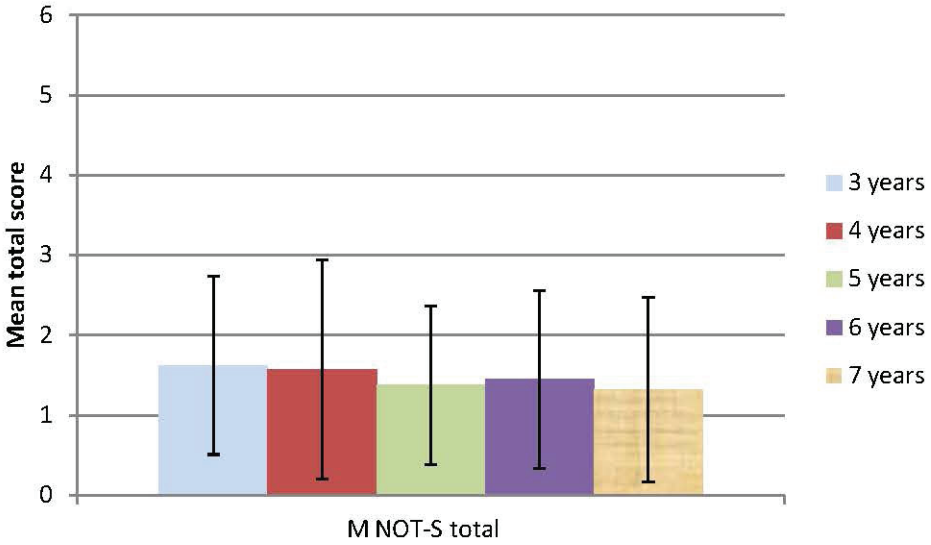

Figure 1. Mean total NOT-S scores and standard deviations according to age group.

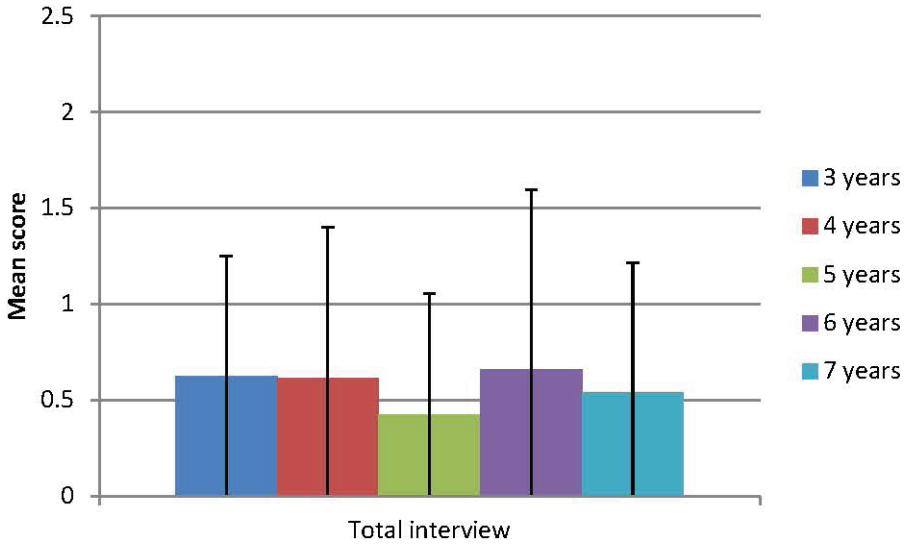

Figure 2. Mean total interview scores and standard deviations according to age group.

to a linear best fit regression, $R^2 = .81$, $p < .005$. For the total interview scores no such trend across age-groups was observed.

In all children 16% (37) had a total NOT-S score of three or more, but the majority, 58% (133), had a total score below two. When studying the number of children with a total NOT-S score of zero the picture is the reversed. The proportion of children without a score on NOT-S for each age group is shown in Figure 4. The number of children with zero increases dramatically between the ages six and seven years old; see Figure 4.

The developmental profile for children 3 to 3:11 and 4 to 4:11 years old is shown in Figure 5. For the domains *III Habits*, *IV Chewing and swallowing* in the interview section and *3 Facial expression* and *5 Oral motor function,* 20% or more of the children show difficulties. In the clinical examination 20% of the 3 to 3:11-year-olds had difficulties in the domain *2 Nose breathing*, but none of the 4-year-old children did. This was the only statistically significant differences between these two age groups, $p < .05$ according to a Mann-Whitney U-test.

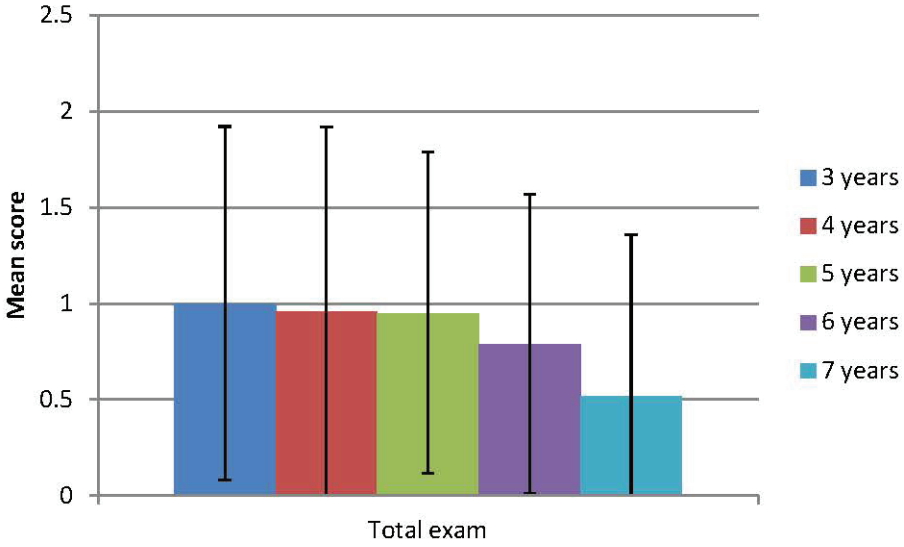

Figure 3. Mean total clinical examination scores and standard deviations according to age group.

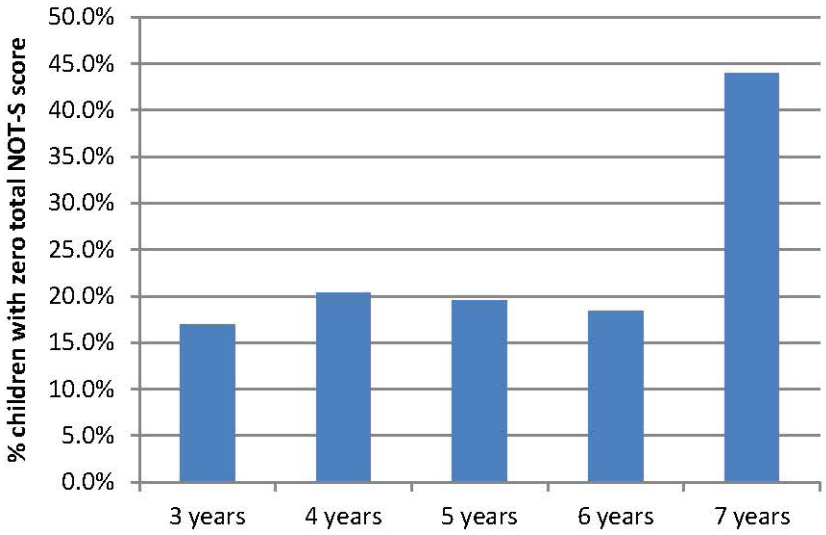

Figure 4. Proportion of children in percent with a total NOT-S score of zero according to age group.

The developmental profiles for children 5:0 to 5:11, 6:0 to 6:11, and 7:0 to 7:11 years old, respectively are shown in Figure 6. After the age of five years old the number of speech tasks is increased and also the demand on speech clarity, thus the increase in deviant speech score compared to the younger age-groups in Figure 5. The five-year-old children had problems in the domain *1 Face at rest* and *5 Oral motor function* in the clinical examination more often than the older age-groups. The difference regarding the domain *1 Face at rest* was statistically significant at $p = .0221$ according to a Kruskal-Wallis test. Twenty percent or more of the five and six-year-old children had problems in the domain *IV Chewing and swallowing* in the interview part and the five and seven-year-olds also in the domain *III Habits*. In the clinical examination more than 20% of all three age groups had problems in the domain *6 Speech* and in the six-year-old group more than 20% also had difficulties regarding *3 Facial expression*.

A comparison across gender showed that girls

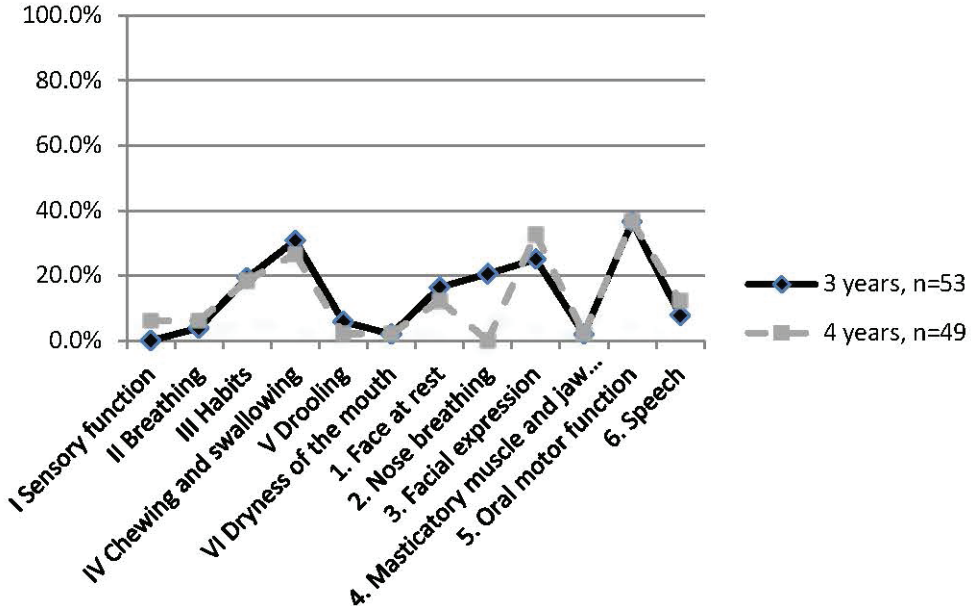

Figure 5. Developmental profile for children 3:0 to 3:11 and 4:0 to 4:11 years old, respectively.

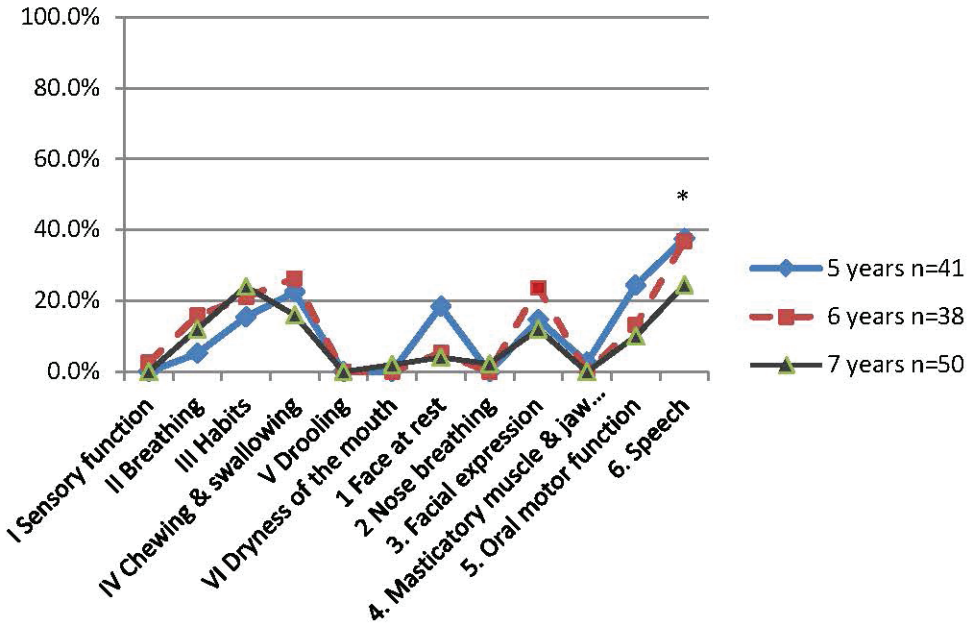

Figure 6. Developmental profiles for children 5:0 to 5:11, 6:0 to 6:11, and 7:0 to 7:11 years old, respectively. *Higher values due to added number of items and demand on speech clarity.

had somewhat lower scores on the clinical examination and the total NOT-S score as compared to boys. This difference was statistically significant according to a Mann-Whitney U-test, $p < .000$ in both cases. For the interview part no gender difference was found.

When analyzing the effects of gender for the specific age groups a significant difference was found for the ages 3.0 to 3:11 an 7:0 to 7:11 years old where girls had significantly lower total NOT-S scores according to a Mann-Whitney U-test $p < .05$ and .01, respectively.

DISCUSSION

Results showed that there was a clear developmental trend as indicated by lower total NOT-S scores with increased age. This was expected as oral motor function is a gradual development during childhood as are most other motor functions. Boys had somewhat higher total NOT-S and total clinical examination values compared to girls. This was especially evident in the youngest and oldest age groups. Previous studies have indicated that boys seem to catch up after about five years of age (Cheng, Murdoch, Goozee, & Scott, 2007; Smith & Zelaznik, 2004). In the present study, four, five, and six-year-old boys and girls had similar scores but at seven years old, girls had significantly lower scores. However, in the six-year-old group girls clearly outnumbered the boys possibly influencing the score.

Children below five years of age received lower scores in the speech domain compared to the older age groups. This is due to the one additional parameter in the speech domain and also the increased demands on speech clarity from five years old. By the age of five, typically developing children have been found to master the fundamental structures of speech (Baird, 2008). However, it is well known that there is a great individual variation in the rate of speech acquisition. The nature of interaction between the motor centers in the brain and sensory feedback from the body during fast, goal-directed movements such as speech is a matter of debate. In voice onset time (VOT) one aspect of this complex interaction may be studied. The analysis of VOT patterns in children offers information on the acquisition of this temporal parameter of speech. Studies of voice onset time (VOT) in children have found that English and Swedish speaking children acquire stable and adultlike VOT-values around 10 to 11 years of age (Lundeborg, Larsson, Wiman, & McAllister, 2012; Whiteside, Dobbin, & Henry, 2003) indicating the complexity of interarticulatory coordination required in speech. This complexity is also reflected in the present study where speech is the domain in the clinical examination with the highest percentage scores also in children 5 to 7 years old. A total of more than 20% of the seven-year-old children still received a score in the speech domain due to problems with clear articulation and/or rhythmic and correct articulatory targets during the diadochokinetic task of producing three pa-ta-ka sequences. In speech development there is an intricate interaction between physiological development of sensorimotor functions, speech production and language in the progressive organization and mapping between auditory speech input and the gestural control of speech production (Smith & Goffman, 2004; Snowling & Hulme, 1994). Clinical assessment of speech and language development typically relies on overt motor behaviors such as speech production. However, the speech part of NOT-S is clearly not sufficient for an evaluation of speech disorders and scores in the speech domain need to be followed up by a more thorough investigation. This is important as children with the most severe delay have also been found to have the most persistent problems (Baird, 1995) and, consequently, should receive therapy. The establishment of reference values regarding different aspects of orofacial sensorimotor functions for typically developing children is an important aid for the clinicians in this work. In a previous study, preschool children with tonsillar hypertrophy were found to differ from the control group in all domains of the structured interview and some of the domains in the clinical examination before surgery (Lundeborg et al., 2009a). At the follow-up six months after surgery, no differences regarding oral sensorimotor functions remained.

In the present study 20% or more of the children in one or more age groups were identified as having problems with: *III habits, IV chewing and swallowing, 3 facial expression, 5 oral motor function* and *6 speech,* with *6 speech* being the domain with the highest score in the older age group and *5 oral motor function* in the younger. Could it be that the children with oral motor problems at the ages of 3 to 4 years old later are the children with diadochokinesis problems? Only a longitudinal study could answer this question.

The goal of a multiprofessional assessment and intervention in children with orofacial problems is to improve or restore vital functions as nose breathing, lip closure, chewing, and swallowing and the accuracy of articulatory movements for one or more speech sounds in order to establish a better base for future development. The present profiles according to age can serve as guidelines for the clinician in the assessment of orofacial sensorimotor functions.

CONCLUSIONS

The total NOT-S score was below two for a majority of the children in the study. There was a clear trend of lower scores with increased age. At age seven years old, 44% of the children scored zero

on NOT-S. However, more than 20% of the seven-year-old children still received a score in the speech domain. Boys had higher scores than girls on the total NOT-S score and also for the clinical examination. The present results can serve as guidelines for the clinician.

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