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The Non-Speech Oral Movement Assessment for Children

Leenke van Haaften[a] Marloes Lagarde[a] Marjo van Gerven[a] Sandra de Groot[a] Celia Harding[b] Lenie van den Engel-Hoek[a] Karen van Hulst[a]

[a]Department of Rehabilitation, Donders Institute for Brain, Cognition and Behaviour, Amalia Children's Hospital, Radboud University Medical Center, Nijmegen, The Netherlands; [b]Division of Language and Communication Science, University of London, London, UK

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Oral movement · Assessment · Children

Abstract
Introduction: Examination of oral movements is often part of an assessment undertaken by a speech and language therapist (SLT). Until now, there have been no specific instruments or tests with reference values for typically developing children in Dutch that exclusively evaluate non-speech oral movements in young children. Therefore, a non-speech oral motor observation list was designed to attempt to bridge this gap: the Non-Speech Oral Movement Assessment for Children (NOMAC). The aim of this study was to evaluate the psychometric properties of the NOMAC in terms of inter-rater reliability and its' construct validity. In addition, we aimed to collect reference values for non-speech oral movements in children. ***Methods:*** Data from typically developing Dutch children aged 2–8 years were collected. Inter-rater reliability was studied by estimating the intra-class correlation coefficient (ICC). Construct validity was investigated by assessing the effect of age group and gender on the mean execution score per item (general linear model). To present normative data, the percentage of the children performing a normal oral motor execution was calculated. ***Results:*** The study includes a total of 318 children, divided into 9 age groups. The inter-rater reliability shows a moderate to excellent ICC for most items. A significant effect of the factor age group on almost all items was seen, confirming robust construct validity. Normative data are presented with the percentage of the children performing a normal oral movement execution. ***Conclusion:*** Non-speech oral movements can be assessed with the NOMAC in children between 2 and 8 years old and can be compared with values obtained from a normative group. It should be used as part of a clinical feeding and speech assessment. Despite the fact that current insights indicate that oral motor training has no value for improving mastication, swallowing, and speech, it is important to know the status of non-speech oral motor capabilities. With this assessment, a complete profile of the child's oral motor abilities can be achieved, supportive of clinical decision making in SLT.

Introduction

The muscles of the craniofacial system are used for many varied functions, such as speaking, with associated facial movements for communicating, along with nutritive movements for eating, drinking, and swallowing.

karger@karger.com
www.karger.com/fpl

Correspondence to:
Leenke van Haaften, leenke.vanhaaften@radboudumc.nl

These motor actions are described as both "speech" and "non-speech" movements [1]. Studies in this area often have focused on how the motor mechanisms for speech differ from non-speech-related movements (oral motor movements), although they are executed by the same muscles. Functions such as speaking, eating, drinking, swallowing, and oral motor skills are known to be performed by the same muscles but controlled neurologically by different and distinct areas of the brain [2]. Speech problems will therefore not always have a direct causal relationship with oral motor problems. Despite this, it is still important to gain a detailed understanding of the oral motor skills of a child referred for speech language therapy. Knowledge about the performance of these skills might be helpful in differential diagnostics related to eating, drinking, and speech problems.

The term "oral motor movements" is a global description referring to both nutritive and non-nutritive movements of the mouth, lips, and tongue. A more extensive distinction has been explained in a review by Kent [1]. This author describes the different forms of non-speech-related oral motor movements (NSOMs) and speech-related sounds: (a) non-speech oral movement; (b) speech-like; (c) para-speech or quasi-speech; (d) non-word repetition; (e) speech. Non-speech oral motor movements cover a wide range of single or complex orofacial movements. Speech-like movements are mainly described as "humming." Quasi-speech or para-speech contains the production of vowels or alternation of syllables with a phonetic structure but without meaning. Non-word repetition is described as repeated sequences of sounds, with a phonetic structure but with no meaning. For this classification, Kent has defined speech as movements that result in an acoustic pattern that corresponds to the phonetic structure of a language [1].

Examination of oral motor movements is often an essential part of a speech and language or swallowing evaluation. It helps to assess the control and coordination of muscles involved in speech and swallowing, and it provides diagnostic insights for formulating treatment plans. Several assessments are available that focus on oral motor skills. An example is the assessment associated with the Nuffield Dyspraxia Program [3]. Subtests of this assessment examine the isolated and sequential non-speech oral motor movements at normal and high speed rates. However, no normative values are available. In the internationally available and widely used oral motor study by Robins and Klee [4] a total score can be calculated on the basis of 86 items, including items related to eating and swallowing, non-speech oral movements, quasi-speech, and speech. Data were collected in 90 normally developing children aged 2;6–6;11 years. The total score can be compared with values obtained from a normative group. The Nordic Orofacial Test-Screening (NOT-S) is used with children aged between 3 and 8 years old and consists of several sections, including chewing, swallowing, and drooling [5]. The clinical examination of this instrument investigates different forms of oral motor movements, namely non-speech oral movements and speech. Normative data were collected in 231 typically developing children aged from 3;0 to 7;11 years [5]. In the paediatric Radboud Dysarthria Assessment, reference lines for four maximal oral motor performance tasks (maximum phonation duration, diadochokinesis, maximum loudness, and melodic range) are presented. With these tasks, quasi-speech is assessed [6]. It can be concluded that until now there is no Dutch instrument or test with reference values of typically developing children that assesses exclusively non-speech oral movements in young children.

Within clinical practice, there is a need for typical reference values which could provide a picture of the range of possibilities of a child's oral motor skills at a certain age. With such a tool that refers to typical reference values, it would be possible to gain insight into what can be considered within or beyond normal limits. With this in mind, a non-speech oral movement observation list was designed: The Non-speech Oral Movement Assessment for Children (NOMAC). It was designed to have a complete Dutch list to assess the physical condition and function of the mouth and related structures. The objective of this examination was to provide insight into the overall neuromuscular coordination of the oral and facial muscles. It requires items corresponding to the function of each of the cranial nerves. That is why, for example, the item "close your eyes" was included, as eye closure involves the facial nerve (cranial nerve VII). For this NOMAC, a wide range of non-speech oral movements were included, following the description of Kent [1]. In addition, the strength of the oral motor muscles during movement is assessed in a number of items. Three items on facial symmetry at rest were also included. Blowing and sucking were added as well as the slurping and swallowing of saliva on request (shown in online suppl. material; for all online suppl. material, see https://doi.org/10.1159/000536485). The 34 items of the NOMAC are arranged according to the anatomy of the face from which an activity is requested (such as the tongue or lips). The non-speech oral movements are stimulated via verbal command or imitation. Most items can be accompanied by a verbal prompt for an extra cue. We hypothesized that the

selected items would show a correlation with age, i.e., older children would be able to execute more items successfully than younger children.

The aim of this study was to evaluate the psychometric properties of the NOMAC in terms of inter-rater reliability and its construct validity. In addition, we aimed to collect normative data for the non-speech oral movements in children aged between 2 and 8 years old.

Method

The Assessment

The Non-Speech Oral Movement Assessment for Children (NOMAC) consists of 34 items and an administration protocol (shown in online suppl. material). The speech and language therapist (SLT) asks the child to perform the non-speech oral movements. If necessary, an extra cue can be given. Examples of extra cues are given on the NOMAC form (shown in online suppl. material). The execution is scored as 0 = not executed, 1 = poor execution, 2 = normal execution. The label "poor execution" is assigned when there was an attempt to execute the movement, but it was done in a suboptimal of deficient manner. The NOMAC form indicates how the item can be elicited by instruction (close your eyes), imitation, or a clue (pretend you are sleeping). It is up to the examiner which way is chosen. It can be seen as additional information. After all, it is all about the execution of the movement and not about understanding the assignment.

Data Collection

For this study, data from typically developing children aged 2–8 years were collected in 9 consecutive age groups (AG, years; months): AG1 2;0 to 2;5, AG2 2;6 to 2;11; AG3 3;0 to 3;5, AG4 3;6 to 3;11, AG5 4;0 to 4;5, AG6 4;6 to 4;11, AG7 5;0 to 5;11, AG8 6;0 to 6;11, AG9 7;0 to 7;11 years. An effort was made to include 15 boys and 15 girls per age group.

Inclusion criteria were:

- healthy children aged between 2;0 and 8;0 years;
- parental consent for participation in the study

Exclusion criteria were:

- swallowing disorder;
- feeding problems, for which (additional) tube feeding is required;
- neurological disease;
- diagnosed with a syndrome;
- orofacial anatomical abnormalities

Data were collected during the period January 30, 2019 to December 1, 2019 by two groups (covering two academic terms) of speech and language therapy students from the HAN University of Applied Sciences (Nijmegen, the Netherlands) as part of their graduation assignment. A total of 5 students collected the data. The study was supervised by 3 members of the SLT team of the Amalia Children's Hospital of the Radboud University Medical Center.

The participants were drawn from nurseries, day care centres, and primary schools located in two different regions of the Netherlands ("east" and "west"), with different degrees of urbanization. Children were seen in small villages and big cities. The socioeconomic status of these districts (zip codes), derived from a number of population characteristics like education, income, and labour market position [7], varied from high to low. For the recruitment of participants, nurseries, day care centres, and primary schools were contacted. After sending information letters, parents or caregivers could register their child. After receiving information about the study and signing an informed consent form, the children were tested at home, at the day care centre, or at school. The administration protocol was used for the assessment and data collection (online suppl. material). The junior researchers were trained by a supervisor (LvdE). The training consisted of several steps. Firstly, the students studied the protocol and tested the NOMAC with each other, making video tapes. These tapes were discussed with the supervisor. Feedback to the junior researchers was given live and based on the video recordings.

The next step of the training was performed with family members, and the same procedure was followed. The last step was the performance of a pilot with two or three children, videotaped and discussed. After the last step, they started with data collection. The same procedure was followed with both student groups.

For the inter-rater reliability 50 video recordings in the groups of youngest children (2;0 to 3;11 years) and 50 video recordings in the groups of oldest children (4;0 to 8;0 years) were made. The assessment was scored directly by the junior researcher who did the assessment and, at another point in time, by one of the other SLT junior researchers involved in the project.

Statistical Analysis

The intra-class correlation coefficient (ICC) was used to test the inter-rater reliability between the two assessors, whereby a correlation coefficient less than 0.5 indicates poor reliability, values between 0.5 and 0.75 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values greater than 0.90 indicate excellent reliability. ICC estimates and their 95% confidence intervals were calculated using SPSS statistical package version 23 (SPSS Inc., Chicago, IL, USA) based on a mean-rating (k = 2), consistency, 2-way mixed-effects model.

Construct validity was established by assessing the effect of age group and gender on the mean execution score per item. A general linear model, univariate, was conducted with the execution score as the dependent variable and age group and gender as fixed factors. It was expected that the score increases per age group.

To present normative data, the percentage of the children performing a normal oral motor execution (score 2) was calculated. In addition, the modal distribution (D-mod) was calculated per age group and per item. The modal spread (D-mod) indicates the modality of the mode relative to the maximum possible modality. This means that a high D-mod indicates that the scores are widely spread across the scores M (missing), 0, 1, and 2 on the NOMAC. A low D-mod indicates that the scores are less spread out across the scores. So when there is a low D-mod, the results are more convincing than when there is a high D-mod. With a high D-mod, there is a high dispersion and a minimal modality. If there is a low D-mod, for a certain age group, the majority of this group scores the same on an item, and this is an indication that the scores are less spread out. To calculate the modal spread, we used the formula:

$$D_{mod} = \frac{R\left(1 - \frac{f\,mod}{n}\right)}{r - 1} \quad (1)$$

Table 1. Overview of the participating children by age group

		N		Total
		boys	girls	
Age group, years;months – up to and including	1. 2;0–2;5	12	13	25
	2. 2;6–2;11	16	14	30
	3. 3;0–3;5	19	21	40
	4. 3;6–3;11	17	20	37
	5. 4;0–4;5	10	17	27
	6. 4;6–4;11	12	16	28
	7. 5;0–5;11	16	28	44
	8. 6;0–6;11	23	24	47
	9. 7;0–7;11	17	23	40
Total		142	176	318

The range of D-mod is 1. The r in the formula represents the outcome space (the number of possible outcomes of the NOMAC items). f_{mod} represents the frequency of the modal outcome, and n represents the total number of observations (the number of children in the relevant age group). The calculation was performed in Excel.

Results

The study included a total of 318 children, aged 2;0 to 7;11 years, divided into 9 age groups (see Table 1). The inter-rater reliability showed a moderate-to-excellent ICC for most items (ICC range from 0.52 to 1.0). Item 30 (facial symmetry: eyes) (ICC 0.32) was found to have poor inter-rater reliability.

A general linear model, univariate, revealed a significant effect of the factor age group for all items, except for item 30 (facial symmetry: eyes), item 31 (facial symmetry: mouth), and item 32 (closed mouth). No significant effect of gender was found, except for the items 13 and 14 (put your tongue to the left or right corner of your mouth). This difference was only seen in the youngest age groups 1, 2, 3, 4, and 5.

Table 2 shows the percentages of children who had a normal execution of the task (score 2), sufficient strength (items 24–29), or normal symmetry (items 30–32) per age group. In addition, it is highlighted when, in an age group, ≥85% of the children scored a 2 (normal execution).

Figure 1 shows the D-mod per age group and per item. It is notable that the data from item 2 (raise your eyebrows), item 3 (frown your eyebrows), item 4 (wrinkle your nose), item 26 (put your tongue tightly in your right cheek), and item 27 (put your tongue tightly in your left cheek) are showing a wide range. There is a decreasing range when children get older for all other items. For almost all items, there is a greater range in the younger age groups, which decreases in age groups 8 and 9.

Discussion

This study evaluated the psychometric properties of the NOMAC and yielded normative data of the execution of non-speech oral movements in 318 typically developing children, aged 2;0 to 7;11 years, divided into 9 age groups. The inter-rater reliability, assessed by the outcome of the scoring by the junior researchers who did the assessment and at a different time by one of the other SLT junior researchers involved in the project, was moderate to excellent. Only 1 item had poor reliability (Item 30, facial symmetry: eyes). The results of this item should be interpreted with caution. Overall, it could be concluded that the NOMAC can be scored reliable.

Construct validity was supported by the reported significant effect of the factor age group for all items: the execution of non-speech oral movements improved with age. The children in the oldest age group were able to execute almost all items of the NOMAC. Less than 85% of the children in the oldest age groups scored a 2 (normal execution) on item 3 (lower your eyebrows: frown) and item 4 (wrinkle your nose). However, there was a clear development seen in both items.

No difference was found between boys and girls, except for item 13 and 14 (put your tongue to the left or right corner of your mouth). Girls acquired the execution of these 2 non-speech oral movements earlier than their male peers. Although several studies show a difference in the development of oral motor function [8] or the

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Table 2. Percentage of children who achieved a score of 2 (accurate execution) by item and by age group; percentages ≥85% are highlighted

item	AG 1	AG 2	AG 3	AG 4	AG 5	AG 6	AG 7	AG 8	AG 9
	2;0–2;5	2;6–2;11	3;0–3;5	3;6–3;11	4;0–4;5	4;6–4;11	5;0–5;11	6;0–6;11	7;0–7;11
Face									
1. Close your eyes	72.0	96.7	95.0	94.6	100.0	96.4	100.0	100.0	100.0
2. Raise your eyebrows	4.0	33.3	45.0	51.4	59.3	71.4	75.0	72.3	85.0
3. Lower your eyebrows: frown	32.0	36.7	55.0	75.7	74.1	71.4	77.3	72.3	82.5
4. Wrinkle your nose	24.0	36.7	47.5	43.2	51.9	50.0	50.0	76.6	75.0
Lips									
5. Open your mouth wide	76.0	90.0	97.5	94.6	100.0	100.0	100.0	100.0	100.0
6. Pout your lips	64.0	60.0	85.0	78.4	85.2	89.3	84.1	91.5	97.5
7. Spread your lips	64.0	90.0	95.0	89.2	100.0	100.0	100.0	97.9	100.0
8. Pout and spread your lips	24.0	33.3	55.0	75.7	74.1	92.9	81.8	91.5	100.0
9. Close your lips tightly	48.0	80.0	85.0	86.5	88.9	100.0	100.0	97.9	97.5
Tongue									
10. Stick out and then retract your tongue	72.0	96.7	97.5	94.6	100.0	100.0	100.0	100.0	100.0
11. Put your tongue up	20.0	43.3	70.0	59.5	85.2	85.7	90.9	70.2	90.0
12. Put your tongue down	48.0	93.3	95.0	94.6	96.3	100.0	97.7	95.7	100.0
13. Put your tongue to right corner of mouth	32.0	66.7	95.0	89.2	96.3	100.0	100.0	100.0	100.0
14. Put your tongue to left corner of mouth	32.0	66.7	95.0	91.9	100.0	100.0	100.0	100.0	100.0
15. Put your tongue in your right cheek	0.0	26.7	45.0	70.3	74.1	89.3	90.9	97.9	100.0
16. Put your tongue in your left cheek	0.0	26.7	47.5	70.3	74.1	89.3	90.9	97.9	100.0
17. Lick your lips	24.0	56.7	85.0	83.8	100.0	100.0	97.7	97.9	97.5
18. Click your tongue	4.0	36.7	57.5	67.6	81.5	92.9	90.9	97.9	90.0
Velum									
19. Blowing	68.0	96.7	97.5	94.6	100.0	100.0	100.0	100.0	100.0
20. Sucking	32.0	43.3	55.0	62.2	81.5	89.3	93.2	97.9	95.0
21. Puff up your cheeks (lips closed)	12.0	36.7	70.0	67.6	88.9	92.9	90.9	91.5	100.0
Cheeks									
22. Open your mouth	80.0	93.3	97.5	94.6	100.0	100.0	100.0	100.0	100.0
23. Close your mouth	80.0	93.3	97.5	94.6	100.0	100.0	100.0	100.0	100.0
Strength									
24. Close your eyes tightly	16.0	30.0	60.0	67.6	81.5	96.4	90.9	97.9	97.5
25. Close your lips tightly	24.0	23.3	60.0	67.6	70.4	100.0	90.9	93.6	97.5
26. Put your tongue tightly in your right cheek	0.0	13.3	15.0	32.4	44.4	57.1	75.0	78.7	87.5
27. Put your tongue tightly in your left cheek	0.0	13.3	17.5	35.1	40.7	53.6	70.5	76.6	85.0
28. Hold your mouth/cheeks closed	28.0	60.0	65.0	78.4	92.6	85.7	93.2	93.6	97.5
29. Hold your mouth/cheeks open	40.0	76.7	77.5	89.2	96.3	92.9	97.7	100.0	95.0
Observation in rest									
30. Facial symmetry: eyes	100.0	93.3	95.0	94.6	96.3	96.4	95.5	95.7	100.0
31. Facial symmetry: mouth	100.0	96.7	97.5	100.0	100.0	96.4	97.7	97.9	100.0
32. Closed mouth	92.0	80.0	92.5	97.3	100.0	92.9	93.2	100.0	97.5
Swallowing									
33. Saliva slurping on request	32.0	56.7	70.0	78.4	77.8	78.6	86.4	89.4	82.5
34. Swallowing saliva on request	16.0	50.0	57.5	64.9	88.9	85.7	97.7	97.9	100.0

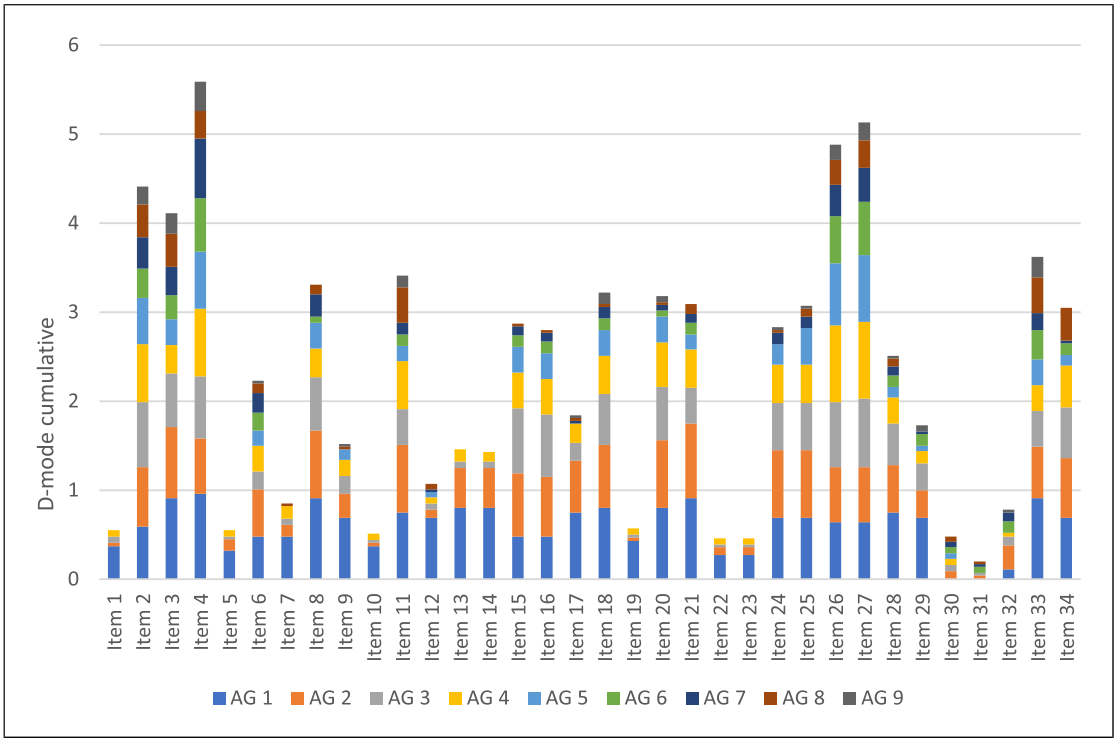

Fig. 1. Overview of modal distribution, per item, per age group. AG 1 2;0 up to and including 2;5, AG 2 2;6 up to and including 2;11; AG 3 3;0 up to and including 3;5, AG 4 3;6 up to and including 3;11, AG 5 4;0 up to and including 4;5, AG 6 4;6 up to and including 4;11, AG 7 5;0 up to and including 5;11, AG 8 6;0 up to and including 6;11, AG 9 7;0 up to and including 7;11 years. AG, age group.

development of saliva control [9] between boys and girls, no differences were found between gender in this study except for items 13 and 14. The difference between boys and girls for item 13 and 14 was not seen from the age of 4;6 years. Therefore, this was not sufficient to compile separate tables for boys and girls.

With the data obtained, we are able to present values obtained from a normative group. These data can be used to determine to what extent the execution of non-speech oral movements of a single child fits the age range of the typically developing group. Our aim was to obtain a first clinical impression of the oral motor abilities of a child, compared with their peers (age related). Young children do not have to perform all the items. We wanted to show the development of these oral movements. In clinical work, it is often mentioned that children are not able to perform, for example, putting the tongue in the left/right cheek. However, with this study, we were able to show that only children >4 years can do. So, Table 2 is important showing the 85% per age group and per item that is able to perform the oral or facial movement. The failure of a specific item should be placed in the context of Table 2. It must be emphasized that the SLP, using the list in a specific child, is aware of the information of Table 2.

The normative data of this study reveal that children in the youngest age group are able to perform items like "close your eyes," "open your mouth," and "stick your tongue out of your mouth." Items that are often asked at a young age in an SLT assessment, such as raising and frowning eyebrows, pushing the tongue into the left or right cheek, were only executed in 50% of the children from 3 to 4 years of age. This suggests that the normative data of this study will support the interpretation of the performance of non-speech oral motor movements during an SLT assessment. It must be emphasized that a large spread was also found for these items. This means that the lower limit of 85% can be used, but that this spread may be taken into account in the assessment of the data of an individual child.

It is comparable to data from, for example, the movement of the fingers. In the development of hand motor skills, researchers observed firstly an increase in coordination of movements, followed by a combination of movement and strength [10]. Non-speech oral motor

movements are performed by the same muscles used for mastication, swallowing, and speech. However, these skills are controlled by different areas of the brain [1, 2]. This task dependency of orofacial muscles is important to consider when using the NOMAC: feeding or speech problems will therefore not always have a direct causal relationship with oral motor execution problems. This point is supported by the study of Potter and Short [11]. These authors examined tongue strength in children with and without speech problems. There was no difference in isolated tongue strength between the children with speech delays and those without speech difficulties. However, in children reduced tongue strength in combination with dysarthric speech problems is indicative for neurological problems [11]. Problems with non-speech oral movements often occur as a result of neurological or anatomical abnormalities [12]. A solid understanding of oral motor abilities in children is important [13, 14]. The strength and swallowing items should therefore be interpreted with caution and might serve as a first clinical assessment. If there are concerns based on this assessment, further instrumental assessments might be necessary.

Therefore, it is essential to interpret the results of the NOMAC within the broader context of a comprehensive SLT assessment. For example, when treating children with severe oral motor issues due to neurological damage, therapeutic interventions should prioritize compensation strategies and safety. On the other hand, children with minor problems benefit from functional training, emphasizing planning, force, and speed.

Moreover, it is crucial not to incorporate NOMAC items into speech therapy as a preparation for feeding or speaking. Rather than training muscles or isolated movements, the focus should be on functional exercises. Oral motor movements constitute only a fraction of the intricate processes involved in speech or swallowing. Studies have consistently demonstrated that practicing these non-speech oral movements does not contribute significantly to mastication, swallowing, or speech support [15, 16]. Instead, these functions should be addressed through functional training, integrated into tasks that mirror real-life situations.

Conclusion

Non-speech oral movements can be assessed with the NOMAC in children between 2 and 8 years old and compared with reference values. It should be used as an essential part of clinical feeding and speech assessments, and it was designed to assess the physical condition and function of the mouth and related structures. Despite the fact that current insights indicate that non-functional oral motor training has no value for improving mastication, swallowing, and speech, it is important to know the status of non-speech oral motor capabilities because it can be supportive in differential diagnosis. With this assessment, a complete profile of the child's oral motor abilities can be achieved, supportive for clinical decision making in SLT.

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Statement of Ethics

This study protocol was reviewed and approved by the Arnhem-Nijmegen Research Committee, approval number 2018-4674, ABR NL68147. Written informed consent was obtained from the participants' parent/legal guardian/next of kin to participate in the study. We received written informed consent for the publication of the images/photos of one of the participants used for the NOMAC score form in the online supplementary material.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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There was no financial support for this study, and therefore no funder or sponsor had any role regarding study design, collection, analysis, and interpretation of data, and writing the manuscript.

Author Contributions

Leenke van Haaften, Marloes Lagarde, Marjo van Gerven, Sandra de Groot, Celia Harding, Lenie van den Engel-Hoek, and Karen van Hulst made a substantial contribution to the design of the work, the acquisition and analysis of data, drafting and reviewing it critically, and final approval of the submitted version, and they agreed on all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Data Availability Statement

All data generated or analysed during this study are included in this article and its online supplementary material. Further enquiries can be directed to the corresponding author.

References

1 Kent RD. Nonspeech oral movements and oral motor disorders: a narrative review. Am J Speech Lang Pathol. 2015;24(4):763–89.
2 Ziegler W. Speech motor control is task-specific: evidence from dysarthria and apraxia of speech. Aphasiology. 2003;17(1):33.
3 Williams P, Stephens H. The Nuffield centre Dyspraxia programme. In: McCauley N, Williams L, McLeod S, editors. Interventions for speech sound disorders in children. Baltimore: Brookes publishers; 2010. p. 159–77.
4 Robbins J, Klee T. Clinical assessment of oropharyngeal motor development in young children. J Speech Hear Disord. 1987;52(3):271–7.
5 Bakke M, Bergendal B, Mcallister A, Sjögreen L, Asten P, Swed Dent JP. Development and evaluation of a comprehensive screening for orofacial dysfunction. Swed Dent J. 2007;31(2):75–84.
6 Ruessink M, van den Engel-Hoek L, van Gerven M, Spek B, de Swart B, Kalf J. Validation of the pediatric Radboud dysarthria assessment. J Pediatr Rehabil Med. 2022;15(2):299–310.
7 Knol F, Boelhouwer J, Veldheer V. Status-ontwikkeling van wijken in Nederland 1998-2010 [Neighbourhood status development in The Netherlands 1998–2010]. The Hague, the Netherlands: Institute for Social Research; 2012.
8 Miller JL, Macedonia C, Sonies BC. Sex differences in prenatal oral-motor function and development. Dev Med Child Neurol. 2006;48(6):465–70.
9 van Hulst K, van den Engel-Hoek L, Geurts ACH, Jongerius PH, van der Burg JJW, Feuth T, et al. Development of the Drooling Infants and Preschoolers Scale (DRIPS) and reference charts for monitoring saliva control in children aged 0–4 years. Infant Behav Dev. 2018;50:247–56.
10 Shaklai S, Mimouni-Bloch A, Levin M, Friedman J. Development of finger force coordination in children. Exp Brain Res. 2017;235(12):3709–20.
11 Potter NL, Short R. Maximal tongue strength in typically developing children and adolescents. Dysphagia. 2009;24(4):391–7.
12 Arvedson JC. Feeding children with cerebral palsy and swallowing difficulties. Eur J Clin Nutr. 2013;67(Suppl 2):S9–12.
13 Clark HM. Neuromuscular treatments for speech and swallowing: a tutorial. Am J Speech Lang Pathol. 2003;12(4):400–15.
14 Kollia B, Tsiamtsiouris J, Korik P. Oral motor treatment: effects of therapeutic feeding on articulatory skills. J Prev Interv Community. 2019;47(1):14–24.
15 Lof GL, Watson MM. A nationwide survey of nonspeech oral motor exercise use: implications for evidence-based practice. Lang Speech Hear Serv Sch. 2008;39(3):392–407.
16 McCauley RJ, Strand E, Lof GL, Schooling T, Frymark T. Evidence-based systematic review: effects of nonspeech oral motor exercises on speech. Am J Speech Lang Pathol. 2009;18(4):343–60.