The effectiveness of device-driven Expiratory Muscle Strength Training (EMST) in total laryngectomy patients; A pilot study

Language, Speech and Hearing Sciences, master Clinical Health Sciences, Faculty of Medicine, Utrecht University, the Netherlands

Name student	: A.F. Kornman (Anne)
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Abstract

Title The effectiveness of device-driven Expiratory Muscle Strength Training (EMST) in total laryngectomy patients; A pilot study

Background Pulmonary function and voice quality of patients after a total laryngectomy has improved over the last decades with the development and use of heat and moisture exchangers (HME) and speech with the voice prosthesis. However, problems with coughing and mucus clearing and its negative consequences on voice quality are still often mentioned complaints. Expiratory muscle strength training (EMST) is a device-driven treatment for improving expiratory pressure generating capacity. Evidence of its benefits has been assessed in a group of healthy elderly, a group with Parkinson disease and in a group of stroke patients.

Aim EMST was tested in this pilot study in a group of total laryngectomized participants to assess the feasibility and effect on expiratory muscle strength. Secondary objective was to assess the effects of EMST on phonation time, vocal range and voice related quality of life.

Method Nine laryngectomized participants performed a four weeks EMST program. Maximum Expiratory Pressure (MEP) and Peak Expiratory Flow (PEF) served as primary outcome measures. Maximum phonation time (MPT), vocal range, VHI-10 and study specific questions were secondary outcome measures.

Results MEP significantly improved over time (Chi-Square 22.64; $p = .000$). No significant effect were found for PEF from baseline to the end of training (Chi-Square 3.73; $p = .444$). No significant effects were found for any of the secondary voice related outcome measures.

Conclusion A four week expiratory muscle strength training program seems feasible in a group of total laryngectomized participants and seems appropriate to improve the maximum expiratory pressure.

Recommendations It should be considered to test EMST in a group less fit participants who mentioned explicitly problems of slime and difficulty with coughing. It is recommended to give special attention at the exhaling technique used during training.

Keywords Expiratory muscle strength, training, total laryngectomy, voice quality

Introduction

With over 600 new diagnoses per year, larynx cancer is the largest group among all head and neck cancers in the Netherlands (1). In patients with advanced laryngeal or hypopharyngeal cancer, or in cases when the disease recurs after treatment with (chemo) radiation, a total laryngectomy (TL) is performed (2).

The removal of the larynx and the subsequent disconnection of the upper and lower airways has consequences for the respiratory system. Breathing occurs directly through a tracheostoma after the total laryngectomy. Therefore, proper conditioning of the breathing air in the nose, i.e. heating, moisturizing and filtering, is lacking. The airflow resistance of the stoma is lower than that of the upper airway, which has negative effects on the pulmonary physiology (3). Daily sputum production, coughing and frequent forced expectoration in order to clear the airway are common complaints of patients after a total laryngectomy (4). Hilgers et al found a significant correlation between respiratory symptoms, voice rehabilitation and several aspects of daily living such as sleeping problems and psychological distress. These findings indicate that respiratory symptoms after total laryngectomy are both frequent and troublesome (5). Pulmonary function after a total laryngectomy can be rehabilitated by using a ‘heat and moisture exchanger’ (HME). The use of a HME reduces the mean daily frequency of sputum production after use of several weeks (6). Different studies reported a significant decrease in frequency of daily coughing, mucus expectoration and stoma cleaning with HME-use (6, 7).

The removal of the larynx within the vocal cords also has serious consequences for speech because of the loss of natural voice. Since the introduction of the voice prosthesis in the early 1980’s, tracheoesophageal speech (TE-speech) with a voice prosthesis has been increasingly used in recent years and is becoming more common worldwide (8). Alaryngeal substitute speech is characterized by a low prosody, high jitter and shimmer, low fundamental frequency and short maximum phonation time in comparison with normal speech (9). These aspects cause a decreased intelligibility and have a negative impact on psychosocial and communicative function (9).

Although the pulmonary function and voice quality has improved the last decades with the development and use of HME’s and speech with the voice prosthesis, laryngectomized patients still complain about problems with coughing and mucus clearing and its negative consequences on their voice quality. The expiratory muscle strength trainer (EMST) is a device-driven treatment for improving expiratory pressure generating capacity. Evidence of its benefits following training comes from numerous studies (10,11,12). EMST is assessed in different patient groups. Kim et al (2009) assessed the effect of an EMST program on maximum expiratory pressure (MEP) and cough function in 18 healthy elderly. MEP significantly increased after the training (11). A significant increase in cough volume acceleration was found in a group with Parkinson disease after EMST training (12). In a group of stroke patients EMST training improved expiratory muscle strength, reflex cough strength, and urge to cough (10).

Because of the positive findings in former studies, EMST training has been tested in this pilot study in a group of total laryngectomized participants to assess if there will be an increase in expiratory muscle strength. To the best knowledge of the author, this is the first study that examined EMST in a group of laryngectomized participants.

We hypothesized that expiratory muscle strength in this group would increase after a 4 week EMST training and would lead to increase expiratory muscle force measured with maximum expiratory pressure (MEP) and peak expiratory flow (PEF). We further hypothesized that phonation time and vocal range would improve. It was reasoned that an increase in expiratory muscle strength would lead to more control of the expiratory muscles which would lead to more control and thus improvement on these voice parameters in this specific group of tracheo esophageal (TE) speakers. As a consequence participant's quality of life, specifically related to vocal function and mucus clearing, would increase was hypothesized.

The main objective of this pilot study was to examine the feasibility and effects of a four week expiratory muscle strength training (EMST) on the maximum expiratory pressure (MEP) and peak expiratory flow (PEF) in a group of laryngectomized participants. Secondary aims were to examine the effects of EMST on voice quality and participant's quality of life, specifically related to vocal function and mucus clearing.

Methods

Participants

In this prospective study, a group of male participants, who undergone a total laryngectomy (TL) participated in this study. By including only male participants, a more homogeneous group has been generated. Time of TL and, if applicable, post-operative (chemo) radiation was at least six months ago. Subjects were recruited from the Netherlands Cancer Institute in Amsterdam. Subjects with a history of lung cancer, severe asthma or tuberculosis were excluded. Reoccurrence of head and neck cancer, uncontrolled or untreated hypertension and a heart attack the previous 12 months were other exclusion criteria. Participants were physically fit to use the EMST-device and able to understand the participant information. For participation, it was not required to have a voice prosthesis. No limitations were made for using a normal HME, to close the stoma manually during speech, or using a hands free device. Nine subjects were eligible and signed an informed consent. The study has been approved by the medical ethical review committee of the Netherlands Cancer Institute (protocol no. N16EMS 2016).

Training design and measurements

The study was a prospective experimental pre-post training design. Participants were instructed to perform a four week training program with the EMST-device.
At baseline different measurements were performed. Maximum expiratory pressure (MEP) in cmH2O and peak expiratory flow (PEF) in L/sec were measured. MEP was obtained with a calibrated digital manometer (Druck DPI 705). The manometer was connected to an adaptor which fit the adhesive peristomal baseplate of the participant. Participants were instructed to inhale calm but deep and then exhale as forcefully as possible. A spirometer (Jaeger Masterscreen CPX) with antibacterial filter (PT medical BV) which fit with the peristomal baseplate was used to obtain the PEF. Participants were instructed to inhale calm but deep and then exhale as hard and fast as the can. A series of three forced expirations was used to obtain MEP and PEF. The mean of this three was used. The mean of the MEP has been used to adapt the EMST. The resistance of the device was set at approximately 80% of the mean MEP with a minimum of 30 and a maximum of 150 cmH2O.
Baseline assessments also included voice recordings. Voice measurements were recorded with ‘Audacity’, a free online audio editor and recorder (13). Maximum phonation time (MPT) in seconds was obtained. Participants were instructed to hold a sustained vowel /a/ as long as possible. The best out of three was used. Vocal range in Herz (Hz) and Decibel (dB) were also obtained. Participants were instructed to perform a tone as low and high possible and a tone as soft and loud possible. The best out of three for each extreme value was used. MPT

and vocal range were acoustically analyzed with PRAAT, a free online computer program for analysis of speech (14). Length of MPT was determined by one of the researchers. Start and end of the voice signal were segmented using the regular waveform. To check the inter-rater reliability, a second researcher analyzed 10 random MPT-samples. Mean absolute difference between both researchers was 0,13 seconds, which was rated as sufficient. To determine vocal range in Hz and dB two separate scripts were used (appendix I).
The Voice Handicap Index-10 (VHI-10) was obtained at baseline for self-assessment of voice disorders and its influencing factors (appendix II). It is a short validated 10 item questionnaire with a minimum score of 0 (no voice problems) to a maximum of 40 (severe voice problems) (15).

After baseline measurements the EMST device was adjusted to 80% of the mean MEP for the first training week. Participants visited the hospital after every training week to measure MEP and PEF again. The device was readjusted weekly to 80% of the newly measured average MEP.
After the four week training program the voice recordings and VHI-10 were measured again. Participants were also asked to score five study specific questions, specially designed for this study, concerning their voice quality and mucus clearing in relation to the start of the training on a linear analogue scale (appendix III). Design of the study is visualized in figure 1.

Measurements + adjustment	Week 0 baseline	After 1 week training	After 2 weeks training	After 3 weeks training	After 4 weeks training
MEP (cmH2O)	X	X	X	X	X
PEF (L/sec)	X	X	X	X	X
Adjustment EMST	X	X	X	X	X
MPT (sec)	X				X
Vocal range Hz	X				X
Vocal range dB	X				X
VHI-10	X				X
SSQ					X

Figure 1: Flowchart of the 4 week training program with EMST-device
Abbreviations: MEP: maximum expiratory pressure; PEF: peak expiratory flow; MPT: maximum phonation time; VHO-10: voice handicap index 10; SSQ: study specific questions

Training device

The expiratory muscle strength training was performed with the EMST150 device © (Aspire Products, LCC). It is a handheld device consisting of a plexiglass tube and mouthpiece (picture 1). Inside the trainer is a variable tension spring controlling a valve that is calibrated in pressure, adjustable from 30 till 150 cmH20. When enough pressure is developed, the valve opens allowing air to flow through the trainer. An adaptor has been made to connect the EMST device at the adhesive baseplate with a small lumen for use of the plug and to connect with the manometer (picture 1). Before each training the voice prosthesis has to be blocked with a plug to avoid air escaping through the voice prosthesis into the esophagus. The plug used during the training is the same participants are accustomed to use in case of leakage through the voice prosthesis. On top of the adapter is an opening which make it possible to breathe through. During a forced exhalation the opening must be closed with a finger to allow the airflow into the EMST.

Picture 1. EMST150

Picture 2. EMST150 with adapter to connect the adhesive baseplate

Training program

After the baseline assessments participants were provided with written and verbal instructions how to perform the training. Every participant was given an EMST. Participants were instructed to perform the training five days per week at home for four weeks. One training session consisted of five sets of five forceful exhalations through the device, a total of 25 breaths per day. Between the five sets a period of 45 seconds rest was held. Participants were instructed to exhale as forceful as possible into the device till the valve inside the EMST device opened. Participants noted the completion of their training on a log sheet during the training program.

Statistical analyses

Analyses were carried out using SPSS software, version 22 (16). To analyze the differences between the weekly measured values of the primary outcome measures MEP and PEF, Friedman's non-parametric 2-tailed repeated measures ANOVA's were performed. Non-parametric tests were used because of the small group (N=9).

For the secondary outcome measures MPT, vocal range and the VHI-10, non-parametric 2-tailed Wilcoxon signed ranks tests were performed.

Concerning the five study specific questions, reliability was checked with a Cronbach's alpha of 0,925. After this a 2- tailed One-Sample test was performed with a 95% confidence interval. A significance level of p = .05 was used for all statistical testing.

Results

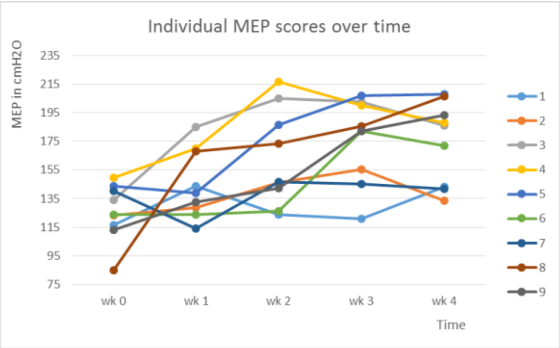
Nine male participants (from 50 to 78 years of age) completed the study. All participants underwent radiotherapy before or after their laryngectomy. Participant characteristics are shown in table 1. Compliance to the training protocol was high. Eight participants had 100% compliance. One participant (number 6) missed four training moments and the assessment after his first training week due to illness. The values measured at starting point for MEP and PEF were imputed for these missing data.

Table 1: Participant characteristics

Participant	Age in years	Time since TL in years	Speech with voice prosthesis: manually or freehands
1	65	13	Freehands
2	67	18	Manually
3	50	3	Freehands/ manually (alternating)
4	68	1	Manually
5	57	15	Freehands
6	63	7	Manually
7	68	3	Freehands/ manually (alternating)
8	57	10	Freehands
9	78	3	Manually

Primary outcome measures

MEP showed a significant improvement over time (chi-square 22.637; p = .000). PEF showed no significant effect over time from baseline to the end of training (chi-square 3.732; p = .444). The individual scores for all participants over time for MEP and PEF are presented in a graph (figure 2). Descriptive statistics of the means and standard deviations of MEP and PEF over time are presented in table 2 and 3 (appendix IV).



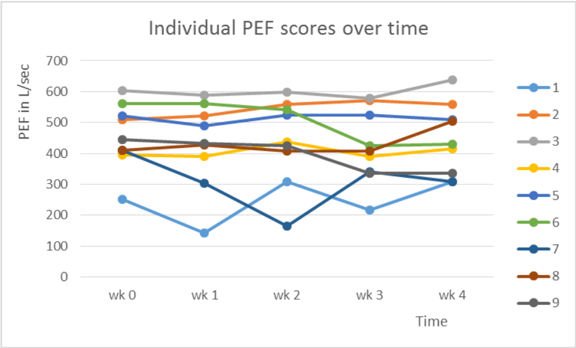


Figure 2: Individual MEP and PEF scores over four weeks' time

Three of the participants already achieved a MEP-score above 187,5 cmH2O during the four week training. From that time, training at 80% of the mean MEP was not possible for these participants since the maximum setting of the EMST is 150 cmH2O. The participants who already achieved a MEP-score above 187,5 cmH2O continued the training with the device set at 150 cmH2O.

After the start of the study it turned out that three participants were not able to block the voice prosthesis with a plug prior to the training due to a narrow stoma and/ or insufficient view of the voice prosthesis. Two participants (participant 2 and 5) continued the training without using a plug. One (participant number 4) continued the training with a larytube in the stoma. Furthermore, it should be noted that leakage of air underneath the adhesive sometimes occurred during measurement of the MEP. Participants mentioned that this also happened sometimes during their training at home.

Secondary outcome measures

No significant effects were found for any of the secondary outcome measures.

MPT varied from 5,72 to 29,32 seconds at the start of the training and from 2,07 to 30,96 seconds after training. Mean MPT pre training was 12,83 seconds; SD 7.45. Mean MPT post training was 12,40 seconds; SD 8.02.

For MPT, a Wilcoxon signed ranks test showed no significant effect (Z = -.415, p = .678)

Mean vocal range in dB was 26,56 dB pre training; SD 7,49 and post training 30,33 dB; SD 5.48. For vocal range in dB, a Wilcoxon signed ranks test showed no significant effect ($Z = -1.544$, $p = .123$).

Mean vocal range in Hz was 150,13 Hz; SD 40.55 pre training and post training 168,25 Hz; SD 35.05. For participant number 4 it was not possible to determine pitch because of a too irregular voice. For this, vocal range in Hz is analyzed over 8 participants. For vocal range in Hz, a Wilcoxon signed ranks test showed no significant effect ($Z = -1.120$, $p = .263$).

Mean VHI-10 was 16,11 points pre training and 16.67 points post training. For VHI-10, a Wilcoxon signed ranks test showed no significant effect ($Z = -.239$, $p = .811$).

Descriptive statistics of minimum and maximum scores, means and standard deviations for the secondary outcome measures pre and post training are also presented in table 4 (appendix V).

For the five study specific questions reliability was checked. Cronbach's alpha was 0,925. If changes were mentioned they were positive but small. No significant effects were found in any of the five study specific questions.

Adverse event

An adverse event occurred with one of the participants in his last training week. After training with the EMST, the voice prosthesis was not in situ anymore. A new voice prosthesis was placed. The assumption has been that the voice prosthesis went into the esophagus due to the built up pressure during the training or that the voice prosthesis might have been pushed into the esophagus during plugging. An X-thorax proved the voice prosthesis was not in the lungs. All participants and the medical ethical review committee were informed. All participants continued the training.

Discussion

This study examined feasibility and effects of a four week EMST training program on the maximum expiratory pressure (MEP) and peak expiratory flow (PEF) for the first time in a group of nine male laryngectomized participants. It was hypothesized that MEP and PEF would increase after a four week EMST training. The results revealed a significant increasement for maximum expiratory pressure. No significant effects was found for the other main outcome measure peak expiratory flow.

The significant increasement of the MEP is consistent with former findings in studies of Kim and Baker (11, 17). Participants who already achieved a MEP-score above 187,5 cmH2O continued the training with the device set at 150 cmH2O. The increase in MEP for these participants would possibly have been larger in case of training with an EMST device with a wider range.

From the three participants who were not able to plug the voice prosthesis, one participant (participant 4) performed the training with a larytube. The assumption has been that a larytube blocked the voice prosthesis mostly during the training but a 100% blockage can not be guaranteed. The other two (participant 2 and 5) performed the training without blocking the voice prosthesis. These two participants showed increasement of the MEP as well. Both participants were able to build up enough pressure to open the EMST during their training. It has been assumed that in these two cases some air might have been leaked into the esophagus during measurement of the MEP and during the training which could have influenced the results. When there has been some leakage of air, less pressure could have been build up in the EMST. This could have led to less improvement compared to the ones who performed the training with a plug.

During the study it was observed that at some moments there was air leakage underneath the adhesive during measurement of the MEP or during the voice recordings. Participants also mentioned that this sometimes happened during their training at home. This could have influenced the results negatively.

Problems with plugging and leakage of air underneath the adhesive are reality for at least a part of the laryngectomized group and must be taken into account in case of an expiratory muscle strength training in this group.

In a study of Wheeler et al (18) a significant effect was found for reflex cough (PEFR in L/sec.) in a group of stroke patients. In this study no significant effects were found for PEF. It is unclear why PEF did not improve in this group. A possible reason for not improving can be an impaired cough technique. No special attention was paid at the exhaling technique during the training. Participants were just instructed to exhale forceful into the device until it opened. Instructing participants in exhaling with use of the abdominal muscles during the EMST training might influence the results on PEF positively.

It was hypothesized that voice parameters and participants quality of life would also improve after EMST training. For the secondary outcome measures maximum phonation time, vocal range, VHI-10 and the study specific questions no significant effects were found.
Deore et al, 2011 (19) presented an overview of studies with a range of MPT between 6.0 to 16.4 seconds of tracheo esophageal (TE) speakers. The wider range in this study (2,07 to 30,96 seconds) is caused by the extreme short MPT of participant 8 and the remarkable high MPT of participant 4. In this study the mean MPT post training is shorter compared to pre training, which is the opposite of what was expected in advance. The outcome can be negatively influenced because the voice recordings of participant 3 were measured again post training because of failing recording equipment. His first attempts of a sustained /a/ seemed better in comparison with his second attempts. Participant 8 had a very short MPT post training of only 2,07 seconds (pre 5,98). The researchers had the impression, although they tried to motivate him, this performance was not his maximum.

Compliance to the training program was high. Participants had to come weekly to the hospital and had to train five days per week for four weeks at home. A possible inclusion bias has been that only physical fit participants were asked to participate. This could have been influenced the results. Because participants were relatively fit already from the start, they possible improved less compared to participants who were less fit and mentioned explicit coughing problems. Plugging the voice prosthesis and connecting the EMST device to the stoma requires some skills of the participants. It is unclear if less fit participants are able to perform the training with such a high compliance to the training protocol.

Because of the small number of participants (N=9) the results of this first EMST study in a laryngectomized group must be interpreted with caution. The outcomes can not be generalized one on one to the entire laryngectomized population.

Conclusion

This pilot study shows that a four week expiratory muscle strength training seems feasible in a group of total laryngectomized male participants and increase the maximum expiratory pressure. The main outcome measure MEP improved significant over four weeks' time. No significant effect was found for the other main outcome measure PEF or for any of the secondary, voice and voice related, outcome measures. It requires some skills of the participants to perform the training. Therefore, EMST training may not be appropriate for the laryngectomy group as a whole.

Recommendations

It should be considered to test EMST in a group of laryngectomized participants who did not plug the voice prosthesis prior to the training. When an improvement is reached as well, users can be spared the hassle of plugging. This way it appears to be suitable for a larger group. In this pilot study all subjects who participate were in a relatively good condition and had a good voice. It would be interesting to assess the feasibility and effects of EMST in a group of less fit elderly participants and/ or participants who mentioned explicitly problems of slime and difficulty with coughing. It is also recommended to include women in a next study, although there seems to be no reason to assume that women cannot perform an EMST training, to be able to assess possible differences in outcomes between both sexes. Finally it is recommended to give special attention at the exhaling technique used during the training to assess if this will help to improve the peak expiratory flow.

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Appendix I: descriptive of scripts used to analyze vocal range in dB and Hz with PRAAT

Dynamic range measurements – vocal range in Decibel

For the "Soft-Loud" measurements, participants pronounced a sustained /a/, three times, as soft as they could followed by three times as loud as they could. The recordings of these sustained /a/ sounds were hand segmented and labeled as "Soft" and "Loud" by a phonetician of the Netherlands Cancer Institute.

An automatic Praat script located the labeled segments and measured the loudness in the central half of each segment, i.e., starting ¼ into the segment up to ¾ of the duration of the segment. The intensity of the recordings was calculated as a function over time with the Praat command settings: To Intensity: 60, 0, "yes"
This command uses a lowest pitch setting of 60Hz. This Pitch parameter determines the window length over which the intensity is calculated.

The loudness is calculated as the energy based average over the central half of the segment using the command: Get mean: startTime, endTime, "energy"
The difference in decibels between the highest "Loud" average intensity value (dB) and the lowest "Soft" average intensity (dB) was chosen to represent the dynamic range of the speech in this recording.

Pitch measurements – vocal range in Herz

In the "Low-High" measurements, participants pronounced a sustained /a/, three times, as low as they could followed by three times as high as they could. The recordings of these sustained /a/ sounds were hand segmented and labeled as "Low" and "High" by a phonetician of the Netherlands Cancer Institute.

An automatic Praat script located the labeled segments and measured the pitch in each. For the "Low" segments, pitch was determined between the boundaries of 60-120Hz, for "High" segments, between 150-500Hz.
Each segment was copied and analyzed with the Praat command settings:
For "Low" segments: To Pitch (cc): 0, 60, 15, "yes", 0.03, 0.45, 0.01, 0.35, 0.14, 120
For "High" segments: To Pitch (cc): 0, 150, 15, "yes", 0.03, 0.45, 0.01, 0.35, 0.14, 500

For each segment the median pitch value was determined using the Praat command:
Get quantile: 0, 0, 0.50, "Hertz"

The lowest “Low” median pitch value and the highest “High” median pitch were chosen to represent the pitch range of each recording. In some cases, no pitch value was found for any of the “Low” segments or any of the “High” segments in a recording.

Appendix II: Voice Handicap Index – 10 item version (VHI-10)

Instructions: These are statements that many people have used to describe their voices and the effects of their voices on their lives. Circle the response that indicates how frequently you have the same experience.

	Never	Almost Never	Some times	Almost Always	Always
My voice makes it difficult for people to hear me.					
People have difficulty understanding me in a noisy room.					
My voice difficulties restrict personal and social life.					
I feel left out of conversations because of my voice.					
My voice problem causes me to lose income.					
I feel as though I have to strain to produce voice.					
The clarity of my voice is unpredictable.					
My voice problem upsets me.					
My voice makes me feel handicapped.					
People ask, "What's wrong with your voice?"					

Appendix III: Study specific questions with linear analogue self-assessment

Instructions: 0 means that no change is experienced. On the left side of 0 (-) indicates a deterioration, right (+) indicates improvement. Place an X in the indicated answer.

1. How do you judge the length of your sentences, compared with 4 weeks ago?

Much shorter						=						Much longer
	-5	-4	-3	-2	-1	**0**	+1	+2	+3	+4	+5	

2. How do you judge the control in loudness of your voice (loud – soft), compared with 4 weeks ago?

Much worse						=						Much better
	-5	-4	-3	-2	-1	**0**	+1	+2	+3	+4	+5	

3. How do you judge the control in pitch of your voice (high - low), compared with 4 weeks ago?

Much worse						=						Much better
	-5	-4	-3	-2	-1	**0**	+1	+2	+3	+4	+5	

4. How do you judge the effort you have to made for speech, compared with 4 weeks ago ?

Much more effort						=						Much less effort
	-5	-4	-3	-2	-1	**0**	+1	+2	+3	+4	+5	

5. How do you judge coughing up, compared with 4 weeks ago?

Much worse						=						Much better
	-5	-4	-3	-2	-1	**0**	+1	+2	+3	+4	+5	

Appendix IV: Descriptives of primary outcome measures MEP and PEF

Table 2: Descriptive statistics of Maximum Expiratory Pressure (MEP)

	N	Mean	Std. Deviation	Minimum	Maximum
MEP in cmH2O (baseline/ pre training)	9	125,48	19,64	85,00	149,67
MEP in cmH2O (after training week 1)	9	145,00	24,09	114,00	185,00
MEP in cmH2O (after training week 2)	9	162,96	33,94	123,67	216,67
MEP in cmH2O (after training week 3)	9	175,63	29,24	120,67	207,00
MEP in cmH2O (after training week 4/ post-training)	9	174,77	28,61	133,33	208,00

Abbreviation:
MEP: Maximum Expiratory Pressure

Table 3: Descriptive statistics of Peak Expiratory Flow (PEF)

	N	Mean	Std. Deviation	Minimum	Maximum
PEF in L/sec (baseline/ pre training)	9	455,89	105,52	252,33	602,33
PEF in L/sec (after training week 1)	9	428,41	138,94	143,00	589,33
PEF in L/sec (after training week 2)	9	440,82	137,15	166,00	599,00
PEF in L/sec (after training week 3)	9	421,19	119,58	217,33	579,67
PEF in L/sec (after training week 4/ Post training)	9	445,52	116,43	308,67	638,67

Abbreviation:
PEF: Peak Expiratory Flow

Appendix V: Descriptives of secondary outcome measures

Table 4: Descriptives MPT, vocal range in dB and Hz and VHI-10

	N	Mean	Std. Deviation	Minimum	Maximum
MPT (pre)	9	12,8278	7,45303	5,72	29,32
MPT (post)	9	12,3967	8,01541	2,07	30,96
Vocal range dB (pre)	9	26,5556	7,48517	19,00	44,00
Vocal range dB (post)	9	30,3333	5,47723	19,00	38,00
Vocal range Hz (pre)	8	150,1250	40,54781	96,00	207,00
Vocal range Hz (post)	8	168,2500	35,04996	115,00	218,00
VHI-10 (pre)	9	16,1111	9,46631	8,00	31,00
VHI-10 (post)	9	16,6667	9,20598	5,00	32,00

Abbreviations:
MPT = Maximum Phonation Time; dB = decibel; Hz = Herz; VHI-10 = Voice Handicap Index-10

Nederlandse samenvatting

Titel Het effect van een uitademingsspierkrachttraining in een groep totaal gelaryngectomeerde patiënten; Een pilotstudie

Achtergrond Met de ontwikkeling en het gebruik van warmte- en vochtwisselaars en stemprotheses zijn de longfunctie en stemkwaliteit van patiënten na een totale laryngectomie de afgelopen decennia aanzienlijk verbeterd. Overmatige slijmproduktie, problemen met ophoesten en de negatieve invloed op de stemkwaliteit blijven echter veelgenoemde klachten. 'Expiratory Muscle Strength Training' (EMST) is een behandeling om de uitademingsspieren te versterken. Eerder onderzoek toonde positief effect in een groep gezonde ouderen, een groep patiënten met de ziekte van Parkinson en in een groep patiënten na een beroerte.

Doel De haalbaarheid van een EMST training in een groep gelaryngectomeerde deelnemers en de effecten op de uitademingsspierkracht zijn onderzocht. Daarnaast is het effect van de training onderzocht op de maximale fonatietijd, het stembereik en de stemgerelateerde kwaliteit van leven.

Methode Negen gelaryngectomeerde deelnemers volgden een vierweekse EMST-training. Maximale uitademingsdruk en piekstroom zijn onderzocht als primaire uitkomstmaten. Maximale fonatietijd, stembereik, VHI-10 en vijf studiespecifieke vragen fungeerden als secondaire uitkomstmaten.

Resultaten Maximale uitademingsdruk verbeterde significant door de tijd. Geen significante effecten werden gevonden voor de overige uitkomstmaten.

Conclusie EMST-training lijkt uitvoerbaar in een groep deelnemers na een totale laryngectomie en lijkt geschikt de maximale uitademingsdruk te verbeteren.

Aanbevelingen Het wordt aanbevolen het effect van de EMST-training te onderzoeken in een groep minder fitte gelaryngectomeerden die expliciet problemen aangeven met overmatige slijmproduktie en moeite hebben met ophoesten. Ook wordt aanbevolen in een vervolgstudie aandacht te geven aan de uitademingstechniek die gebruikt wordt tijdens het uitvoeren van de training.

Trefwoorden Uitademingsspierkracht, training, EMST, totale laryngectomie, stemkwaliteit