

Physiology of the breathing rest during speech – A cross-sectional study in vocally healthy adults

Die Physiologie der Atempause beim Sprechen – Querschnittsstudie bei Stimmgesunden

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Abstract

Background: Various voice therapy concepts in German-speaking countries, such as the Schlaffhorst-Andersen concept or breath-rhythm-adapted phonation method (AAP) work on the breathing pause between exhalation and inhalation in order to help patients achieve an economical and powerful voice production. However, so far this key concept has not been sufficiently studied in a systematic and data-based manner. Internationally, the breathing rest is occasionally referred to as *pre-inspiration*. The purpose of this study is to investigate the existence of the breathing rest during speech.

Methods: A cross-sectional study of 28 blinded, vocally healthy adult women (n = 23) and men (n = 5) with a mean age of 28.5 (21 to 57) with multiple measurement time points was conducted. Muscle activity in the diaphragm was assessed by surface electromyography during inhalation, exhalation, and breathing rest using predefined criteria in relaxed and speech breathing (reading a list of single words). Using SPSS, we conducted a two-factor ANOVA with repeated measures for the mean values of the breathing phases (inhalation, exhalation, breathing rest) and breathing activity (relaxed breathing, speech breathing). Afterwards, we used Bonferroni-corrected pairwise comparisons.

Results: ANOVA showed no significant differences between relaxed and speech breathing (p = .56). Bonferroni-corrected pairwise comparisons revealed that the breathing rest was significantly different in mean values from inhalation (Mean = .87, SD = .2) and exhalation (Mean = .69, SD = .16, p < .001). In terms of duration, all breathing phases differed significantly from each other in relaxed (Mean = 1.59, SD = .86) and speech breathing (Mean = .34, SD = .12, p = .002).

Conclusion: Our study of German-speaking vocally healthy adults demonstrated for the first time a measurable breathing rest before an inspiration in both relaxed and speech breathing. Even though these results provide external evidence for working on and with breathing rests in voice therapy, these should be confirmed in a larger study.

Abstrakt

Hintergrund: In der Stimmtherapie im deutschsprachigen Raum wird z. B. nach dem Konzept Schlaffhorst-Andersen oder der Atemrhythmisch Angepassten Phonation (AAP) mit und an der Atempause zwischen Ausatmung und Einatmung für einen ökonomischen, leistungsfähigen Stimmgebrauch gearbeitet. Dieses Kernkonzept wurde bisher noch nicht ausreichend systematisch und datenbasiert untersucht. International ist die Atempause als *Pre-inspiration* beim Sprechen ansatzweise bekannt. Mit dieser Studie soll der Fragestellung nachgegangen werden, ob eine Atempause existiert.

Methodik: Eine Querschnittsstudie bei 28 verblindeten, stimmgesunden, erwachsenen Frauen (n = 23) und Männern (n = 5) mit einem Durchschnittsalter von 28,5 (21 bis 57) mit mehreren Messzeitpunkten wurde durchgeführt. Die Muskelaktivität des Diaphragmas wurde mittels Oberflächen-Elektromyografie (EMG) in Einatmung, Ausatmung und Atempause in Ruhe- und Sprechatmung (Lesen von Einzelwörtern) untersucht.

Ergebnisse: Die Berechnungen mittels zweifaktoriellen ANOVAs mit Messwiederholung für die Mittelwerte der Atemphasen (Einatmung, Ausatmung, Atempause) je Atemaktivität (Ruheatmung, Sprechatmung) zeigten keine signifikanten Unterschiede (p = 0,56) zwischen Ruhe- und Sprechatmung bezüglich der mittleren Diaphragmenaktivität. Bonferroni-korrigierte paarweise Vergleiche ergaben, dass sich die Atempause im Mittelwert signifikant von Einatmung (Mean = 0,87, SD = 0,2) und Ausatmung (Mean = 0,69, SD = 0,16, p < 0,001) unterscheidet. In Bezug auf die Dauer unterscheiden sich alle Atemphasen signifikant voneinander in Ruheatmung (Mean = 1,59, SD = 0,86) und Sprechatmung (Mean = 0,34, SD = 0,12, p = 0,002).

Fazit: Die Ergebnisse deuten darauf hin, dass bei stimmgesunden, deutschsprachigen Erwachsenen sowohl in Ruhe als auch Sprechatmung eine Atempause vor der Einatmung existiert. Die Ergebnisse tragen zur externen Evidenzbildung für die Arbeit an und mit Atempausen in der Stimmtherapie bei. Weitere Untersuchungen zur Überprüfung der Allgemeingültigkeit der Atempausenexistenz sollten auf Basis der vorliegenden Ergebnisse durchgeführt werden.

Keywords:

breathing pause, breathing rest, surface electromyography (EMG), diaphragm, speech breathing, muscle activity, voice therapy

Schlüsselwörter:

Atempause, Oberflächen-Elektromyografie (EMG), Diaphragma, Sprechatmung, Muskelaktivität, Stimmtherapie

BACKGROUND

An elementary aspect of voice therapy is the work on breathing as a prerequisite for vocalisation. Releasing the respiratory muscles after exhalation and before the new inhalation is an important component of three-phase breathing. Through numerous interconnections, breathing affects voice, speech and processes in the body (Coblentz & Muhar, 1965; Lang & Saatweber, 2011). The founders of voice therapy methods used their wealth of experience, observational skills and extensive experimental research to come to the above conclusions. Hence, this contribution to the field of internal evidence has yet to be backed up by external evidence. Over the years, new methodological and technical approaches have been developed, and this professionalised approach demands external evidence to support practical action (§135a SGB V, last amended by Art. 1 G v. 11.5.2023, I No. 123).

The breathing rest in German-speaking voice therapy

In the German-language concepts and methods of voice therapy based on the work of Schlaffhorst-Andersen, Coblentz-Muhar, Haupt and Middendorf's respiratory therapy, the breathing rest - after exhalation - is a core element. In other well-known concepts like Smith Accent Method (Thyme-Frøkjær & Frøkjær-Jensen, 2014) only two phases (inhalation and exhalation) are considered.

The breathing rest in the Schlaffhorst-Andersen concept

In their anatomical-physiological explanation of the *Schlaffhorst-Andersen concept*, Lang & Saatweber, 2011 present the three-phase nature of breathing in detail.

During the breathing rest, the activity of the respiratory muscles is in a state of equilibrium with the

elastic recoil forces of the lungs. This is the point at which muscle metabolism is at its most undisturbed, enabling a moment of regeneration. The three-phase breathing rhythm is inherent to the organism and varies according to the situation and the individual.

In the *Schlaffhorst-Andersen concept*, the focus is on becoming aware of and encouraging the breathing rest, because this regeneration is seen as being essential for a powerful and economical vocal performance.

The breathing rest in Respiratory-Rhythmically-Adapted Phonation

Coblentz and Muhar (1965) based their method of *Respiratory-Rhythmically-Adapted Phonation (AAP)* on the reflexive interplay of phonation and the diaphragm, and used it to design a procedure for voice training. They conducted experiments on breathing during phonation and derived their method from an experiment on 400 participants (varying from newborn to adults), who were examined in standing and sitting positions, while breathing through a mask into a pneumotachograph, which measured their respiratory volume. In addition, intrathoracic pressure was measured using an oesophageal probe and sound power via a corresponding device. The measurements were made with the participant in a state of relaxed breathing, during phonation on the vowel /a:/ as well as while reading poetry. In their investigation of the relationship between lung volume, oesophageal pressure and sound power, the authors stated that air escapes at the end of exhalation and pressure is relieved, which can create powerful impulses for inhalation. They called this the breathing rest. Statistics were not reported and risks or bias not discussed.

The breathing rest in Middendorf's respiratory therapy

Middendorf (2007), the founder of respiratory therapy, stated:

The three-phase breathing rhythm with inhalation, exhalation and rest is the ideal breathing rhythm. It varies between individuals and situations and is innate. It is a natural rhythm that rises from the unconscious, becomes perceptible and provides a reliable sense of security. When producing sound, it is equally important not to actively take the new breath or to prolong the sound beyond the residual breath so that a deep breath has to be taken. Instead, the breath should commence and develop on its own. In recent literature, Faller (2019) stated:

Breathing rests occur in relaxed breathing, shorten during periods of stress and fall away during speaking and singing because of the lengthened exhalation. They are followed by a reflex inhalation. Inhalation takes place in 0.2 seconds, which requires good breathing mechanics. Due to the *Abspannen* (release of tension) at the end of the exhalation the new inhalation suddenly falls in. However, due to certain influencing factors (for example, stress), the breathing rest in relaxed and phonatory breathing may disappear altogether. Rutte and Sturm (2018) also note that the respiratory rest is shortened or completely absent during physical stress or mental strain.

The breathing rest in integrative voice therapy

Haupt (2010) incorporates content and methods from physiology, psychology, sociology, pedagogy and art in her method of *integrative voice therapy*, from which she constructs a voice function circle with different fields of work.

For the area of respiration, Haupt uses elements of the methods developed by Schlaffhorst-Andersen, Coblenzer and Middendorf (as described above), among others. Breathing is understood in accordance with the above. The shortening or absence of the breathing rest is seen, for example, in the psychosocial context of the patient's stressful daily life. Methodologically, in the field of respiratory therapy, first a long and then a short breathing rest is practised. If both are mastered, the reflex-like air replenishment as described by Coblenzer (1965) is practised in the sense of *Abspannen* as a flexible elasticity of the diaphragm.

The breathing rest in international literature

Internationally, different terms are used for the short phase between exhalation and inhalation, and different explanations are provided.

Boyd and Basmajian (1963) found that there are two other respiratory phases besides inspiration and expiration in which the respiratory movement is at rest

and no air flows into or out of the lungs, by investigating 25 rabbits. The authors called the phases “pre-inspiration” and “pre-expiration”, which they observed in relaxed breathing. Henderson et al. (1965) showed that there are differences in pausing between reading and spontaneous speech. In reading, breathing only occurred at grammatically meaningful points, whereas in spontaneous speech, “hesitation-pauses” occur additionally and to a greater extent.

Grosjean and Collins (1979) investigated pauses in speech in 6 subjects. They subdivided inhalation during *breath pauses* into “pre-inspiration, inspiration and post-inspiration” (Grosjean & Collins, 1979, p. 102). *Pre-inspiration* can possibly be equated with the breathing rest, which is described and assessed in this paper. The authors stated that 36% of the breath pause is used for *pre-inspiration*. This involves either continuing to exhale or maintaining a constant subglottic pressure. *Pre-inspiration* was interpreted as a phase that is comfortable to maintain due to equalisation with atmospheric pressure, rather than maintaining the high subglottic pressure of *post-inspiration*. They concluded that *pre-inspiration* can be shortened as the rate of speech is increased, while *inspiration* and *post-inspiration* necessarily remain the same length.

Research following examined pauses in speech in relation to sentence length in reading tasks and assessed respiratory physiology. Fuchs et al. (2013) found that long sentences result in deeper inhalations and longer pauses than short sentences.

Based on this, Trouvain et al. (2016) found that in fluent and non-fluent speech (concerning learning new languages), there are filled and unfilled pauses. In non-fluent speech, more unfilled pauses were found. Speech pauses also occur due to hesitation because of searching for the right wording, morpho-syntactic encoding, word choice or social interaction in the language. They stated that the physiology of inhalation and exhalation during pauses in speech should be studied kinematically with the aim of distinguishing audible from silent inhalations.

In this sense, the present study fundamentally and systematically investigates the phenomenon of the breathing rest in both relaxed and speech breathing by measuring respiratory muscle activity and duration. The following research question was investigated:

Are there significant differences between the breathing phases (inhalation, exhalation and breathing rest) in vocally healthy adults, during different breathing activities (relaxed and speech breathing) and their interaction in terms of duration and percentage value of the mean “Maximum Voluntary Contraction” (MVC)?

METHOD

In a prospective cross-sectional study, $n = 28$ blinded subjects (23 female, 5 male) with a mean age of 28.5 years ($SD = 9.99$, $min = 21$, $max = 57$) were included. Subjects were blinded in relation to the research topic and question. The study was carried out at the University of Applied Sciences and Arts (HAWK) in Hildesheim, Germany, between April and May 2022. Ethical approval was granted by the responsible committee of the HAWK under reference number HAWK_B_23_11.04.22.

Data Collection

First, subjects filled in two questionnaires, the Vocal Tract Discomfort (VTD) scale and a self-developed questionnaire for collecting personal data (profession, age, gender, exercise frequency, self-perceived voice use privately/professionally/for leisure activities using visual-analog scales, voice therapy in the previous year, voice training and symptoms of voice disorders). We used hard- and software developed by VICON Motion Systems Ltd. (2022). We utilised a computer, a video camera (model Bonita 720c [100 Hz]) and the electromyography, model m32ORX, by MYON. The control of the measurements and the editing of the data was carried out in *Nexus* and *proEMG* (VICON Motion Systems Ltd., 2022).

Inclusion and Exclusion Criteria

Only subjects aged > 18 years, who gave informed consent, and who completed the study protocol were included in the study. To exclude voice disorders, the German version of the Exchange to VTD with a cut-off below 26 points was used (Lukaschik et al., 2017). Moreover, participants were asked if there were any periods of hoarseness > 2 weeks (to exclude structural causes) or limited vocal resilience or other voice complaints in the past year (Reiß, 2009). If more than two of these four items applied, the person was excluded from the present work. Only subjects with a complete study protocol were included in the analysis. Moreover, people with an occupation in the field of speech and language therapy or voice training were excluded if they had received voice training with content relating to a breathing rest. Further, people with any degree of acute or chronic respiratory condition were excluded, as well as those with cardiovascular disease. Finally, we excluded daily smokers and subjects with thick tissue in the intercostal area, as this is a limitation for the method EMG, which we used. In case of Sub_20,

we decided to include the data, because this person was a non-frequent daily smoker.

Experiment procedure

The experiment followed a standardised protocol (see Figure 1). The pretest was necessary to construct the experiment. Steps 1-4 were performed with each person to record EMG and video data.

0. Pretest:

Preparing the experiment, we tested EMG signal quality in relation to body posture and different electrode position points. Since SENIAM (2022), a main source of standardised EMG measure points, did not provide any for diaphragm measurement, measuring points as listed by Dos Reis et al. were tested (2019). In order to measure maximum performance, it is advisable to use static, fixed exercises leading to maximum movement excursion (Konrad, 2011). For the maximum manoeuvre, a modified version of Kofler's (1952) sipping exercise was used. This exercise could be implemented quickly and correctly by the pretest participants and achieved the highest values in the EMG when the maximum inhalation capacity was reached. This state was then maintained as long as possible. The procedure proved more suitable in the present pretest than previously described manoeuvres by Dos Reis et al. (2019) and most likely meets Konrad's (2011) recommendation to use statically fixed exercises to measure maximum muscle activation.

Experts from the host laboratory supported the development of the procedure and provided advice on the best use of EMG measurement and processing. Over

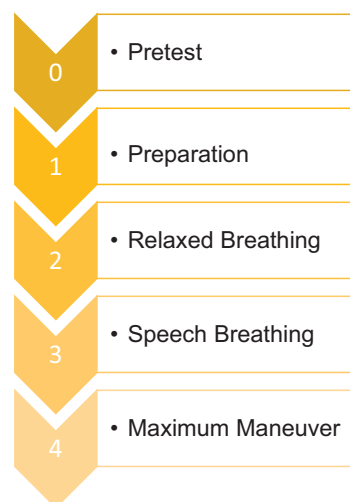


Figure 1. Test procedure

a period of six months, we also tested and agreed on the scope and order of tasks.

1. Preparation:

Subjects lay down on a treatment couch in a sound-proofed area. A list of words was affixed in the field of view. Skin was cleaned and hair was removed in the lower costal area. The electrodes, including the transmitter, were attached in the 7th intercostal space on the right half of the body facing laterally on the middle clavicular line. The distance between the electrodes was 1 cm. Cometa Micro Golden Electrodes with 5 mm diameter were used (Cometa srl, 2021). To test the measuring point, the maximum manoeuvre required in the experiment was first practised and then carried out. If necessary, the electrode position was corrected.

2. Relaxation exercise:

Relaxed breathing was detected by EMG, while subjects performed a relaxation exercise in the lying position. The measurement started one minute after the instruction (“Close your eyes and think of a place where you can relax and enjoy yourself, for example, sunbathing on the beach”) and lasted for a minimum of 30 seconds.

3. Reading task:

Speech breathing was detected by EMG, while subjects read a list of mono- to four-syllable words with final phoneme [m] in the lying position. See Appendix. The list contained 39 words written one below the other by using single words, steering by means of syntactic structures could be ruled out and the participants breathed when it was individually necessary.

4. Maximum manoeuvre:

In the lying position, participants breathed in slowly and as much as possible through a constriction (30-cm straw with a diameter of 2 mm and narrowed ends). A maximum manoeuvre is used to normalise the data. The maximum innervation point found in the EMG data represents 100% muscle activity. Accordingly, the percentages of muscle activity in relaxed and speech breathing could be achieved.

Data processing

The collected data from EMG and video were processed in *Nexus*. First, the raw data were processed in *proEMG* with the following filters:

- Butterworth Low-Pass (Cut-off 499 Hz, 2nd order)
- Butterworth High-Pass (Cut-off 70 Hz, 2nd order)
- Root Mean Square (50 ms)

Figure 2 visualises the process from the raw data to the filtered result as an example. Suitable respiratory phases were then marked in the video and EMG according to defined criteria (see Table 1).

Electrocardiogram (ECG) artefacts could not be adequately filtered to maintain the highest possible measurement quality. The *proEMG* gave a calculation of mean values and duration for each of three inhalations, exhalations and breathing rests as a percentage of the defined peak value of the maximum manoeuvre (%MVC). The mean calculation averaged all percentages of the curve

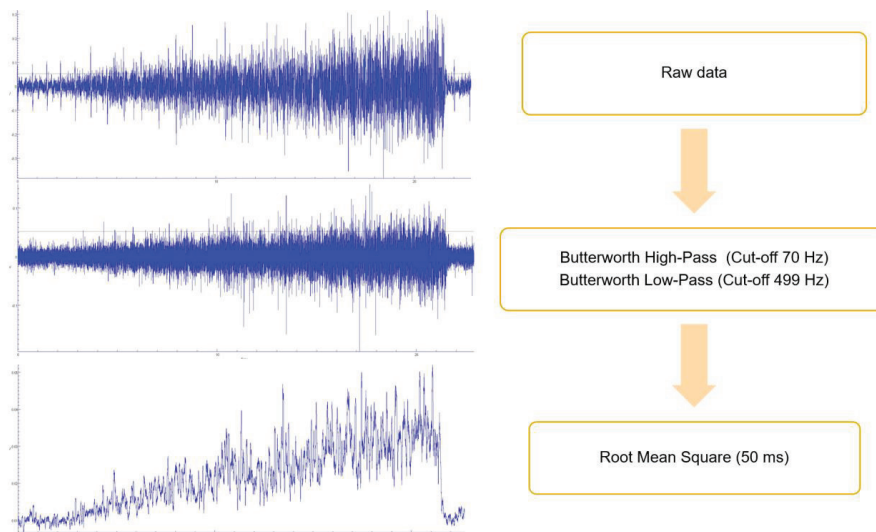


Figure 2. Processing of the raw EMG data with filters during a maximum inhalation

Type of result		Start Breathing rest	Start Inhalation	Start Exhalation
Articulation/Lips	Relaxed breathing	Closed	Closed	Closed
	Speech breathing	Closed after final [m]	Opening	Use for word beginning
Breathing movements Chest and abdomen		None	Lifting	Lowering
Exclusion		• Interference signal • Lip licking, swallowing, throat clearing, yawning		

Table 1. Visual selection criteria for marking breathing phases

reached within a marker. Duration indicates the length of time between two markers.

Values for the three breathing phases (inhalation, exhalation, breathing rests) and the two different activities (relaxed and speech breathing) were calculated for each person. The procedure of averaging was chosen, because each breathing cycle is individual (Lang & Saatweber, 2011).

For the following calculations, a total of 17 measured values per person was available.

Statistical Analysis

Statistical analysis was performed using SPSS from IBM (2019). Demographic data were summarised by median, interquartile range (I50), mean and standard deviation (SD). To examine the muscle activity and duration of the respiratory phases during relaxed and speech breathing, we performed two-factor repeated measures Analysis of Variance (ANOVA). The first factor was activity (relaxed and speech breathing), the second factor was breathing phase (inhalation, exhalation and rest), and the interaction term was activity × breathing phase. The Bonferroni correction was applied to the post hoc tests for the breathing phases (inhalation, exhalation, breathing rest) in Model A (Mean %MVC) and Model B (duration in seconds).

RESULTS

Descriptive statistics

Table 2 describes the sample and the measured values in detail.

Most of the participants worked as physiotherapists (54%), occupational therapists (14%) or social workers (11%). The mean VTD score was 11.9 points (SD = 8.93). Some people reported periods of hoarseness (13%), limited vocal resilience (3%) or other voice complaints (7%) such as frequent throat clearing. If only one item regarding a voice disorder

was reported and the VTD score was below the cut-off of 26 (Lukaschik et al., 2017), no voice disorder was assumed.

Only one person reported occasional smoking (> 1 month) of a hookah, which was not classified as regular smoking.

Only 15% had voice-intensive leisure activities such as choir/solo singing or political work.

Overall, participants used their voice frequently, both privately (median = 3, I50 = 0) and professionally (median = 3, I50 = 1). Some people had already received voice or speech training (10%) but were not aware of the breathing rest and could still be considered blinded.

Two-factor repeated measures ANOVA was performed based on Table 3.

Additionally, equality of variances (= sphericity) was tested for each model (Hemmerich, 2022). We used the Mauchly test and, where appropriate, the Greenhouse-Geisser or Huynh-Feldt correction.

Results: Mean Diaphragmatic Activity

The two-factor ANOVA with repeated measures (Table 4) shows that the mean muscle activity in %MVC does not differ significantly in relaxed and speech breathing ($F(1.27) = 3.49$, $p = .07$, $\epsilon^2 = .11$).

In contrast, the breathing phases (Huynh-Feldt sphericity = .87) differ highly significantly from each other ($F(2.54) = 15.58$, $p < .001$, $\epsilon^2 = .36$). Bonferroni-corrected pairwise comparisons show that there is no difference between inhalation and exhalation (Mean = .186, SD = .128, $p = .47$), but the breathing rest is highly significantly different from both inhalation (Mean = .87, SD = .2, $p < .001$) and exhalation (Mean = .69, SD = .16, $p = .001$). See Figure 3.

The interaction of relaxed and speech breathing (Greenhouse-Geisser sphericity = .73) with the breathing phases is not significant ($F(2.54) = .48$, $p = .56$, $\epsilon^2 = .17$).

Variable (n = 28)		Min	Max
Age Mean (SD)	28.5 (9.99)	21	57
Gender n (%)			
	female	23 (82)	
	male	5 (18)	
Profession n (%)			
	Physiotherapist	15 (54)	
	Occupational therapist	4 (14)	
	Infant pedagogue	2 (7)	
	Social worker	3 (11)	
	Other	4 (14)	
VTD Scale Mean (SD)	11.9 (8.93)	0	31
Periods of hoarseness in the last year? n (%)			
	no	24 (86)	
	yes	4 (14)	
Limited vocal resilience in the last year? n (%)			
	no	27 (96)	
	yes	1 (4)	
Other voice complaints in the last year? n (%)			
	no	26 (93)	
	yes	2 (7)	
Voice use private Med (I50)	3-frequent (0)	1	5
Voice use professional Med (I50)	3-frequent (1)	3	5
Voice-intensive leisure activity n (%)			
	no	24 (86)	
	yes	4 (14)	
Have you had voice or speech training? n (%)			
	no	25 (89)	
	yes	3 (11)	
Smoking? n (%)			
	no	27 (96)	
	yes	1 (4)	

Abbreviations: n = Number; Med = Median; SD = Standard deviation; I50 = Interquartile range; VTD = Vocal Tract Discomfort

Table 2. Descriptive Statistics - Sample

Results: Duration of respiratory phases

Model B of the two-factor ANOVA with repeated measures (Table 3 and 4) shows that the duration in seconds differs highly significantly with a strong effect in relaxed and speech breathing ($F(1.27) = 57.48$, $p < .001$, $\epsilon^2 = .68$).

Similarly, the duration of the respiratory phases (Mauchly's W sphericity(2) = .84, $p = .11$) differs highly significantly with a strong effect ($F(2.54) = 55.14$, $p < .001$, $\epsilon^2 = .67$). Bonferroni-corrected pairwise

comparisons show that all breathing phases are highly significantly different: inhalation from exhalation (Mean = -.92, SD = .12, $p < .001$), inhalation from the breathing rest (Mean = .37, SD = .11, $p = .006$) and exhalation from breathing rest (Mean = 1.28, SD = .15, $p < .001$).

In this model, the interaction of relaxed and speech breathing with the breathing phases (Greenhouse-Geisser sphericity = .73) is also significant with a strong effect ($F(1.46, 39.34) = 8.43$, $p = .002$, $\epsilon^2 = .24$). See Figure 6.

Model	Breathing phase	N	Relaxed breathing	Speech breathing
A Mean %MVC	Inhalation Mean (SD)	28	25.35 (10.26)	26.24 (10.06)
	Exhalation Mean (SD)	28	25.30 (10.47)	25.92 (10.47)
	Breathing Rest Mean (SD)	28	24.61 (10.17)	25.24 (10.05)
B Duration in Seconds	Inhalation Mean (SD)	28	2.18 (.85)	.48 (.11)
	Exhalation Mean (SD)	28	2.55 (1.13)	1.95 (1.12)
	Breathing Rest EMG Mean (SD)	28	1.59 (.86)	.34 (.12)

MVC = Maximum Voluntary Contraction; SD = Standard deviation

Table 3. Descriptive statistics ANOVA

Model	Factor	Sphericity	df	Error df	F	p	ϵ^2
A Mean % MVC	Breathing activity	-	1	27	3.49	.07	.11
	Breathing phase	.87 ³	2	54	15.58	< .001	.36
	Breathing activity* Breathing phase	.73 ²	2	54	.48	.56	.17
B Duration in Seconds	Breathing activity	-	1	27	57.48	< .001	.68
	Breathing phase	.84 ¹ p = .11	2	54	55.14	< .001	.67
	Breathing activity* Breathing phase	.73 ²	1.46	39.34	8.43	.002	.24

MVC = Maximum Voluntary Contraction; df = degrees of freedom; F = F-Ratio; p = significance; ϵ^2 = effect strength

¹ Sphericity assumed according to Mauchly's W

² Sphericity according to Greenhouse-Geisser

³ Sphericity according to Huynh-Feldt

Table 4. Results of two-factor ANOVA with repeated measures

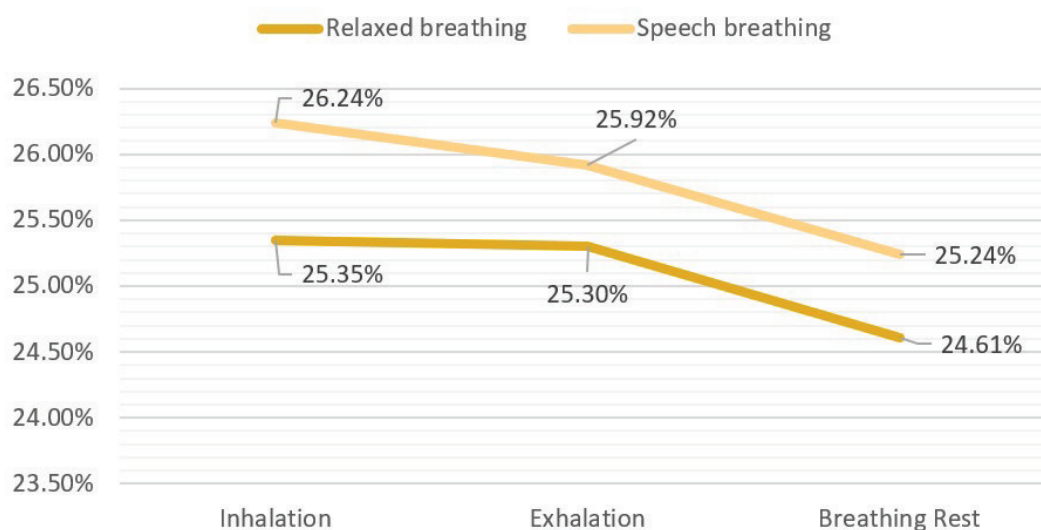


Figure 3. Mean muscle activity in %MVC per breathing phase in relaxed and speech breathing

DISCUSSION

In this prospective cross-sectional study, we examined 28 vocally healthy adults who were outcome blinded and did not work with voice or speech in a professional context. The phenomenon of the breathing rest in both relaxed and speech breathing was investigated by measuring respiratory muscle activity and duration. We found a breathing rest between exhalation and inhalation in both experiment conditions: relaxed breathing and speech breathing. The duration of the breathing rest was shortened in correlation with the inhalation from relaxed to speech breathing, as summarised in Figure 6. Further, mean muscle activity decreased during the breathing rest to such an extent that this breathing phase differed significantly from inhalation and exhalation (see Figure 3).

Interpretation: Mean Diaphragmatic Activity

For the calculation of the mean values (Model A), no significant difference can be assumed between relaxed and speech breathing. This means, on average, the recruitment of muscle activity for speech breathing is not significantly higher. However, if we look at the breathing phases inhalation, exhalation and rest, there are highly significant differences. The Bonferroni-corrected pairwise comparisons show that the breathing rest is significantly different from inhalation and exhalation in terms of mean muscle activity. This supports the main intention of the study that the breathing rest can be considered as a separate breathing phase. It is statistically significantly different from the established breathing phases inhalation and exhalation. The autonomy of the breathing rest as

a separate breathing phase can equally be applied to relaxed breathing and to speech breathing, as no significant differences were shown between the breathing activities relaxed and speech breathing as well as the interaction of the breathing activity and the breathing phases. If the breathing rest were to disappear, as Faller (2019) assumes, there should be no difference to exhalation or inhalation and significant differences between relaxed and speech breathing as well as the interaction (breathing activity*breathing phase) should be detectable. However, the results show that the breathing rest is distinguishable from inhalation and exhalation in terms of muscle activity and is evident in both relaxed and speech breathing.

No statement can yet be made about the regenerative effect of the breathing rest, which is assumed in some literature (Coblentz & Muhar, 1965; Lang & Saatweber, 2011). In the included sample muscle activity increased from relaxed to speech breathing for all breathing phases, which includes the breathing rest (see Figure 3).

This means that it cannot be assumed that the same low level of activity is achieved during speech breathing as during relaxed breathing. However, the sample studied consists of speech-untrained individuals who are not yet able to consciously control the quality of release in the breathing rest. It is possible that trained speakers who consciously use the breathing rest as a moment of regeneration would measure lower muscle activity values in the breathing rest during speech. Occasionally, a continuous increase in activity throughout the speaking time was observed during data analysis (see Figure 4).

From experience, people then report that it becomes tiring to speak after a certain period.

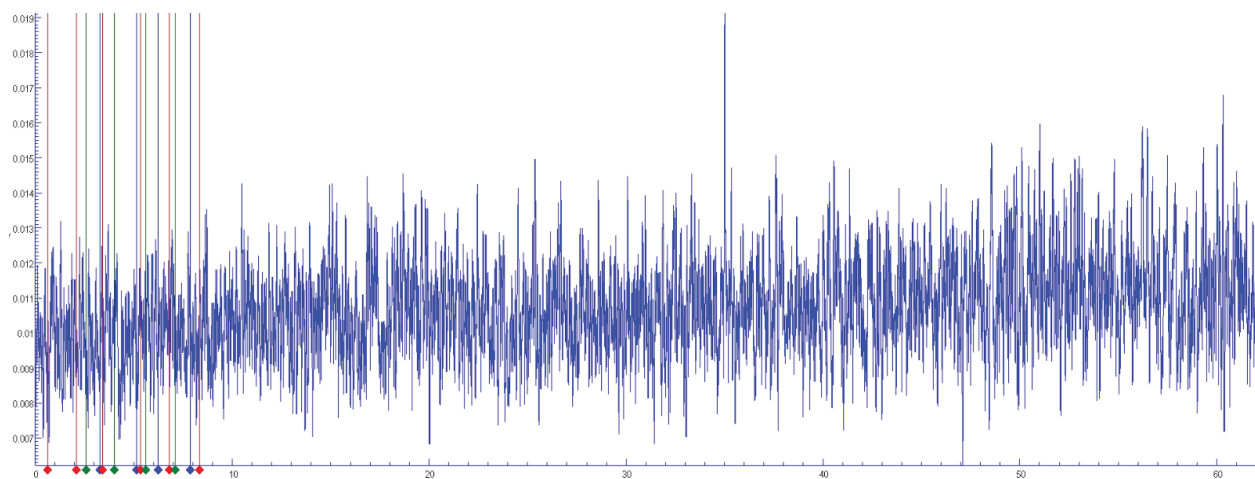


Figure 4. EMG filtered data of speech breathing. Activity level increases

From a clinical point of view, this is an indication that the measured moment of regeneration is not yet sufficient and that more work on and with the breathing rest may be worthwhile for this speaker. It is also possible that the enumerative nature of the text selection increased activity levels in an attempt to complete the task as quickly as possible.

Interpretation: Duration of respiratory phases

In Model B on the duration of activities and breathing phases, all factors as well as the interaction differ from each other. The mean duration in speech as compared to relaxed breathing is highly significantly shorter ($p < .001$). The respiratory phases inhalation, exhalation and rest are also highly significantly different from each other, shown by the Bonferroni-corrected pairwise comparisons. Similarly, the

interaction breathing activity*breathing phase is significant in this model. It can be observed that all breathing phases shorten from resting to speech breathing. Exhalation is consistently the longest, even though it shortens by about half a second from relaxed to speech breathing. This is due to the text chosen for the experiment, which consisted of a list of single words. Participants were therefore more likely to enumerate, which may have caused them to breathe more quickly than they would have done with longer phrases. When analysing the data, short breathing phases were also often selected because some persons exhaled too much and/or used their abdominal muscles at the end of a long exhalation, which would have distorted the EMG results (see Figure 5). At this point, it becomes clear that the laboratory situation is not the same as the everyday situation and that the choice of text had a significant impact on the results.

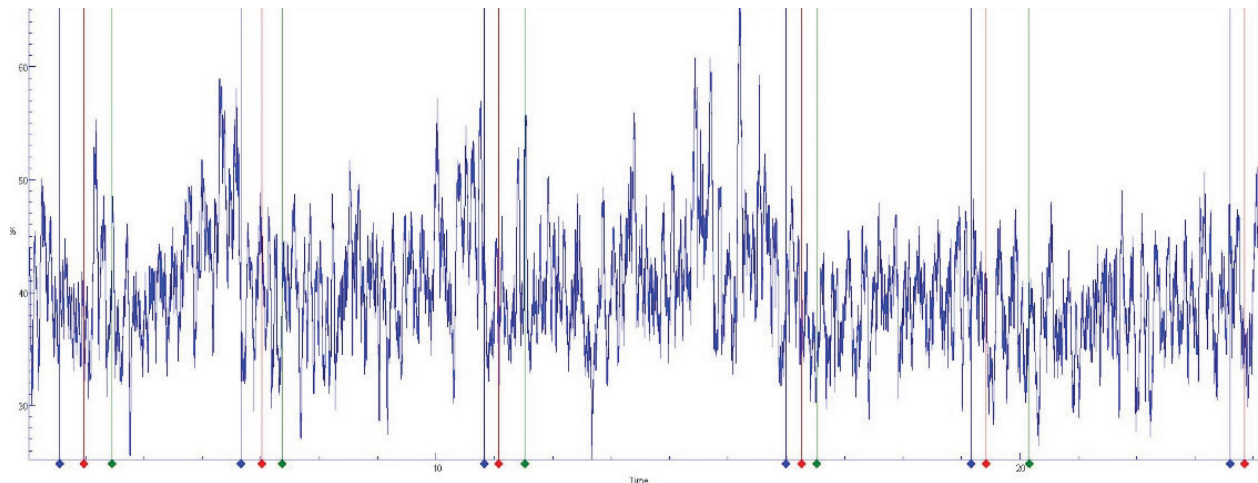


Figure 5. Use of the abdominal muscles at the end of exhalation

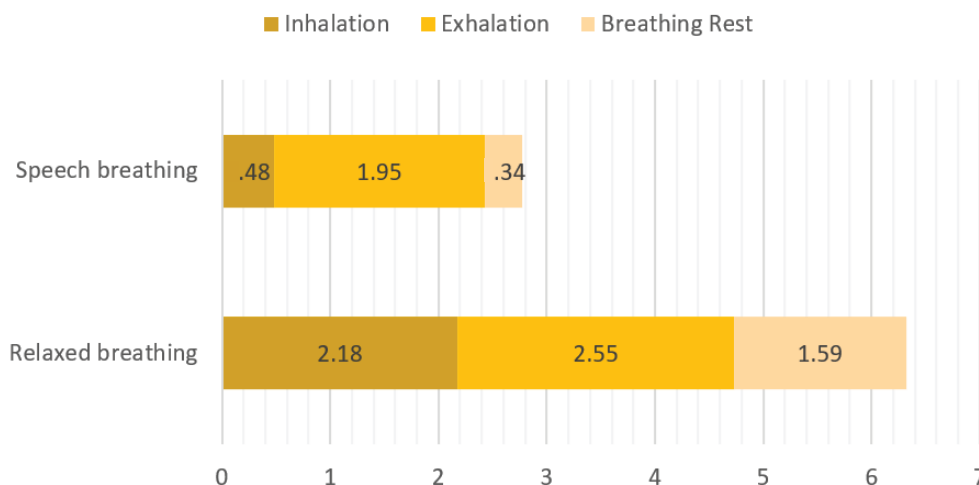


Figure 6. Duration of breathing phases in seconds

The inhalation is shortened along with half a second to .48 seconds, while the breathing rest is shortened by one second to .34 seconds (see Figure 6). The shortening of the inhalation in speech breathing corresponds to the data from Faller (2019) and Coblenzer and Muhar (1965).

Innovations of this Study

Electromyography was chosen to carry out the experiment. This is a new method for studying breathing rests during speech in contrast to previous studies (Coblenzer & Muhar, 1965; Fuchs et al., 2013; Grosjean & Collins, 1979; Henderson et al., 1965; Trouvain et al., 2016). Stepp (2012) and McFarland and Smith (1989) state that surface EMG is a useful examination method for the speech and swallowing system, including the diaphragm, if it is used correctly and specifically. Surface EMG is a sensitive technique. It is susceptible to interference. For this reason, the pre-test was conducted to guarantee a high experimental design and to ensure the most valid and reliable data possible. Nevertheless, the data must be considered against the background of the measurement conditions. Differences in tissue properties, crosstalk due to the use of abdominal muscles during speech and the choice of measurement site, which had to be carefully determined, were probably the most significant influences on EMG measurement quality.

In order to check whether EMG is an adequate method for assessing breathing rests compared to acoustic assessment, we also performed a method comparison using Bland-Altman plots (Bland & Altman, 1986). We found that a purely visual assessment using EMG tended to measure a longer breathing rest (~25%) than an audio-visual assessment using voice analysis (measured by audio and video). However, for the purpose of the study, EMG gives comparable results to an acoustic measurement of the breathing rest.

Experiment Procedure

Both the experimental procedure and the data processing are well established and could be standardised based on the available material for future research.

Nevertheless, we observed some of the participants performing the maximum manoeuvre differently. This could not be eliminated while practising in preparation. They used different breathing types (clavicular, costal, abdominal) and recruited different accessory breathing muscles, so that the maximum value peaks in the EMG varied. As these corresponded to the 100% mark for MVC

normalisation, the achieved percentage values in relaxed and speech breathing also differed.

The text selection (word list) was suitable for the research question. Due to the lack of syntactic structures, participants breathed when they felt it individually necessary. The fact that they were blinded to the research question supported unconscious speech breathing.

However, reading a word list is prosodically different from spontaneous speech and could therefore have had an effect on speech breathing.

Limitations

Despite efforts to obtain valid measurement results and a standardised, objective procedure, risks of bias and limitations must be considered. The study looked at the breathing rest between exhalation and inhalation in speech, which theoretically should occur in all people around the world. Nevertheless, we assume that the results can only be transferred to the German language, as other languages use different speech tempi and other lengths of breath pause during speech (Trouvain et al., 2016). However, the results on the relaxed breathing rest could be considered generally valid and independent of language.

Another limitation is the sample. It was very young (mean age of 28.5 years, SD = 9.99, min = 21, max = 57), mostly female (23 female, 5 male). This is not representative of the German population as a whole, which is on average 44.6 years old (Statistisches Bundesamt, 2023a) and 50.7% female (Statistisches Bundesamt, 2023b).

In future studies a more heterogeneous sample concerning these characteristics should be assessed.

One important inclusion criterion was vocal health, which we assessed using a self-developed questionnaire and an established dysesthesia questionnaire (Lukaschyk et al., 2017). In retrospect, these criteria used alone are not sufficient for the exclusion of a voice disorder. As this is only one domain of the ELS protocol (European Laryngeal Society), in future studies the in- or exclusion should be supported by additional domains of voice diagnostics (Dejonckere et al., 2001).

FUTURE PERSPECTIVES AND BIG PICTURE

As we assessed only vocally healthy subjects, further research could clarify whether people with voice disorders do not exhibit a breathing rest and whether this lack of a breathing rest is a relevant factor in developing voice disorders. A correlation

of non-rest breathing with psychological factors (for example, stress) should also be further investigated.

The results presented here contribute to external evidence-building in voice therapy. The core element of Schlaffhorst and Andersen's concept, that breathing is a three-phase process (Lang & Saatweber, 2011), can be confirmed. Also the assumption of Coblenzer and Muhar (1965) that air replenishment in speech breathing is a rapid, reflex-like action, can be supported by our findings. However, the present data cannot be used to comment on the quality of breathing rests. The fact that the moment of muscular release lasts a very short time does not indicate whether

its effective use would be sufficient to enable the speaker to continue speaking for a longer period of time without signs of vocal fatigue. There is still a need for further research on this point.

Another important aspect in this field of research is the breathing during reading, during spontaneous speech, during dialogues and during other positions and movements of the body. This would help to obtain greater external validity and to draw more conclusions about the broader existence of the breathing rest in everyday life.

There are no conflicts of interest within the scope of the study.

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Appendix

Bahndamm	heilsam
Regenwurm	System
zahn	Milchschaum
Grashalm	Alm
Kamm	Minimum
Strom	Hohlraum
Sonnenschirm	Museum
dumm	Schlamm
Tagestraum	Eigentum
Turm	Reim
Baustellenlärm	Konsum
Gramm	Reichtum
herum	Kostüm
Gebrumm	angenehm
Qualm	Spülschwamm
Tannenbaum	Slalom
Atom	Holzleim
Wachstum	Kram
Bienenschwarm	Lieblingsparfüm
stumm	