

Singing Therapy Improving Peak Flow, Speech and Eating Abilities in Adults with Cerebral Palsy

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Abstract

Introduction: Individuals with cerebral palsy (CP) often suffer from speech impairments and dysphagia due to impaired motor control of the tongue and lips. **Aim:** To investigate the effect of singing on peak flow, speech- and swallowing abilities in individuals with CP. **Method:** Ten adults with CP received one-to-one singing lessons by a professional singing teacher for one hour twice a week for 6 months. **Methods:** The peak flow, swallowing-, speech-, and eating abilities were investigated pre, and after 3 months and 6 months of singing. **Results:** The meal analysis revealed that an average of eleven factors was improved after 6 months of singing. Nine out of ten participants improved their pronunciation of the letter “N” and seven participants improved their pronunciation of the letter “G”. The singing lessons increased the peak flow significantly ($p = 0.02$; Pre = 246 ± 36 , 3 months = 287 ± 34 , and 6 months = 336 ± 48). Self-reported difficulties on a 1 - 10 scale reduced significantly for both swallowing ($p = 0.039$) and speaking ($p = 0.049$). **Conclusion:** 6 months of singing lessons improve the peak flow, speech-, swallowing- and eating abilities in adults with CP. The present study indicates that singing is a very promising intervention for the treatment of speech and eating impairments in individuals with CP.

Keywords

Singing, Cerebral Palsy, Pronunciation, Eating, Swallowing, Mealtime

1. Introduction

Cerebral Palsy (CP) is a non-progressive motor disorder resulting from damage

to the developing brain, with a prevalence of 2.11 per 1000 live births [1]. Besides motor impairment dysfunctions of speech, dysphagia and drooling are also common in CP, affecting social participation, and psychological health [2] [3]. The speech impairment in CP involves one or more subsystems including respiration, laryngeal-, velopharyngeal, and oral-articulatory function, or the coordination amongst these systems [4] [5].

In addition, individuals with CP frequently suffer from swallowing difficulties and dysphagia, which causes malnutrition [6]. According to a study by Norte and Colleagues (2019) more than 80% of the CP population they studied was malnourished or at risk of malnutrition [7]. The same study showed that around 35% of the CP individuals were underweight [7]. Malnutrition has not only been detected in children with mild-to-severe CP but also in adults with CP [8]. The nutritional status is worsening with increasing Gross Motor Function Classification System levels (GMFCS levels) both in regards to a higher prevalence and to multimorbidity [9] [10].

Currently, no unitary standardized therapy has been proven effective as treatment for speech and swallowing impairments in CP due to the heterogenic nature of the disorder and the wide range of subsystems that are affected. However, one way to activate and train all involved subsystems is singing [11]. Singing is the production of musical words or sounds with the voice and is a much more complex physical activity than speaking due to the greater length of phrases and greater range of pitch required [11]. Moreover, singing involves breathing, use of the larynx, tongue, lips, fascial muscles, respiratory muscles and postural muscles [12] [13] [14]. The neural adaptations to singing training have been observed in professional singers who have increased right hemispheric volume in the ventral primary somatosensory cortex (larynx S1), the adjacent rostral supramarginal gyrus (BA40), as well as in secondary somatosensory (S2) and primary auditory cortices (A1). Additionally, professional singers have shown to have an increased grey-matter volume in S1 [15].

Moreover, it has been shown that singing has very positive psychological and social benefits and can alleviate symptoms of depression [16]. One study showed a significant improvement of the HADS-D score (Depression assessment score) and health-related quality of life (HRQL) after three to 6 months of group singing therapy [17]. Furthermore, various studies have shown that singing therapy has beneficial effects for quality of life, functional communication, speech, motor function, cognitive status and lung function in various patient groups including Parkinsons disease, cystic fibrosis and chronic obstructive pulmonary disease [18] [19] [20] [21] [22]. The cardiorespiratory system is exercised during singing training, which results in enhanced respiratory muscle strength and an optimized breathing [11]. Furthermore, singing can also cause changes in neurotransmitter excretion from the brain, including an upregulation of oxytocin, immunoglobulin A, and endorphins resulting in improved immune function and increased happiness [11].

The aim of the present study was to investigate the effect of a 6 months singing intervention twice a week with a professional singing teacher on speech impairment, swallowing difficulties, and respiration in adults with CP. The hypothesis of the present study was that singing improves speech, swallowing and eating abilities in adults with CP.

2. Materials and Methods

2.1. Participants

Eleven adults with CP were recruited for this study; however, one individual dropped out after 6 weeks due to mental health problems. The demographic data of the 7 male and 3 female participants was as follows: age 34.4 ± 12.3 years, body height 1.70 ± 0.10 m, body mass 60.2 ± 16.1 kg, and BMI 21.3 ± 4.9 (kg/m²) (for additional participant characteristics and clinical information see **Table 1**). All participants gave informed consent and the present protocol was in accordance with the Helsinki Declaration and approved by the Regional Ethics Committee for the Capital Region of Copenhagen (Protocol number H-18064377).

Table 1. Participant characteristics.

ID	Gender	Age	Height	Weight	BMI	GMFCS	EDACS	Speech impairment	CFCSDiagnosis	Placement of lesion	Other diagnoses	Medication	Self reported change in eating ability			Self reported change in drinking ability				
													Very positive change	Positive change	No change	Negative change	Very positive change	Positive change	No change	Negative change
CP1	M	39	1.64	37.4	13.9	5	III (TD)	Highly affected	IV	Spastic CP	Unknown	Epilepsi medication		X						X
CP2	M	21	1.8	75	23.1	2	I (IND)	Lightly affected	II	Spastic CP	left side	none	none		X					X
CP4	F	53	1.68	65	23.0	5	II (IND)	Highly affected	III	Spastic CP	frontal	none	none	X						X
CP5	M	30	1.66	48	17.4	5	IV (TD)	Highly affected	IV	Spastic CP	frontal	Dystoni	none		X					X
CP6	F	23	1.65	51	18.7	1	II (IND)	Lightly affected	I	Spastic CP	Cerebellum	none	none			X				X
CP7	M	31	1.72	62	21.0	3	II (IND)	Highly affected	III	Spastic CP	unknown	Type I Diabetes	none	X				X		
CP8	M	31	1.7	93	32.2	1	II (IND)	Lightly affected	II	Spastic CP	left side	Epilepsi	Epilepsi medication	X						X
CP9	M	26	1.67	66	23.7	3	II (IND)	Highly affected	IV	Spastic CP	left side & frontal	none	none		X					X
CP10	M	58	1.7	60	20.8	3	II (IND)	Lightly affected	II	Spastic CP	unknown	none	none			X				X
CP11	F	32	1.55	45	18.7	5	II (RA)	Lightly affected	III	Spastic CP	unknown	Epilepsi	Epilepsi medication		X					X

EDACS levels I = Eats and drinks safely and efficiently, II = Eats and drinks safely but with some limitations to efficiency, III = Eats and drinks with some limitations to safety; there may be limitations to efficiency, IV = Eats and drinks with significant limitations to safety, V = unable to eat or drink safely - tube feeding may be considered to provide nutrition. Level of assistance: S = IND (independent), RA = (Requires assistance), TD = (Totally dependent); CFCSDiagnosis levels: I = A person independently and effectively alternates between being a sender and receiver of information with most people in most environments, II = A person independently alternates between being a sender and receiver with most people in most environments but the conversation may be slower, III = A person usually communicates effectively with familiar communication partners, but not unfamiliar partners, in most environments, IV = The person is not always consistent at communicating with familiar communication partners, V = A person is seldom able to communicate effectively even with familiar people.

2.2. Intervention

The participants completed 6 months of singing intervention in which they had individual singing lessons with a professional singing teacher for 1 hour twice a week. The singing teacher planned and designed all singing lessons individually after each participant's specific needs. Thus for participants with major speech impairments, the lessons focused on word pronunciation whilst individuals with major swallowing impairments the lessons included exercises for the motor control of lips and the tongue during singing. All participants also practiced self-chosen songs after their personal liking.

All sound recordings were recorded using the free, open source, cross-platform audio software Audacity 2.3.2 (<https://www.audacityteam.org/>). Sound recordings were made using a Focusrite Scarlett 2i2 3rd Gen. soundcard and a Shure SM7B Vocal studio microphone (Copyright © 2009-2021 Shure Incorporated, Niles, Illinois, USA). All recordings were standardized so that the 7 ambulant individuals were standing while singing, and 3 non-ambulant individuals were sitting in their wheelchair while singing. The microphone was placed 5 cm from the mouth of the participants. The Focusrite soundcard had the same gain settings for all recordings. The first recorded singing exercise was the "Santa" exercise. For this exercise the participants were asked to sing "Ho-ho-ho" three times. The participants were instructed to activate their abdominal muscles as much as possible while doing this exercise. For visual and qualitative assessment of the loudness and frequency range of singing, a spectrogram was created for a representative participant (CP7). Next, the participant sang "Happy birthday", and were instructed to sing the song as well and clear as possible. Finally, the participants were asked to sing a self-chosen note and hold it for as long as possible. The time was recorded by the investigator using a handheld stopwatch.

During the mealtime analysis a certified occupational therapist asked the participants to say the sounds N, G and NG. These sounds were chosen since the pronunciation of the letters "N" and "G" are activating the same tongue movements as used during eating and swallowing and these sounds therefore are particularly challenging to say for individuals with CP. This was however not recorded during the singing session but scored by the occupational therapist.

2.3. Mealtime Evaluation and Test of Oral Motor Function

The same certified occupational therapist analyzed the eating abilities of all participants Pre, after 3 months and after 6 months of singing intervention. The participants were video-recorded while eating a self-chosen meal. In addition, various motor control exercises were performed in order to test the motor function of the mouth and tongue including: stretching the tongue out towards the chin and nose; stretching the tongue towards the right and the left outside the mouth; pronunciation of the sounds "N", "G" and "NG", and cleansing of the mouth from food (see all recorded variables in the supplementary material **Table I**). Subsequently self-reported changes in eating and drinking abilities were recorded.

2.4. Peak Flow Measurements

Expiratory peak flow was measured using a hand-held Peak Flow Meter (EU) with a standard range of 60 - 900 L/min (Pinnacle[®], Essex, UK). In order to avoid any familiarization effects all participants were asked to exhale into the device several times before the measurements were recorded. The Peak Flow measurements were continued until the participants reached their peak level at least 3 times without increasing any further.

2.5. Self-Reported Difficulties

During the tests that were made Pre, after 3 months and after 6 months of singing intervention, the participants were asked to do a supraglottic swallow exercise which means that the participants had to swallow, then cough and then swallow again. The participants then had to rate the level of difficulty at a scale from 1 to 10 (1 being not difficult at all, and 10 being very difficult). The participants also rated their difficulties with normal swallowing and speech on the same scale.

2.6. Anecdotal Observations by the Singing Teacher and the Participants

After each singing session, the singing teacher wrote a journal for each participant. In these journals, the singing teacher reported observations on improvements made by both the teacher and the participants.

After the intervention the participants were asked whether they could feel any differences in their speech and swallowing abilities and they were given the chance to describe the process they went through during the intervention with their own words.

2.7. Statistics

Subject characteristics are shown in mean \pm SD. The data from the peak flow measurements, the one-note singing, and the 1 - 10 scale questions were analyzed using a one-way ANOVA for repeated measurements. A p-value below 0.05 was considered to be significant. All statistical analyses were conducted in Sigmaplot (Systat Software, Inc. 2014 version 13.0, Germany). All figures were made in GraphPad Prism 8 (GraphPad Software, Inc., San Diego, CA, USA). In this study we based our sample size calculation mainly on data from previous trials investigating changes of the peak flow after singing therapy. The expected changes in peak flow following singing exercises were calculated as percentages to the baseline values. Subsequently the mean standard deviation (SD) and the required sample size to detect the group difference with a power of 80% and a Bonferroni corrected significance level of 0.005 was calculated and showed that a sample size of $n = 10$ would result in sufficient statistical power.

3. Results

3.1. Swallowing and Speech Abilities

The meal and oral motor skill assessments that were made revealed that the eating

skills and the oral motor skills improved significantly over time: Eating skills: ($p = 0.0003$; Pre = 15.3 ± 2.8 , 3 months = 11.6 ± 2.5 and 6 months = 11.1 ± 2.4) (**Figure 1A**), and oral motor skills: ($p = 0.0001$; Pre = 18.5 ± 3.3 , 3 months = 13.9 ± 3.9 and 6 months = 12.0 ± 3.5) (**Figure 1B**). When taking all mealtime factors together the present data showed a significant improvement of the combined eating skills after 6 months of singing intervention ($(p = 0.0001$; Pre = 33.8 ± 5.8 , 3 months = 25.5 ± 6.1 and 6 months = 23.1 ± 5.8) (**Figure 1C** and supplementary material **Table I**). Furthermore, the mealtime analysis showed that all participants improved in oral motor skills and eating abilities at 6 months. On average, eleven different factors (11 ± 4.6 [AU]) were improved (Supplementary material **Table I**).

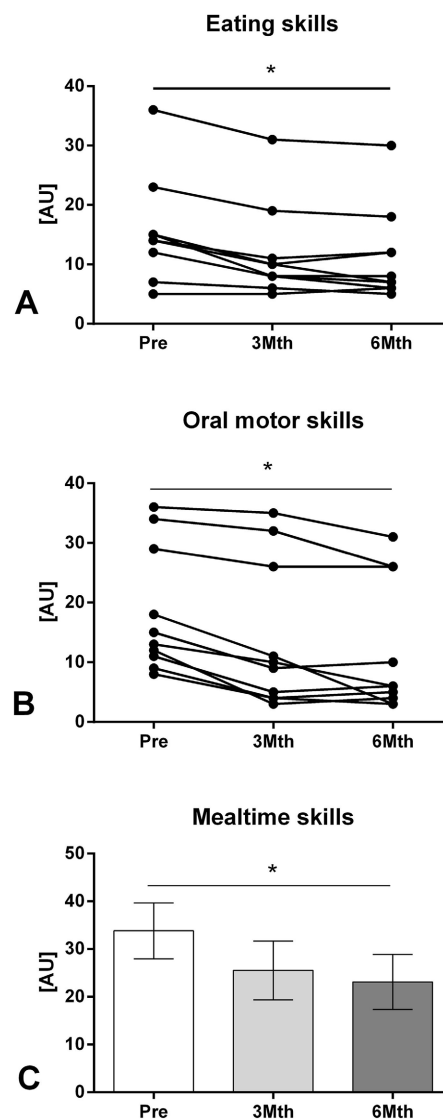


Figure 1. Mealtime analysis of eating skills [AU] (A), oral motor skills [AU] (B) and a combination of all factors influencing the mealtime [AU] (C). The occupational therapist rated all skills from 3 to 0 (see Supplementary **Table I**). The graphs show the sum of score rates in each category. All measurements were made Pre, after 3 months and after 6 months of singing practice. Data are shown as mean \pm SD. The level of significance is ($p < 0.05$). *indicates significance.

3.2. Lung Function

The peak flow increased significantly over time ($p = 0.02$; Pre = 246 ± 36 , 3 month = 287 ± 34 and 6 months = 336 ± 48) (Figure 2 Top). The one-note singing increased significantly over time ($p = 0.005$; Pre = 8.9 ± 1.4 , 3 months = 13.5 ± 2.5 and 6 months = 12.9 ± 2.4) (Figure 2 Bottom).

3.3. Singing Abilities

All participants sang the song Happy Birthday both pre, after 3 months and after 6 months of singing practice, and the recordings from one participants singing Happy Birthday have been added to the supplementary material (Supplementary material II & III). When listening to the pre recording it is very difficult to hear which song the participant is singing (Supplementary material II). However, after six month of singing practice twice a week the song is easy to recognize (Supplementary material III).

3.4. Spectrogram

The spectrogram of the Santa exercise from one representative participant indicated an increased voice level across a large range of frequencies following the intervention (Figure 3).

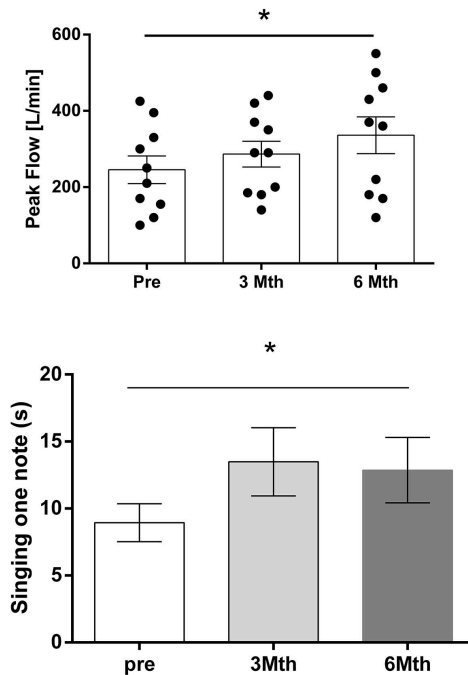


Figure 2. Top figure: The average Peak flow measurements [L/min] of ten individuals with CP Pre, after 3 months and after 6 months of singing practice. Bottom figure: Timing of ten individuals with CP singing one note as long as possible (Pre, after 3 months and after 6 months of singing practice). Data are shown as mean \pm SD. The level of significance is ($p < 0.05$). *indicates significance.

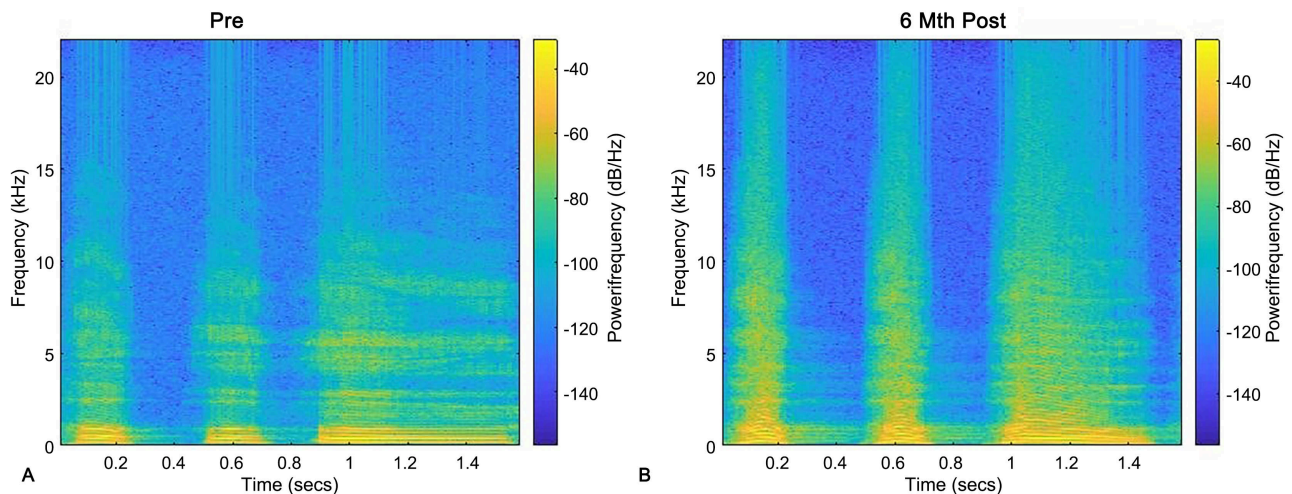


Figure 3. An example of a spectrogram during the Santa exercise from one individual with CP pre and after 6 months of singing practice.

3.5. Self-Reported Swallowing and Speech Difficulties

The self-reported difficulty of performing a supraglottic swallowing exercise was significantly decreased over time ($p = 0.044$; Pre = 5.29 ± 0.90 , 3 months = 3.53 ± 0.93 and 6 months = 2.94 ± 0.84) (Figure 4A). The self-reported difficulty of normal swallowing exercise was significantly decreased over time ($p = 0.039$; Pre = 4.25 ± 0.97 , 3 months = 1.96 ± 0.40 and 6 months = 2.26 ± 0.31) (Figure 4B). The self-reported difficulty of speaking was significantly decreased over time ($p = 0.049$; Pre = 4.48 ± 1.05 , 3 months = 2.8 ± 0.52 and 6 months = 2.63 ± 0.56) (Figure 4C). The self-reported changes in eating and drinking ability showed that eight out of ten participants (80%) reported positive effects on their eating abilities at 6 months (Table 1). In addition, five out of ten participants reported positive effects on their drinking skills after the singing intervention (Table 1).

3.6. Mealtime Eating and Drinking Abilities

The amount of time that the participants needed to complete the self-chosen meal decreased by 25% (Pre: 12.9 ± 6.31 min; 3 months: 13.1 ± 7.45 min; 6 months: 9.6 ± 4.88 min, Figure 5) but did not reach the level of significance ($p = 0.158$).

3.7. Anecdotal Observations

3.7.1. Singing Teacher Journals

No negative side effects were reported by the participants, but several positive effects of the singing were noticed by the participants. This included better lip and tongue control, less drooling, better posture (in non-ambulant participants), increased ability to memorize lyrics, increased self-confidence, improved ability to cough and clear the throat (in non-ambulant participants), improved swallowing and eating abilities and less biting in the cheeks and tongue, better and deeper breathing and better lung function (Table 2).

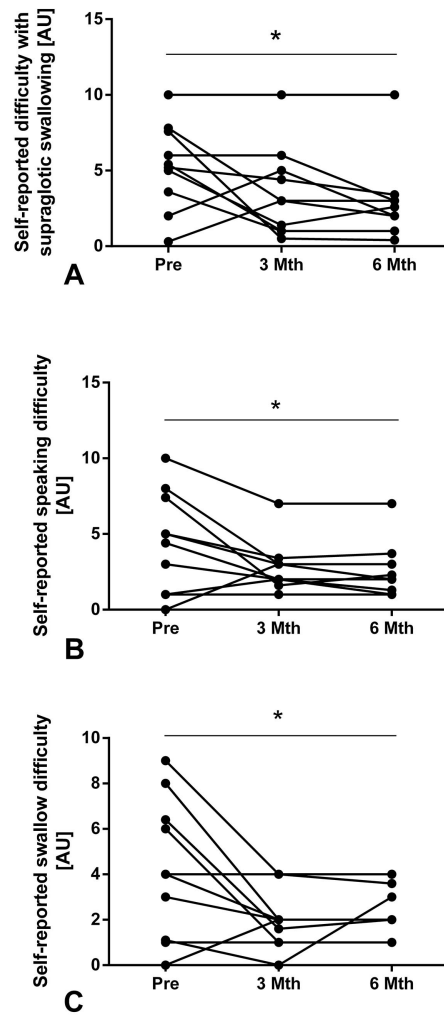


Figure 4. Self-reported level of difficulty from 1 to 10 of supraglottic swallowing, speaking and normal swallowing. (A) the level of self-reported difficulty of supraglottic swallowing [AU], (B) the level of self-reported difficulty of speaking [AU], (C) the level of self-reported difficulty of normal swallowing [AU]. All measurements were made Pre, after 3 months and after 6 months of singing practice. Data are shown as mean \pm SD. The level of significance is ($p < 0.05$). *indicates significance.

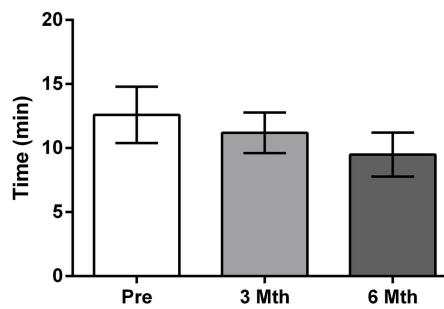


Figure 5. Time spent on eating the same meal pre, after 3 months and after 6 months of singing practice. Data are shown in minutes as mean \pm SD. The level of significance is ($p < 0.05$).

Table 2. Anecdotal observations of the singing teacher during singing classes.

	1 Mth	2 Mth	3 Mth	4 Mth	5 Mth	6 Mth
CP1	The participant feels great joy in being able to do something without the helper being present	The participant feels that slime in his neck is less disturbing because it slides easier down the throat		The participant feels that it is easier for him to breathe now		The participant tells that his friends from his sportsteam told him that he is much easier to understand now when he speaks
CP2	The participant feels less tension in his jaws	The participants tells that he feels that he has become a new hobby now - which is singing			The participant tells that strangers understand him more easily now and that they rarely ask him to repeat what he says.	The participant tells that he has become much more confident and now dares to talk to strangers for example at a flea market because he is confident that they will understand him
CP4	The participant chokes very often, both when she eats food but also just from her own saliva	The participant feels that it is already much easier for her to swallow when she eats	The participant feels that she can breathe better and take deeper breath than before			The participant tells that she chokes very rarely now, and that her difficulties with swallowing are almost completely gone.
CP5	The participant has no language and very little control over tongue, lips and face muscles. He accidentally bites himself in the tongue and cheeks very often until he bleeds.	The participant can now provoke and execute a better cough in order to free his airways from slime.	The participant relaxes more in his upper body, face and neck. The helpers report that the participant has started to mumble while he sleeps. He is beginning to learn different sentences.	The family of the participant feels that it is now easier to include the participant into a conversation since he nos can say yes and no.	The participant reports that he doesnt bite himself in the tongue and cheeks anymore and that he speaks spontaneously	The participant feels that he can breathe and cough much better than before. Most importantly the participant now uses verbal communication to choose food or to say yes, no, hello etc.
CP6		The participant feels that she is breathing deeper and that she has learned to use her stomach for breathing	The participant feels that her lips are more flexible			The participant feels that she has learned to relax her face and release the tension in her shoulders and neck.
CP7	The participants talks with vocal fry. The participant has anxiety that is related to his drooling. He is very anxious of drooling in public.		The participant feels that his pronunciation has improved and some of his friends have noticed improvements. Also is vocal fry is almost gone.			The participant tells that he is not drooling anymore and that his anxiety which is triggered by his drooling now is gone.
CP8		The participant feels that his posture has improved and that it gets easier to get rid of slime that is stuck in the neck				The participant feel an improvement in his breathing and in how he used his airflow during talking
CP9	The participants feels a lack of connection between tongue and his brain	The tongue is more flexible than before. His family notices improvements in his speech	Improved motor control of his lips and improved breathing		Improved control of his tongue. He is drooling less.	The participant feels that his control of his lips and tongue has improved his speech and made his pronunciation more clear and easy to understand
CP10	The participant feels great frustration because he has difficulties remembering lyrics and melodies	The participants feel and improvement of his memory and in his breathing.				The participant feels that he can use some of the techniques that he learned to remember lyrics to remember his groceries list and daily chores. He feels a big improvement of his memory.
CP11	The participant is sitting very bent over forward and has difficulties straightening herself up.	The participant feels a little improvement in her posture and can feel that her breathing improves.		The participant can now sit with a straight back throughout the entire session		The participants feel that both her posture, breathing and sound quality when she speaks has improved. It is easier for her to talk and follow a conversation.

3.7.2. Observations of the Participants

No negative effects of the intervention were reported by the participants, but several positive improvements were pointed out, including: increased joy when eating, less coughs, improved swallowing, improved chewing, less food residue in and around the mouth, improved drinking, improved tongue function, improved mouth closure, improved awareness when eating, (Table 3).

4. Discussion

The aim of the present study was to investigate the effect of a 6 months singing intervention on speech impairment, swallowing difficulties, and respiration in adults with CP. The results indicate that this type of intervention can improve all these parameters.

Table 3. Anecdotal observations of the participants.

Pre	3 Mth	6 Mth	Self evaluation of eating and drinking (6 Month post)
CP1 I rarely get choked by food. I often have small tensions in my throat that cause me to swallow incorrectly. I eat all kinds of food.	Swallowing is not problematic but sometimes it's a little difficult to swallow. It depends on the day and on how much tension I feel in my body.	When I keep quiet its unproblematic. I eat all kinds of food.	Chewing and swallowing food is slightly improved.
CP2 I eat pretty much every thing but I mostly avoid to eat hard things such as hard meat.	I have a good meal experience, and I eat all kinds of food.	I have a good meal experience, and I eat all kinds of food.	I can now sense food reissue in my mouth after eating. I use my tongue or brush my teeth to cleanse my mouth after eating. When I drink I have less coughs than before because I don't absorb as much air when I drink anymore.
CP4 For the most part my eatig experience is fine. Sometime I a am swallowing down the wrong pipe. Sometime I even get my own saliva into the wrong pipe. I eat all kind of food.	I have a good meal experience and I eat all kinds of food.	I have a positive meal experience with almost no difficulties with swallowing and I eat everything.	I do not swallow down the wrong pipe as much. I can feel my tongue is much more active and that I can get my tongue further forward. I feel a little improvement in drinking especially when I drink from a bottle.
CP5 My experience varies a lot in terms of how I feel and some days I cough a lot and get the food down the wrong pipe. The consistency of my food varies depending on who is making the food.	I think it's getting easier to eat. I don't have to concentrate as much. I don't get food down the wrong pipe as often.	I clearly experience that it has become easier to eat than before. I no longer think in the middle of the meal "Do I want to eat more".	I have become more aware of where the food is in my mouth. I experience fewer coughs. It's much better.
CP6 I eat all kind of food. I am aware of how I eat when I eat with others. When I drink I take big sips and it does not look good. It is better when I take small sips and use straws.	I never get anything in the wrong pipe. However, when I think about it too much and want make it perfect then it does not go as well.	I don't have problems with swallowing food. My concerns regarding my meal time is more related to cutting out food, and bring the food to the mouth and spills, especially when I eat with strangers.	I feel no change
CP7 Yes I eat all kinds of food. I'm a little slower at eating than other people. Mashed potatoes are my favorite food, maybe because it is easy to eat?	I don't think about my meal time experience. I eat all kinds of textures and consistencies. My favorite food has always been mashed potatoes, maybe because it is easy to eat?	I do not feel that I have as much food and saliva in the corner of my mouth as before. I discovered eating with my mouth closed. And I eat all kinds of food.	I eat and drink with more with a closed mouth and I can chew and swallow more quietly
CP8 I eat all kinds of food and I experience no challenges. I am pretty good at figuring out what is easy to chew.	I think my mealtime is going very well.	I don't experience any difficulties in eating.	I've become better at chewing. I chew food a little more thoroughly.
CP9 I am very concerned about the social aspects of eating because talking and eating at the same time is difficult. I smack and get food residue on my mouth. I eat all kinds of food.	I eat all textures. I think about eating a little slower and about drinking a little more water. And I might cough a little less. I don't get so much food stuck on the roof of my mouth and on my teeth. I don't get food down the wrong pipe as much.	I think I am a little better at chewing my food. I don't get food down the wrong pipe as often. I eat everything	I am better at chewing and my mouth is less open. And I don't get food in the wrong pipe as often.
CP10 I eat everything. I don't think so much about it. I eat to survive.	The meal time is nothing special for me. It is a good feeling to be full. I eat everything.	Eating is a natural thing, I don't think about any challenges and I eat everything even hard foods.	No changes experienced, and no remarks
CP11 The food slides quickly down my throat. I eat all kinds of food.	Eating is going well, we now have quiet time while eating. I eat all kinds of food.	Eating is going fabulous.	Even harder slide down my throat smoothly and doesn't get stuck (pointing on her throat). And also when drinking it is easier to swallow.

The meal and oral motor skill assessments revealed that the participants improved on several parameters after the intervention. Both the eating skills and the oral motor skills showed significant improvements after the singing intervention (**Figure 1**). The average of improved factors was eleven, and that included improvements in the two participants who did not report any change during the self-reported evaluation of the mealtime. Additionally, six participants improved the "maneuvering of food around in the mouth, gathering the food and moving it towards the back of the mouth" factor indicating improved eating skills. Seven participants improved getting their tongue forward in their mouth indicating improved motor function of the tongue. Nine out of ten participants improved their pronunciation of the letter "N" and seven participants indicated improved pronunciation of the letter "G". The pronunciation of the letters "N" and "G" are activating the same tongue movements as used during eating and swallowing which also indicated improved eating abilities. Eating dif-

difficulties and poor nutritional status occur frequently in patients with CP [23] [24]. One study showed that malnutrition in hospitalized adults with CP is associated with increased mortality [8]. The present study indicates that singing is a useful tool to improve eating ability in adults with CP which potentially could counteract malnutrition.

Both at 3 months and 6 months of singing there was an increase in peak flow in the adults with CP with some participants increased their peak flow twofold (Figure 2B). Studies investigating singing as treatment of Asthma patients have also observed an improved respiratory function and increases in peak flow [25] [26]. This result is very promising as respiratory problems are a major challenge for individuals with CP [27] [28] [29]. Reid *et al.* 2012 reported that the most common causes of death in individuals with CP are respiratory issues [28]. The authors showed that the risk of death from respiratory issues for adults with CP was fourteen times higher than for typical developed adults [28]. Another treatment that has positive effects on respiratory function is feedback-guided respiratory training [30]. In individuals with CP, feedback-guided respiratory training using a SpiroTiger device has been shown to improve respiratory function, increase the forced vital capacity by 50% and increase the forced expiratory volume by 40% [30]. However, one major advantage of singing compared to feedback-guided respiratory training using a SpiroTiger device is that the participants really enjoyed the singing lessons, and therefore were very engaged in the training [31]. Previous studies have reported up to 100% compliance in singing interventions [32] which speaks in favor of singing interventions.

In addition to the improved peak flow, the present study observed a significant increase when the participants were asked to sing a note and hold it for as long as possible. Holding a note for a prolonged time requires superior control of expiratory muscles [33]. Expiratory muscle strength is essential for the production of an adequate expiratory pressure that is necessary for voice production or airway clearance during coughing. One study investigating the effects of choir singing on patients with structural heart disease observed an increased respiratory muscle strength and quality of life of these patients following the intervention [34]. Respiratory muscle strength was not measured in the present study. However, the self-reported effect of the singing intervention indicated an improved ability to release the airways and improved coughing which might be linked to increased respiratory muscle strength.

The self-reported levels of difficulties for supraglottic swallowing, normal swallowing and speech abilities decreased significantly after 6 months of singing. This means that the participants themselves experienced that it had become easier for them to speak and swallow. The supraglottic swallowing exercise (swallow, cough, swallow) is a difficult task which tests the muscular control that may be a key factor for the improved eating speed observed in several individuals. Even though it is not a quality to eat fast per se, eating slowly has been shown to reduce the quality of life of individuals with CP as it is decreasing the joy of eat-

ing and impairs the ability to socialize during a meal [35]. Thus, the improved swallowing abilities after the singing intervention have increased the joy of eating for several participants. Furthermore, a previous study on Parkinson's patients has observed that eight weeks of group singing significantly improved swallowing abilities [36]. The authors observed that the group singing resulted in a prolonged laryngeal elevation, which protected the airway from foreign material for longer periods of time during swallowing [36].

The self-reported difficulties of speaking also decreased significantly over time. Several of the participants reported that they are better understood by strangers during conversations, that their communication abilities when using a phone has improved, and that they do not need to repeat themselves as often as before the intervention. Several participants stated that they have improved self-confidence when they approach strangers and that this improves their quality-of-life significantly. Singing has previously shown to have beneficial effects on speech impairments in patients suffering from different neurological disorders including Parkinson's disease, stuttering, aphasia and autism [37]. The fluency-enhancing effect on speech through singing has been well documented [38] [39] [40]. A study by Andrews *et al.* (1982) showed that singing reduced the frequency of stuttering by more than 90%, presumably due to the increased duration of phonation [40]. The speech pattern of patients with Parkinson's include decreased loudness, breathy vocal quality, and short phonation time, which is associated with decreased glottal closure and respiratory function [41]. Some studies have used singing interventions to improve the speech in Parkinson's patients and have shown promising results. One study by Haneishi *et al.* (2018) showed that 12 - 14 singing sessions led to an increase in speech intelligibility and vocal intensity [42]. The participants that were enrolled in the present study shared some speech difficulties with Parkinson's patients and experienced the same positive effects from singing.

The sound recordings of the Santa exercise ("Hohoho") reveal that the participants appeared to be able to use a greater frequency range with an increased sound level following the intervention. The current data also revealed that the participants were able to speak louder and more powerful than before the singing intervention (results not shown). Furthermore, when listening to the recordings of the participants singing Happy Birthday pre and after 6 months of singing practice (Supplementary material I & II) the improved singing and voice strength is very clear. These observations are in line with a recent review from Rachel B. Goldenberg 2008. In this review, the author suggests that singing can be used as an adjunctive treatment against respiratory diseases in various conditions [43].

The anecdotal observations from the singing teacher and the participants during the singing intervention revealed several unexpected improvements including improved memory, posture, reduced drooling and improved jaw control (Table 2 and Table 3). Since the participants had to learn to sing different songs, especially one participant dealing with impaired sight was forced to remember

the lyrics of the songs. Before the intervention, this participant had to record a shopping list on a memo on the phone because the participant was not able to memorize a shopping list. After the intervention, the participant remembered the lyrics of several songs and was also able to remember a shopping lists and was not relying on recorded memos when grocery shopping any more. This is in line with previous studies showing beneficial effects of singing in patients with dementia [44]. Särkämö *et al.* (2016) showed that singing was beneficial especially for the working memory in patients with dementia [45]. Together these observations indicate that individuals with CP that are challenged with their memory might benefit from singing.

Another unexpected finding was related to sitting posture. A good posture is of great importance for proper singing [46]. Especially, a correct posture of the head and neck is necessary for an optimized voice production [47]. Furthermore, it is well-known that abdominal muscles play essential roles in singing [48]. The meal analyses showed that the eating posture was improved not only in the former described participant, but in three participants (Supplementary material **Table I**).

These anecdotal improvements were unexpected but not objectively quantified in the present study. Future studies should assess these factors objectively to verify the observations of the present study.

5. Limitations

The present study did not include a control group to quantify changes of the measured variables in individuals not conducting 6 months of singing practice. However, a sudden significant improvement of eating and speech abilities in adult individuals with CP is very unlikely. Furthermore, all the measurements were done at three time points separated by three month which would wash out any test-learning effect. Another limitation is the sample size of the study, however, ten subjects created enough statistical power to reflect significant changes during the present intervention.

6. Conclusion

The present study shows that 6 months of singing intervention improved the peak flow and both speech- and eating-abilities. Furthermore, a meal analysis revealed that the participants improved eating and oral motor skills including less drooling, improved handling of food in the mouth, less food residue in and around the mouth, improved chewing, swallowing and increased joy when eating. These results indicate that singing is a promising therapeutic tool to improve speech- and eating-impairments in adults with CP.

Research Ethics

All participants gave informed consent and the Regional Ethics Committee for Copenhagen (Protocol number H-18064377) approved the protocol.

Statement of Contributorship

All authors have contributed to the current manuscript. Jessica Pingel had the idea for the project, applied for ethics, conducted the singing recordings, analyzed the data and wrote the first draft of the manuscript. Christina T Andersen and Peter Raffalt analyzed data and Christina performed the occupational therapy testings and evaluations. Camilla Kowalczyk performed all singing lessons and wrote diaries after each session. All authors read the manuscript and gave their input. All authors have approved the manuscript in its current form.

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Patient and Public Involvement Data

During the development, progress, and reporting of the submitted research, Patient and Public Involvement in the research was included at all stages of the research

Key Findings

- Professional singing lessons improve speech- and swallowing abilities in adults with CP.
- Singing is a very promising intervention for speech impairment and dysphagia in individuals with CP.
- Professional singing lessons improve the peak flow in adults with CP.

What the Study Has Added

The present study indicates that singing is a very promising intervention for the treatment of speech and eating impairments in individuals with CP.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Supplementary Material

- 1) Supplementary **Table I**—Mealtime analysis
- 2) Supplementary material II: Sound recordings (MP3 file) of Happy Birthday Pre intervention
- 3) Supplementary material III: Sound recordings (MP3 file) of Happy Birthday after 6 month intervention

Supplementary Material I

The Meal	CP1			CP2			CP4			CP5			CP6			CP7			CP8			CP9			CP10			CP11				
	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth	Pre	3 Mth	6 Mth		
Eating posture	3	3	3	1	0	0	1	1	1	2	2	2	0	0	0	0	0	1	0	0	0	1	1	1	1	1	0	0	0	2	1	1
Voice before the meal	1	1	1	0	0	0	1	0	0	1	1	2	0	0	0	1	1	1	0	0	0	0	1	1	1	1	1	0	1	1	1	1
Taking food to the mouth	3	3	3	1	1	1	1	1	0	3	3	3	1	1	1	1	1	1	0	0	0	1	1	1	1	1	0	0	1	1	1	1
Closing mouth around food and fork	1	1	1	1	0	1	1	1	0	2	2	2	1	0	0	1	1	1	0	1	1	1	0	1	1	1	1	0	1	0	0	0
Chewing	2	2	2	1	1	1	2	2	1	3	2	3	1	1	1	2	1	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1
Maneuvering food around in the mouth, gathering the food into a ball and moving it towards the back of the mouth	2	2	1	1	1	1	2	1	1	3	2	2	1	1	1	2	1	1	1	1	1	1	1	1	2	1	1	1	1	2	1	1
Swallowing	2	1	1	1	1	1	1	1	1	3	2	2	0	0	0	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	0	1
Post swallowing	2	2	1	2	1	0	1	1	1	3	2	2	0	0	0	1	1	1	1	0	1	1	1	1	1	1	0	1	2	1	1	
Dropoling	1	1	1	1	0	0	0	0	0	3	2	1	0	0	0	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Food residue around the mouth	1	1	1	1	1	0	1	1	0	3	3	2	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0
Food residue in the mouth	1	1	1	1	1	1	1	0	0	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Drinking; closing the mouth around a glass or straw	2	1	1	1	0	0	2	1	1	3	3	3	1	1	1	1	1	1	0	0	0	1	0	1	1	1	0	0	1	1	0	0
Number of observed swallowing errors	1	0	0	0	0	1	1	0	0	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Eating time per meal (min)	---	---	---	5	3.45	3	14	11	6.30	28	16	12.50	10.30	11.20	10.45	7.40	8.57	4.20	12	15	18	12	13.31	11.42	15.30	17	14.55	9.30	5	5		
Cough after 10 min post eating	0	0	1	0	1	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Food residue in the mouth 10 min post eating	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1	1	0	0	0	1	1	1	0	1	1	1	1	1	0	0
Oral motor skills																																
Opening of the mouth	2	1	1	0	0	0	1	1	0	2	2	2	0	0	1	0	0	0	1	1	1	1	1	1	1	0	1	0	0	0	0	0
Closing the mouth	2	2	1	1	1	1	1	0	0	2	2	1	1	1	1	0	1	1	1	0	0	0	1	1	1	1	0	0	1	0	0	0
Motor control of the jaw	2	2	1	0	1	0	2	1	0	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
Lead the tongue around the mouth on the teeth (both directions)	3	3	3	1	1	1	1	1	1	3	3	3	2	1	1	2	2	2	0	0	1	3	3	3	2	1	2	1	1	1	1	1
Licking around the mouth with tongue (both directions)	3	3	3	1	1	1	1	1	1	3	3	3	2	1	1	2	1	1	0	0	0	3	3	3	1	1	0	1	0	0	0	0
Tongue to nose	3	3	3	1	0	0	2	2	1	3	3	3	2	1	1	1	1	0	1	1	1	3	3	3	2	1	2	1	0	0	0	0
Tongue to chin	3	3	3	1	0	0	2	1	0	1	1	1	1	0	1	1	0	0	1	1	1	2	1	1	1	1	0	1	1	1	1	1
Tongue to the right side (om)	3	3	3	0	0	0	1	0	0	3	3	3	0	0	0	1	1	1	0	0	0	2	2	2	0	0	0	0	0	0	0	0
Tongue to the left side (om)	3	3	3	0	0	0	1	0	0	3	3	3	1	0	0	1	1	1	0	0	0	2	2	2	0	0	0	0	0	0	0	0
Tongue forward	3	3	1	1	0	0	2	1	0	2	2	2	1	0	0	1	0	1	1	0	0	2	2	2	1	0	0	1	0	0	0	0
Tongue behind the teeth at the roof of the mouth	3	3	1	0	0	0	1	2	0	3	3	3	0	0	0	1	0	0	0	0	0	3	2	3	2	2	2	1	2	1	1	1
Pronunciation of N	2	1	1	1	0	0	1	1	0	3	2	2	0	0	0	1	0	0	1	0	0	1	1	0	1	1	0	1	1	0	0	0
Pronunciation of G	1	1	1	1	0	0	1	0	0	3	3	2	0	0	0	1	1	1	1	0	0	3	2	2	1	1	0	1	0	0	0	0
Pronunciation of NG	1	1	1	1	0	0	1	0	0	3	3	2	0	0	0	1	0	1	1	0	0	2	2	2	0	0	0	1	0	0	0	0

3 = Significantly affected, 2 = very affected, 1 = slightly affected, 0 = not affected; om = outside mouth.

Supplementary Material II_Pre

<https://www.youtube.com/watch?v=KZs-yWRH7X0>

Supplementary Material III_Post

<https://www.youtube.com/watch?v=-OyIERkIxDe>