Vocal Quality After a Performance in Actors Compared to Dancers

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SUMMARY

State of the art: Theater actors are a high risk group for developing voice disorders.

Aims: The first purpose of this study was to examine and compare the objective and subjective vocal quality between professional theater actors, non-professional theater actors and a control group of professional dancers. Secondly, the impact of one theater performance on the objective and subjective vocal quality was investigated within and between the groups. It is hypothesized that actors will experience vocal fatigue and a deteriorated vocal quality compared with dancers as a result of the vocal load during the performance. Dancers will face more general fatigue and smaller vocal changes due to the impact of a performance including stress, decompensation and physical fatigue.

Methods: Recordings of 27 professional actors, 19 non-professional actors and 16 professional dancers were collected before and after a performance using the PRAAT software. Voice samples included sustained vowel phonation, continuous speech, aerodynamic measurements and voice range profile. Both Acoustic Voice Quality Index and Dysphonia Severity Index were computed. For auditory-perceptual evaluations the GRBASI scale was used. Several questionnaires were completed pre and post performance to capture vocal risk factors.

Results: Vocal quality between groups showed lower fundamental frequency (f_o) values (female), larger fundamental frequency (female) and intensity ranges and a longer maximum phonation time (female) in professional actors compared to non-professionals. Professional dancers showed higher Acoustic Voice Quality Index values compared to non-professional actors. Dysphonia Severity Index, Voice Handicap Index, Vocal Tract Discomfort Scale and GRBASI results did not differ between groups at the baseline. Both objective measurements and questionnaires did not show significantly different results post performance. Questionnaires revealed poor vocal habits in professional actors.

Conclusion: Professional actors have better vocal capacities than non-professionals. Dancers' vocal quality is worse than actors. The results show no impact of one performance on the vocal quality in theater actors and dancers. The long-term impact of performing, however, is subject for further research.

Key Words: Vocal quality; Acoustic analysis; Impact; Theatre actors; Dancers; Performance

INTRODUCTION

Vocal performers constitute a high risk group for development of voice disorders due to the physiological demands imposed on their respiratory and laryngeal systems, as well as environmental, psychological and social conditions. The actors' population is exposed to high professional demands. Theater actors experience a lot of pressure and stress caused by job insecurity and their typical lifestyle: they work late, have irregular work schedules, have social duties and their work environment changes frequently.[1, 2, 3]

Van Houtte, Van Lierde[4] demonstrated that 16% of the patients who consulted the Ear, Nose and Throat department for dysphonia were artists. According to Lerner, Paskhover[5] 62% of first year drama students have an incomplete glottal closure, 59% have laryngeal hyperfunction and 55% have a decreased mucosal wave. In a study with 26 theater actors 50% reported vocal complaints after a performance. They had a mean Acoustic Voice Quality Index (AVQI) of 3.48 which corresponds with mild dysphonia.[6] Furthermore, little is known about the prevalence of voice disorders in professional theater actors. During stage performances and rehearsals, it is hypothesized that actors may overload their vocal mechanism by exceeding the center of their voice range profile and are more likely candidates for vocal injury,[7] even though they have a more favorable glottal setting, providing a higher glottal closing speed while projecting their voices on stage compared to non-actors.[8] Actors have a higher degree of both laryngeal and pharyngeal activities such as pharyngeal compression and medial and anterior-posterior laryngeal compression, compared to vocally untrained subjects. This higher activity is associated to speaking voice training and not to hyperfunctional vocal behavior, perceived as overuse of the voice. It is a strategy to avoid vocal fold damage while producing the desired voice quality.[9] Early studies by Bartholomew[10] described the desirability of a concentration of energy around 2600–3000 Hz in spectrographic analysis for producing a good operating male singing voice. This resembles the male actor's formant, also related to the perception of good and projected voice quality.[8,11, 12, 13, 14, 15, 16] Master, De Biase[17] did not find evidence of an actor's formant cluster in actresses' voices. Voice projection for this group of actresses seemed to be mainly a result of a laryngeal setting instead of vocal tract resonances.

Vocal fatigue as a result of laryngeal overload is considered a frequent symptom in actors.[18] Kitch and Oates[19] conducted a study where actors reported through a self-rating questionnaire about their vocal fatigue. Actors mentioned "power" aspects (eg, voice projection) as most altered. The causes of their vocal fatigue were vocal misuse, being "run down", high performance demands, and using high pitch and volume levels. According to a study by Ferrone, Leung,[20] actors show symptoms of vocal abuse while performing their lines. To interpret the perfect character, they often need to imitate voices, to scream, to shout, to grunt, to groan or to cry, which can be associated with vocally violent behavior.[21] They also need to show a various scale of emotions during performances.[22] Actors need to change their prosody and voice quality a lot to drive the perception of emotion in their acting.[23] Guzman, Correa[24] observed an impact of expressing emotions on the spectral energy of the voice, which can impact the vocal quality.

The work environment of actors can affect the quality of the voice in a negative way as well. Goulart and Vilanova[25] found that a significant portion of the professional actors in their study had complaints related to professional voice use, especially associated to workplace conditions, such as type of stage. The Italian stage is a rectangular stage, in which the relationship between actors and spectators is always front. This type of stage allows great visibility and acoustics. The arena type of stage may be circular, with the audience occupying the whole area around the stage, or rectangular, with the audience seated on three or four of its sides. When actors project their voices, they compete with ambient noise and thus, tend to increase vocal intensity and make greater effort to speak. In addition to the type of stage, the performance may need the presence of large amounts of onstage smoke, which the performer inhales before and during the show.[26] If these factors are added to stage dust and the ongoing use of various sprays, there are many possible voice complications. Some stages and props are dusty or moldy, such as curtains, flats, and costumes. Professional theater actors, who probably spend the equivalent to a full-time workweek in these environments, inhaling these substances, are at risk for developing voice disorders. Sometimes actors wear heavy costumes or make-up which can hamper the vocal projection and the articulation. They need to posture in an unnatural way to portray their character and the amplification is often absent or badly placed.[27] In a study by Rothman, Brown[28] it was concluded that the environment in which speech therapists record experimental samples from professional voice users should be considered as a variable that can affect results.

Despite these multiple risk factors and given the knowledge that professional actors have a significantly higher expertise about vocal hygiene than student actors,[29] previous studies are inconsistent with application of vocal hygiene into the workplace.[30] Student actors receive professional training in order to become a professional actor in a high school or university for audiovisual communication. The age of this population group is usually between 18 and 25 years, which differs significantly from the population of professional actors.[29] A study by Timmermans, De Bodt[2] showed a relatively higher tobacco, alcoholic and caffeinated drinks consumption in a subject group of future elite vocal performers (n = 36), compared to a control group (non-vocal non-professionals without a vocal pathology or vocal complaint, n = 68). Their habit of eating later in the day can cause gastroesophageal reflux disease and they do not regularly do warm-up exercises.[2,31] Different results were reported in the study by Gehling, Sridharan,[32] stating lower tobacco use in musical actors than Timmermans, De Bodt.[2] However, it should be mentioned that musical actors sing during a highly exhausting choreographed production and combine it with acting. This unique performance genre, typically consisting of eight shows a week, requires heavy vocal demands,[33] causing the musical actors to experience a different lifestyle compared to theater actors. Twenty-nine percent of a group of 48 Brazilian actors admitted using marijuana on a regular basis. In addition, 31% indicated taking some type of continuous medication.[25] The subjects in this study did not report any vocal difficulties caused by either the use of marijuana or continuous medication. However, Meehan-Atrash, Korzun[34] suggested that smoking cannabis is associated with changes in vocal fold appearance, respiratory symptoms, and negative lung function changes, especially in heavy smokers. Additionally, Roy, Merrill[35] reported a positive association between the use of continuous medication, such as high blood pressure medication and depression or anxiety medication, and voice disorders.

Inconsistency in the results concerning the application of vocal training and hygiene during actors' professional education is clearly described in the studies of Walzak, McCabe,[36] Villafuerte-Gonzalez, Valadez-Jimenez,[37] Pomaville, Tekerlek,[38] Tower, Acton.[39] The first research group examined "the knowledge gained and behavioral changes made by vocal performers after attending a vocal hygiene education program, which revealed significant improvements concerning the knowledge about the larynx, voice production and vocal hygiene. In addition, a behavioral inventory revealed improved hydration habits, decreased caffeine and alcohol intake, and healthier responses to symptoms of throat irritation or vocal fatigue." Tower, Acton[39] and Villafuerte-Gonzalez, Valadez-Jimenez[37] found improvements in vocal function (respectively increased mean fundamental frequency and reduced jitter and shimmer) whereas Walzak, McCabe[36] did not see significant changes for most of the acoustic measurements and some that deteriorated (increased shimmer).

Few studies have investigated the impact of a performance on the objective and subjective vocal quality of the actor's voice. Concerning the impact of a performance on the voice of singers and musical theater actors, Pacheco and Behlau[40] reported that "the immediate impact of vocal demand after a show is perceived as positive, and the singers considered their voices ready for a new performance." Exertion of the voice is very common during a performance. Bagnall and McCulloch[41] designed a study to explore the role of exertion in maintaining and optimizing the voice. The focus of this study was the possibility that increasing exertion could improve the voice and might result in the voice user experiencing less strain and, therefore, more comfort and ease. Subjects participated in a "Voicecraft" workshop, involving specific contraction of laryngeal, head, neck and back musculature to achieve intelligent shaping of the larynx and vocal tract for specific acoustic variations. During the training, subjects developed the ability to apply exertion to particular muscle groups, which, when contracted, conclude in various acoustic advantages, including the reduction of acoustic noise in the speaking voice. Recordings were made before and immediately after participation in the training, consisting of reading a passage and producing a sustained /i/ vowel. Afterwards, measurements were analyzed on a perceptual and acoustical level. The authors indicated that vocal quality improved, meaning, phonation with an increased ease and comfort and with an increase in the use of specific exertion. These results correlated with Ferrone, Galgano,[42] stating that an exertion technique can actually develop an improved vocal strength and flexibility.

Emerich, Titze[7] investigated the actor's voice during stage performances and suggested that some participants tend to surpass the center of their Voice Range Profile. Novak, Dlouha[18] performed tape recordings a few minutes before and after a theater performance in 45 actors. They analyzed the fundamental frequency, the center of gravity of the spectrum, the skewness of the slope through Long-Term Average Spectrum and did subjective evaluations on the actor's voices. Only the skewness of the slope, which was a little higher in males and lower in females, and the difference in shift of f_o between males and females differed significantly. The subjective vocal quality did not change afterwards, except for 3 men with a higher pitch. Ferrone, Leung[20] evaluated one actor before and after a series of eight performances. Despite the fact that the vocal technique of the actor was defined as vocally violent behavior by eleven out of twelve professional listeners, it did not result in vocal symptoms. The study revealed a post performance improvement in phonational range, maximum intensity levels, perturbation measures and s/z ratio. D'haeseleer, Meerschman[6] measured the vocal quality of stage actors before and after a performance and found no changes in objective vocal quality, measured by the AVQI. A subtle amelioration of the auditory-perceptual grade of dysphonia, evaluated by the GRBASI scale was found after performing. In contrast to the study by D'haeseleer, Meerschman,[6] Rangarathnam, Paramby[30] demonstrated significant deterioration in auditory-perceptual measures (CAPE-V) and mean expiratory airflow in 18 stage actors after stage performances and rehearsals, reflecting that actors are subjected to substantial phonotrauma. Knowledge of vocal hygiene and vocal training did not influence the results. The different outcomes in these two studies might have been caused by the use of different auditory-perceptual assessment tools (GRBASI vs CAPE-V) and the experience of the raters across the studies.

In none of the studies outlined above a control group or a multidimensional voice assessment with both the AVQI and Dysphonia Severity Index (DSI) was incorporated in the study design. To meet this limitation, a control group consisting of professional dancers and an extensive multidimensional voice assessment with more acoustic data and questionnaires were included in this study. Dancers perform on stage, but do not use their voice during a performance. This is the first study comparing the impact of a vocal and physical performance on the vocal quality in two groups of performers. By including a control group of dancers, it is possible to measure the additional effect of vocal load during performing.

The first purpose of this study was to examine and compare the objective and subjective vocal quality between professional theater actors, non-professional theater actors and professional dancers. Including non-professional actors in this study allows us to see the extent of the impact of having a professional education, experience, and living the fulltime “artist lifestyle.” Non-professional actors do not have as many performances as professional actors; neither did they have an extensive training or years of experience. It is hypothesized that professional actors would have a better vocal quality than non-professional actors due to aforementioned factors. Secondly, the impact of one theater performance on the objective and subjective vocal quality was measured within the groups and compared. It is hypothesized that actors will experience vocal fatigue and a deteriorated vocal quality as a result of the vocal load during the performance. Additionally, the authors wanted to map risk factors and vocal habits of professional theater actors in comparison with other performers.

METHODS

This research project was completed according to the Declaration of Helsinki and approved by the Ethics Committee of the Ghent University Hospital with the following registration number: B670201629828. A pre-test post-test design was managed. A written informed consent was signed by each participant.

Subjects

Voice samples of 63 subjects were collected before and after a performance (mean duration 83 minutes; SD 31 minutes; min. 30 – max. 150 minutes). Twenty-seven professional actors

(PA, 13 women, 14 men), who earn their living with acting, and 20 non-professional actors (NPA, 13 women, 7 men), who did not earn any money with performing, were included. Both groups had to spend at least 4 hours a week on acting and had to have Dutch or English as their first or second language. Being educated in performing arts was not part of the inclusion criteria. Musical actors were excluded from this study due to the different voice use during the combination of singing and acting. Sixteen professional dancers (PD, 12 women, 4 men) were recruited as a control group. Inclusion of a control group of professional dancers allowed the authors to measure the additional effect of vocal load during performing. Identical to the professional actors, professional dancers had to earn their living with performing and had to have Dutch or English as their first or second language. All subjects were between 16 and 48 years old, with a mean age of 28.9 (SD 8.70). Non-professional actors and professional dancers were significantly younger than the professional actors. Five participants out of 63 were non-Dutch (English) speaking participants, all part of the control group (professional dancers). These five participants were bilingual and used English as their first or second language. They had to have a leading or a relevant supporting role in the performance. Subjects did not undergo a laryngeal screening to determine whether there was presence of laryngeal pathology, as all data collection was performed outside the Ghent University Hospital. The subjects performed on Italian stages, without microphones. Participation to the study was unpaid, all subjects joined voluntarily. Subject characteristics can be found in Table 1.

TABLE 1.
Subject Characteristics: Descriptive Statistics and *P* Values

		Mean (SD)	*P* Value	*P* Value (Post-hoc)
Age (y) men	Professional actor	37.9 (5.32)	**<0.001**	**PA – NPA: <0.001**
	Non-professional actor	22.0 (1.16)		**NPA – PD: <0.001**
	Professional dancer	38.3 (4.73)		PA – PD: 0.986
Age (y) women	Professional actor	33.6 (6.97)	**<0.001**	**PA – NPA: <0.001**
	Non-professional actor	21.4 (2.94)		NPA – PD: 0.850
	Professional dancer	22.7 (5.18)		**PA – PD:<0.001**
Performance (hours in a week)	Professional actor	8.0 (3.99)	**<0.001**	**PA – NPA: 0.001**
	Non-professional actor	3.9 (1.68)		NPA – PD: 0.902
	Professional dancer	3.4 (3.97)		**PA – PD: <0.001**
Rehearsals (hours in a week)	Professional actor	22.9 (13.94)	**<0.001**	**PA – NPA: <0.001**
	Non-professional actor	6.3 (4.00)		NPA – PD: 0.106
	Professional dancer	14.3 (9.61)		PA – PD: 0.061
Duration of the performance (min)	Professional actor	87.2 (25.05)	**<0.001**	PA – NPA: 0.204
	Non-professional actor	100.8 (28.93)		**NPA – PD: <0.001**
	Professional dancer	52.3 (19.07)		**PA – PD: <0.001**
Vocal load during the performance (min)	Professional actor	54.4 (15.69)	**<0.001**	PA – NPA: 0.183
	Non-professional actor	43.7 (24.71)		**NPA – PD: <0.001**
	Professional dancer	3.4 (5.83)		**PA – PD: <0.001**
Experience (y)	Professional actor	12.6 (6.15)	0.081	
	Non-professional actor	8.5 (4.45)		
	Professional dancer	11.1 (6.96)		

Abbreviations: NPA, non-professional actor; PA, professional actor; PD, professional dancer.
To compensate for inflated type 1 errors, an adjusted α (=0.01) was included.

Voice recordings

The voice samples were recorded with a Samson C01U Pro USB Studio Condenser Microphone, digitized at a sampling rate of 44.1 kHz. The mouth-to-microphone distance was between 20 and 30 cm during every recording, pre and post performance. The calibration procedure of Maryn and Zarowski[43] was used to calibrate the microphone. These samples were recorded and analyzed using Praat software program for acoustic analysis (Institute of Phonetic Sciences, University of Amsterdam, The Netherlands[44]). Data collection was executed maximum 30 minutes before the start of the performance for pre testing, and within 10 minutes after the performance for post testing. The most acoustically favorable room in the theater hall was selected to perform the recordings and was used for pre and post measurements. The subjects were instructed to produce a sustained vowel /a:/ at a habitual pitch and loudness for 5 seconds. Sustained vowels are measured in a more easily controlled environment than continuous speech. The variances in sustained vowels can be reduced and thus allow for reliable attainment of perturbation and signal-to-noise ratio (SNR) parameters. Additionally, sustained vowels do not illustrate certain speech characteristics, such as speaking rate, dialect, intonation, and articulatory aspects.[45] To reach their habitual pitch and loudness, subjects were instructed to say "1, 2, 3" before producing the /a:/. The sustained vowel was subsequently analyzed as a midvowel segment of at least 3 seconds. Continuous speech during the reading of a phonetically balanced text "Papa en Marloes"[46] was recorded at habitual pitch and loudness. For non-Dutch speaking participants (*n* = 5), the phonetically balanced text "The Northwind and The Sun" was used. The first two sentences were acoustically analyzed and the remaining sentences were recorded for the perceptual voice evaluations. Additionally, subjects were cued to produce the sustained vowel /a:/ for as long as they could, in order to capture their maximum phonation time (MPT). Furthermore the subjects were instructed to produce the vowel /a:/ as a glissando from the habitual pitch or intensity to the lowest fundamental frequency (F_{low}), the highest fundamental frequency (F_{high}), the highest intensity (I_{high}) and the lowest intensity (I_{low}).

Objective voice assessment

The maximum phonation time (MPT; in seconds) for the sustained vowel /a:/ was measured. The longest phonation time of three trials was included in the study. The sustained vowel /a:/ was acoustically analyzed and the fundamental frequency (f_o, in Hz) was calculated. The investigators determined the f_o and intensity range of each participant, using the vowel /a:/ in a glissando. Participants were instructed to reach their absolute highest/lowest fundamental frequency (excluding vocal fry) and softest/loudest intensity by producing a glissando. The best result was selected out of three different tokens. The objective vocal quality of a participant was constructed by means of the DSI[47]. This measurement is based on the weighted combination of four different voice parameters: maximum phonation time (MPT, in seconds), the highest fundamental frequency ($F_{high,}$ in Hz), lowest intensity ($I_{low,}$ in dB), and the jitter (%). The formula of the DSI is: $DSI = 0.13 * MPT + 0.0053 * F_{high} - 0.26 * I_{low} - 1.8 * Jitter (\%) + 12.4$. DSI normally varies between −5 and +5, with −5 being the severely dysphonic and +5 reflecting good vocal quality with a cut-off point of 1.6.[48]

To our knowledge, the most studied multiparameter model to capture vocal quality successfully on sustained vowels and on continuous speech, is the AVQI.49, 50, 51, 52, 53 In these studies, varying degrees of hoarseness, normal and disordered voices, were assessed and the AVQI showed good external validity. In this study, the AVQI[49] was determined for each subject, using the sustained vowel and continuous speech recording. Maryn and Weenink[50] have shown that the AVQI is a powerful and valid method to calculate overall dysphonia in speech. The AVQI is a multiparameter index consisting of six different parameters: smoothed cepstral peak prominence (CPPS), harmonics-to-noise ratio (HNR), shimmer local (SL), shimmer local dB (SLdB), general slope of the spectrum (slope) and tilt of the regression line through the spectrum (tilt). The algorithm of Maryn, De Bodt[49] for detection, segmentation and concatenation of the voiced samples was used in Praat, as some of the above mentioned acoustic measurements are only valid for voiced segments of the continuous speech sample. To determine the AVQI, the following formula is applied: AVQI = 9.072–0.245 * CPPs – 0.161 * HNR - 0.470 * SL + 6.158 * SLdB – 0.071 * Slope – 0.170 * Tilt and varies from 0 to 10. A higher AVQI score correlates with an overall poor vocal quality, with a cut-off point of 2.91.

Auditory-perceptual evaluation

The auditory-perceptual evaluation was performed on the continuous speech samples, using the GRBAS scale of Hirano,[54] proposed by the Japan Society of Logopedics and Phoniatrics.[55] This scale has five different determined parameters: G (grade), R (roughness), B (breathiness), A (asthenicity) and S (strain).[54] Due to the need for an additional instability factor, a sixth parameter was included.[56] A four-point rating scale (0 = normal, 1 = slight, 2 = moderate, 3 = severe) was used for each parameter. The voice samples were randomized and rated blinded, to subject group and time, by both investigators. The researchers listened multiple times to the voice samples with ear headphones. The inter-investigator reliability was calculated (%) as well, using Cohen's Kappa.

Self-evaluation questionnaires

In order to obtain the subject's history, participants had to fill in a questionnaire prior to the performance (Dutch *n* = 57, English *n* = 5). This investigation included voice influencing factors such as alcoholic consumptions, smoking and sleep deprivation, and was based on the questionnaire of the European Laryngological Society protocol.[57] The psychosocial impact of vocal difficulties was measured using the Dutch[58] or English[59] version of the Voice Handicap Index (VHI). This index is a self-perception questionnaire with 30 different statements, divided into three categories – functional, emotional and physical disabilities – consisting of 10 statements each. Each statement had to be answered on a four-point rating scale according to suitability (0 = never, 1 = almost never, 2 = sometimes, 3 = almost always, 4 = always). The total score varies between 0 and 120. The more self-perceived disability caused by voice difficulties, the higher the score.

In the interest of examining the vocal tract discomfort, the subjects had to fill in the Dutch[60] or English[61] version of the Vocal Tract Discomfort Scale (VTDS). The VTDS is expressed by eight different symptoms or sensations that the subject can experience in the throat: burning, tight, dry, aching, tickling, sore, irritable, and lump in the throat. The subject had to define the frequency (0 = never, 1 = seldom, 2 = sometimes, 3 = more than sometimes, 4 = often, 5 = very often, 6 = always) and severity for each sensation or symptom (0 = none, 1 = almost none, 2 = mild, 3 = more than mild, 4 = moderate, 5 = more than moderate, 6 = extreme) on a 7-point Likert scale. A higher score means a more frequent and intense perceived symptom.

Likewise, the subjects were asked to fill in the Dutch or English version of the Corporal Pain Scale (CPS;[62]). This scale obtains results about the possible presence of self-perceived corporal pain sensations. It consists of 12 corporal pain symptoms of two different categories: firstly the proximal corporal pain located next to the larynx, neck, and shoulder girdle. These symptoms contain mandible pain, tongue pain, sore throat, neck pain, shoulder pain and diffuse pain. The second category consists of distal corporal pain located in other regions of the body, being headache, earache, back pain, chest pain, arm pain and hand pain. Participants had to indicate the frequency (never, sometimes, often, almost always, always) and intensity (10-point scale with 0 meaning no pain and 10 meaning extreme pain) for each corporal pain symptom. A higher score on the 10-point scale means a higher perceived intensity of the pain symptom.

The VHI, VTDS and CPS were completed before and after the performance to see whether there was an influence of external factors such as stress on the participant. Finally, a questionnaire regarding the vocal load and abuse during the performance was filled in by both the participant and the investigator after the performance.

Statistical analysis

SPSS 24.0 (SPSS Corp., Chicago, IL) was used for the statistical analysis of the data. Analyses were conducted at $\alpha = 0.05$. To assess the subject characteristics between the three groups, one-way ANOVAs were used (post hoc Scheffe). A linear mixed model was used to compare the objective voice measurements and scales between groups and between the scores before and after the performance within and between groups (Bonferroni correction included). Twenty-seven analyses were conducted with a linear mixed model. To compensate for inflated type 1 errors, an adjusted α (=0.01) was included for the linear mixed model analyses.[63,64] Time (pre and post), Group (professional actors, non-professional actors, professional dancers) and Time × Group interactions were specified as fixed factors. A random intercept for subjects was included. Within-group effects of time were determined using pairwise comparisons. Age and sex were added in the model as covariates. Restricted maximum likelihood estimations and scaled identity covariance structures were used during the analyses. The auditory–perceptual differences (GRBASI) between groups were calculated with a Kruskal-Wallis Test. Between performances within groups, a Wilcoxon Signed Ranks Test was used. Cohen's Kappa was run to determine the interrater reliability for the subjective vocal measurements. Categorical variables were compared using a Pearson $\chi 2$ test (2 × 3 table). If ≥20% of the cells had an expected count < 5 or the smallest expected count was < 2, a Fisher's exact test was used.

RESULTS

Subject characteristics

Comparing the groups, significant differences in age of the participants were found. Professional actors were significantly older than non-professional actors and professional dancers (PA – NPA: male and female: $P < 0.001$, PA – PD: female: $P < 0.001$) and male professional dancers were significantly older than male non-professional actors ($P < 0.001$). Average performance time per week (hours per week) differed significantly between the groups (PA – NPA: $P = 0.001$, PA – PD: $P < 0.001$) as well as the rehearsal time (PA – PD: $P < 0.001$). The duration of the performance on the testing day differed as well. The dancers' performance was significantly shorter than the performance of the actors ($P < 0.001$). Vocal load was significantly higher in the actors (NPA – PD, PA – PD: $P < 0.001$). Years of experience did not significantly differ between the three groups. Subject characteristics are reported in Table 1.

TABLE 2.
Objective Measurements: Descriptive Statistics and *P* Values

		Professional Actors Mean (SD)	Non-professional Actors Mean (SD)	Professional Dancers Mean (SD)	Main Effects (Adjusted)		
					Time	Group	Time x Group
f_o men	*Pre*	97.8 (14.13)	114.0 (20.07)	89.1 (5.00)	0.265	0.235	0.820
	Post	105.7 (20.50)	119.2 (23.19)	102.6 (24.29)			
f_o women	*Pre*	177.3 (28.26)	200.7 (27.69)	191.1 (20.63)	0.018	**0.001**	0.800
	Post	186.3 (36.81)	212.7 (33.96)	197.1 (22.67)			
DSI	*Pre*	6.7 (2.03)	5.6 (1.52)	6.0 (2.46)	0.767	0.011	0.646
	Post	5.8 (1.91	5.8 (1.91)	5.8 (1.80)			
MPT (s) men	*Pre*	24.7 (8.0)	19.7 (4.10)	20.2 (4.20)	0.060	0.042	0.064
	Post	23.6 (6.93)	24.0 (5.52)	29.2 (9.68)			
MPT (s) women	*Pre*	20.0 (5.95)	17.1 (4.29)	19.4 (4.76)	0.522	**<0.001**	0.566
	Post	20.6 (6.15)	18.1 (6.50)	18.9 (5.04)			
Jitter ppq5 (%)	*Pre*	0.2 (0.09)	0.2 (0.08)	0.2 (0.12)	0.245	0.016	0.766
	Post	0.3 (0.14)	0.2 (0.10)	0.3 (0.12)			
I_{low} (dB)	*Pre*	52.2 (6.87)	57.2 (6.38)	52.3 (8.66)	0.716	0.225	0.645
	Post	52.5 (6.52)	56.5 (8.19)	53.4 (7.90)			
I_{high} (dB)	*Pre*	100.7 (5.46)	99.5 (5.51)	95.7 (10.58)	0.129	0.917	0.135
	Post	99.5 (6.65)	95.1 (9.44)	95.9 (11.04)			
I_{range}	*Pre*	48.5 (6.16)	42.3 (5.47)	43.4 (6.17)	0.061	0.149	0.421
	Post	47.0 (6.07)	38.6 (6.45)	42.9 (8.28)			
F_{low} (Hz) men	*Pre*	68.0 (18.76)	78.2 (20.82)	82.0 (5.35)	0.849	0.158	0.658
	Post	67.0 (11.81)	84.8 (18.75)	85.0 (20.54)			
F_{low} (Hz) women	*Pre*	117.0 (16.33)	157.1 (16.15)	146.4 (18.03)	0.761	**<0.001**	0.072
	Post	118.2 (16.64)	150.2 (19.35)	154.4 (15.66)			
F_{high} (Hz) men	*Pre*	686.2 (141.85)	783.7 (121.97)	725.1 (136.03)	0.910	0.959	0.622
	Post	682.6 (141.01)	816.5 (137.40)	612.5 (201.76)			
F_{high} (Hz) women	*Pre*	1021.5 (208.37)	990.8 (229.14)	985.3 (300.73)	0.515	**0.007**	0.666
	Post	1023.3 (223.17)	929.3 (261.81)	982.7 (222.92)			
F_{range} men	*Pre*	618.2 (149.86)	705.5 (132.98)	643.1 (130.68)	0.884	0.930	0.708
	Post	615.6 (146.18)	731.7 (142.93)	527.5 (208.55)			
F_{range} women	*Pre*	904.5 (210.75)	833.7 (236.22)	838.9 (302.36)	0.507	**0.003**	0.763
	Post	905.0 (221.14)	779.1 (266.06)	828.3 (221.74)			
AVQI	*Pre*	3.2 (0.95)	2.9 (0.92)	4.0 (1.45)	0.886	**<0.001**	0.861
	Post	3.1 (1.29)	2.9 (0.92)	3.9 (1.17)			
CPPS	*Pre*	13.7 (2.17)	13.3 (1.92)	11.9 (2.58)	0.784	**<0.001**	0.802
	Post	13.6 (2.52)	13.6 (1.80)	12.0 (2.11)			
HNR	*Pre*	16.2 (2.70)	17.8 (2.40)	15.0 (3.36)	0.906	**0.002**	0.931
	Post	16.0 (3.34)	17.7(2.42)	15.4 (3.22)			
Shimmer local (%)	*Pre*	5.9 (1.85)	5.4 (2.03)	7.8 (2.84)	0.920	0.016	0.379
	Post	6.3 (2.28)	5.8 (3.22)	7.0 (3.00)			
Shimmer local dB	*Pre*	0.5 (0.13)	0.5 (0.10)	0.7 (0.23)	0.908	**<0.001**	0.426
	Post	0.6 (0.16)	0.5 (0.17)	0.7 (0.24)			
Slope of the LTAS	*Pre*	−17.3 (3.83)	−18.0 (6.17)	−17.7 (4.64)	0.244	0.146	0.392
	Post	−16.2 (3.69)	−18.2 (5.17)	−17.1 (4.96)			
Tilt of trendline through LTAS	*Pre*	−10.2 (0.93)	−10.3 (1.42)	−10.4 (1.01)	0.693	0.801	0.439
	Post	−10.4 (0.87)	−10.1 (1.35)	−10.5 (0.79)			

Abbreviations: AVQI, Acoustic Voice Quality Index; CPPS, cepstral peak prominence; DSI, Dysphonia Severity Index; f_o, fundamental frequency; F_{low}, lowest fundamental frequency; F_{high}, highest fundamental frequency; I_{low}, lowest intensity; I_{high}, highest intensity; LTAS, long-term average spectrum.; MPT, Maximum Phonation Time; ppq, period perturbation quotient.
To compensate for inflated type 1 errors, an adjusted α (=0.01) was included.

Vocal quality in professional and non-professional actors and professional dancers: group comparisons

Objective measurements

For every speech sample the signal-to-noise ratio (SNR) was measured. Samples with a SNR below 20, were excluded (*n* = 1). Excluding one male professional with this reason, voice samples of 62 participants were analyzed. Descriptive statistics and adjusted p values are reported in Table 2. Age and sex are added in the model as covariates. Comparing the vocal quality between the different groups, female professional actors show significantly lower f_o values than female non-professional actors before and after the performance (resp. $P = 0.002$ and $P = 0.001$), significantly lower F_{low} values than non-professional actors and professional dancers (PA – NPA: $P < 0.001$ before the performance and $P = 0.001$ after the performance, PA – PD: $P = 0.009$ before the performance and $P = 0.001$ after the performance), significantly higher F_{high} values than non-professional actors after the performance ($P = 0.004$) and a significantly larger fundamental frequency range than non-professional actors ($P = 0.002$ after the performance). MPT values are significantly longer for female professional actors compared to non-professionals and professional dancers (PA – NPA: $P < 0.001$ before and after the performance, PA – PD: $P = 0.006$ after the performance). The mean DSI is not significantly different between the three groups. Professional dancers have significantly higher AVQI scores compared with actors ($P = 0.001$ before the performance and $P = 0.002$ after). These results are reflected in the following AVQI parameters: CPPS (PD – PA: $P = 0.002$ before the performance and $P = 0.001$ after, PD – NPA: $P = 0.007$ after the performance), HNR (PD – NPA: $P = 0.005$), and shimmer local dB (PD – NPA: $P < 0.001$ before the performance, PD – NPA: $P = 0.002$ after). Main effect p values for null findings are reported in Table 2 as well.

TABLE 3.
Perceptual Evaluation Using the GRBASI Scale: Descriptive Statistics and *P* Values

		Professional Actors		Non-professional Actors		Professional Dancers			
		Mean (SD)	*P* Value	Mean (SD)	*P* Value	Mean (SD)	*P* Value	*P* Value (Between Groups)	Cohen's Kappa
Grade (G)	*Pre*	0.0 (0.19)	1.000	0.1 (0.32)	0.317	0.1 (0.35)	1.000	0.505	0.572
	Post	0.0 (0.19)		0.1 (0.23)		0.1 (0.34)			0.384
Roughness (R)	*Pre*	0.3 (0.56)	1.000	0.1 (0.23)	0.157	0.3 (0.49)	0.083	0.088	0.642
	Post	0.3 (0.48)		0.2 (0.38)		0.1 (0.34)			0.823
Breathiness (B)	*Pre*	0.3 (0.47)	0.705	0.2 (0.38)	0.180	0.3 (0.62)	0.317	0.548	0.719
	Post	0.3 (0.48)		0.3 (0.48)		0.3 (0.45)			0.669
Asthenicity (A)	*Pre*	0.0 (0.19)	0.317	0.1 (0.23)	0.564	0.0 (0.00)	0.157	0.688	0.651
	Post	0.0 (0.00)		0.1 (0.32)		0.1 (0.34)			0.651
Strain (S)	*Pre*	0.0 (0.00)	1.000	0.1 (0.32)	0.317	0.1 (0.35)	0.317	0.178	0.651
	Post	0.0 (0.00)		0.1 (0.23)		0.1 (0.25)			1.000
Instability (I)	*Pre*	0.0 (0.00)	1.000	0.1 (0.32)	0.317	0.0 (0.00)	1.000	0.106	0.659
	Post	0.0 (0.00)		0.1 (0.23)		0.0 (0.00)			1.000

Subjective measurements

Table 3 displays the results of the auditory-perceptual evaluation using the GRBASI scale. There are no significant differences in pre measurements between the three groups. Cohen's Kappa was implemented to measure the inter-investigator reliability of the auditory-perceptual evaluation (GRBASI), which can be found in Table 3 as well. Most of the Kappa values are substantial until almost perfect agreements. However there is one parameter, Grade (post), which shows a fair agreement.

In comparison with non-professional actors and professional dancers, professional actors are more deprived of sleep (frequently: PA 37%, NPA 26%, PD 20%) and drink more alcohol in general (frequently: PA 63%, NPA 47%, PD 21%). Professional actors smoke more than non-professional (yes: PA 33%; NPA: 10%), although these results did not differ significantly.

Actors talk, shout, cry, laugh and perform imitations significantly more than dancers ($P < 0.001$). Twenty-two percent of the professional actors never perform vocal warm-up exercises and 22% do it frequently, whereas 32% of non-professional actors never perform vocal warm-up and 10% do it frequently. Seven per cent of the professionals and 5% of the non-professionals do vocal cool-down exercises sometimes after a performance. None of the dancers does vocal warm-ups or vocal cool-downs. These results are displayed in Table 4.

TABLE 4.
Voice Influencing Factors: Descriptive Statistics and *P* Values

		Professional Actors %	Non-professional Actors %	Professional Dancers %	Professional Dancers *P* Value (Between Groups)
Fatigue/sleep deprivation	*Hardly*	11.1	5.3	33.3	0.213
	Sometimes	51.9	68.4	46.7	
	Frequently	37.0	26.3	20.0	
Smoking in general	*No*	44.4	78.9	46.7	0.107
	Passive	0.0	5.3	6.7	
	Previously	22.2	5.3	13.3	
	Yes	33.3	10.5	33.3	
Alcohol in general	*Hardly*	3.7	15.8	28.6	0.065
	Sometimes	33.3	36.8	50.0	
	Frequently	63.0	47.4	21.4	
Stress	*Hardly*	3.7	5.3	6.7	0.459
	Sometimes	59.3	57.9	80.0	
	Frequently	37.0	36.8	13.3	
Talking continuously and for a long time during performance	*No*	23.1	29.4	100.0	**<0.001**
	Yes	76.9	70.6	0.0	
Shouting during performance	*No*	19.2	11.8	100.0	**<0.001**
	Yes	80.8	88.2	0.0	
Whispering during performance	*No*	61.5	76.5	100.0	0.222
	Yes	38.5	23.5	0.0	
Crying during performance	*No*	40.0	29.4	100.0	**<0.001**
	Yes	60.0	70.6	0.0	
Laughing during performance	*No*	7.7	17.6	100.0	**<0.001**
	Yes	92.3	82.4	0.0	
Coughing during performance	*No*	76.9	52.9	100.0	0.110
	Yes	23.1	47.1	0.0	
Imitations during performance	*No*	34.6	76.5	100.0	**<0.001**
	Yes	65.4	23.5	0.0	
Vocal warm-up	*No*	22.2	31.6	100.0	**<0.001**
	Sometimes	55.6	57.9	0.0	
	Frequently	22.2	10.5	0.0	
Vocal cool-down	*No*	92.6	94.7	100.0	0.783
	Sometimes	7.4	5.3	0.0	
	Frequently	0.0	0.0	0.0	

To compensate for inflated type 1 errors, an adjusted α (=0.01) was included.

Descriptive statistics and adjusted p values for the VHI, VTDS and CPS can be found in Table 5. The majority of the subjects perceive no problems before and after the performance, which results in a VHI total score below 20. Scores below 20 are within normal limits. Although there a 6 professional actors, 6 non-professional actors and 3 professional dancers that report a mild voice disability before the performance. After the performance, still 3 professional actors, 6 non-professional actors and 0 professional dancers state having a mild voice disability. CPS intensity results are significantly higher for dancers compared to professional actors ($P = 0.010$). No significant results were found for the VTDS. These null findings are reported in the Table 5.

TABLE 5.
Self-evaluation Questionnaires: Descriptive Statistics and *P* Values

			Professional Actors	Non-professional Actors	Professional Dancers	Main Effects (Adjusted)		
			Mean (SD)	Mean (SD)	Mean (SD)	Time	Group	Time x group
	VHI	*Pre*	12.9 (7.93)	14.2 (8.92)	12.5 (9.02)	0.085	0.191	0.070
		Post	11.9 (8.56)	16.1 (11.59)	6.9 (6.75)			
VTDS	Frequency	*Pre*	9.7 (5.00)	9.6 (7.02)	9.7 (7.42)	0.483	0.073	0.319
		Post	10.2 (4.71)	10.7 (7.33)	7.1 (6.25)			
	Intensity	*Pre*	13.4 (6.99)	11.7 (8.25)	13.9 (11.23)	0.496	0.068	0.826
		Post	13.3 (6.88)	12.4 (7.27)	12.4 (11.67)			
CPS	Frequency	*Pre*	8.1 (3.97)	8.7 (4.68)	9.5 (3.89)	0.213	0.384	0.758
		Post	8.4 (3.94)	8.3 (4.06)	7.9 (4.37)			
	Intensity	*Pre*	21.8 (11.99)	26.3 (12.01)	27.9 (15.51)	0.121	**0.009**	0.516
		Post	21.3 (12.00)	26.1 (13.51)	22.9 (13.35)			

Abbreviations: CPS, Corporal Pain Scale; VHI, Voice Handicap Index; VTDS, Vocal Tract Discomfort Scale.
To compensate for inflated type 1 errors, an adjusted α (=0.01) was included.

Impact of performance on the voice

Objective measurements

Considering the impact of a performance within and between the three groups, no significant measurements were detected.

Subjective measurements

The GRBASI-scores before and after the performance do not differ significantly within the three groups. No other significant differences are identified while analyzing the impact within and between the groups.

DISCUSSION

The study aimed to examine the vocal quality in professional and non-professional theater actors in comparison with a control group of professional dancers. As would be expected, several subject characteristics differed significantly. Non-professional actors have fewer rehearsals and performances than professionals, and dancers' performances are shorter than actors'. Furthermore, dancers experience less vocal load during their performances than actors. When analyzing the results, significant differences in multiple vocal parameters are found among the three groups.

Firstly, female professional actors show significantly lower fundamental frequencies (f_o) than female non-professional actors. This may be the result of shorter, thicker, and more relaxed vocal folds, generating less intense glottal adduction.[65] It confirms that professional actors have a more favorable glottal setting.[8] Although there is a significant age difference between the groups, age would not be a possible explanation for this finding because age was added as a covariate in our statistical model. Secondly, female professional actors have lower lowest fundamental frequencies than non-professional actors and professional dancers. They also show a higher highest fundamental frequency than non-professional actors, causing a wider overall fundamental frequency range. These fundamental frequency range capacities suggest that professional actors have more refined vocal capacities and have better control over their voices.

Moreover, maximum phonation time (MPT) is significantly longer in professional actors compared to non-professional actors and professional dancers. Feudo, Harvey[66] indicated that actors with training achieve longer MPT values. Consequently, as the MPT and the highest fundamental frequency are two of the DSI's parameters, professional actors have better DSI values than non-professional actors and professional dancers. Higher mean DSI scores reflect more excellent vocal capacities in professional actors. It is stated by other authors that elite vocal performers have better control over their voices.[67]

Remarkably, only the non-professional actors show a mean pre AVQI score below the cut-off point of 2.91. The professional actors and dancers have mean scores above the cut-off point, correlating with mild dysphonia. A possible explanation for the professional actors' mild dysphonia might be their rather poor vocal habits such as smoking and drinking, or the fact that they experience a lot of vocal load during the performances such as shouting, crying, laughing, or imitations. This finding about professional actors affirms previous research.[6] Dancers on the other hand did not receive any professional voice training and might use their voice badly. Comparing the AVQI scores between the groups, professional dancers show significantly poorer AVQI scores than actors. This is exposed in their CPPS, HNR and shimmer local dB values. A study by Heman-Ackah, Michael[68] reports that lower CPPS correlates with breathiness and hoarseness in general.68, 69, 70, 71 Furthermore, lower HNR values and higher shimmer local dB values result in higher AVQI values.[50] In a study by Ramel and Moritz,[72] 66% of professional dancers reported experiencing muscular tension such as tightening the jaws. Misuse of the muscles used in phonation, including muscles of the larynx, pharynx, jaw, tongue, neck, and respiratory system, can contribute to incorrect vocal use.[73] Additional to the previous statement about dancers lacking vocal knowledge and vocal education, it might be possible that due to their muscular tension, it might have an effect on the voice as well. Future research should include endoscopic data to support this statement. Auditory-perceptual evaluation (GRBASI scale) indicates no significant differences between the three groups.

VHI scores, measuring psychosocial impact on the vocal quality, display no significant differences among the groups either. The question arises whether the VHI is relevant for actors and dancers as all mean scores were below 20, which corresponds with the absence of a voice handicap. It is possible that this scale is not sensitive enough for this specific group of elite vocal performers.[6] Considering the CPS, intensity measurements show higher values for dancers compared to professional actors. Intensive physical activities performed by dancers might have caused this difference. It is possible that this physical exhaustion can lead to a general fatigue in the whole body.

The second purpose of the study was to examine the impact of a single performance on the vocal quality of professional and non-professional actors in comparison with professional dancers. Objective evaluations show that the overall vocal quality measured with multiparameter indices DSI and AVQI does not change after the performance. This is in accordance with the findings of D'haeseleer, Meerschman,[6] Ferrone, Leung[20] and Novak, Dlouha.[18] It should be mentioned that no full Voice Range Profile was measured during this study. Participants were merely instructed to reach their highest/lowest fundamental frequency and softest/loudest intensity by producing a glissando. The best result was selected out of three different tokens. D'haeseleer, Meerschman[6] discovered a trend of an increased fundamental frequency in 26 professional theater actors after a single performance. They related this increase to a vocal warm-up effect. In this study the same trend is revealed. The mean fundamental frequencies in both actor groups show higher f_o after the performance, although these differences were not significant. A possible explanation might be that a performance can have a similar effect on the voice as vocal warm-up. The GRBASI scale demonstrates no significant differences before and after the performance in the three groups. This contradicts the findings of D'haeseleer, Meerschman,[6] who proved a subtle amelioration in overall grade (G) after the performance.

Comparing the three standardized questionnaires, no significant differences were detected in the VHI, VTDS and CPS results. Although dancers encounter more physical pain than actors at the pre performance measurements, their complaints, which could be caused by previous performances and physical exercises, do not significantly deteriorate after a single performance. The absence of similar changes in actors can be due to a lower level of physical efforts during performing, compared to dancers.

Taking these observations into account, there is no direct impact of a single performance on the objective and subjective vocal quality, even though the actors were exposed to vocal abuse during performing. Furthermore, this study did not reveal any influence of vocal load, physical effort or external factors such as stress on the vocal quality after a single performance. However, good coping behavior of the subjects can be an underlying cause of the non-observed impact of stress.[3]

Self-evaluation questionnaires about the patient's history show that professional actors may have an overall extrovert lifestyle which is reflected in their vocal habits and general health. These results are similar to the conclusions of the studies by D'haeseleer, Meerschman,[6] Timmermans, De Bodt[2] and Martin and Battaglini.[74] Acknowledging the percentages in Table 4, it seems that professional actors drink more alcohol, smoke more and are more deprived of sleep than non-professional actors. In a study by Brodsky,[75] roughly 45% of professional actors reported tobacco use and Gehling, Sridharan,[32] Maxwell, Seton,[76] Brener, Billy[77] and Gajewski and Poznańska[78] stated that alcohol use was higher in the group of professional actors compared to non-professional actors. Martin and Battaglini[74] reported that the high levels of alcohol and tobacco use might be associated with a coping strategy to several physical burdens as well as psychological burdens, which might be caused by work-related problems such as pressure of expectation and performance, castings or examinations, lack of self-confidence, and fear of the future.[77, 79] Additionally, smoking cigarettes can be presumed as stress relieving behavior.[80] The difference of smoking prevalence between professional and non-professional actors could be related to the significant age gap. In the literature, a decline of 14% in smoking prevalence between 2006 and 2014 has been reported.[81] Therefore, it might be possible that the smoking habit of professional actors would be associated with a generational trend. An extroverted, sociable, more risk-taking and sensation-seeking lifestyle was described in the study by Marchant-Haycox and Wilson.[82] Whether the findings in this study correspond with the aforementioned lifestyle is subject for further research. The questionnaires reveal more vocal abuse during the performance such as shouting, talking a lot, crying, laughing and imitations. Hypothetically, dancers are more disciplined, achievement-oriented and conscious about their body and general health,[82] which declares the obtained results.

One out of five professional actors and one out of three non-professional actors never do vocal warm-up exercises before a performance in general. Only one out of five professional actors and one out of ten non-professional actors reports to do it frequently. These findings are not reflected in the study by D'haeseleer, Meerschman.[6] It is stated by several authors that vocal warm-up exercises prevent vocal injury and prepare the actor for the vocal activity.[8, 84, 85, 86] In this study, few subjects reported use of vocal cool-down exercises, which in general is less common.[6, 86]

Despite being a unique study in Belgium, it has some limitations and weaknesses. Firstly, the significant age gap between professional actors and non-professional actors and professional dancers could be avoided during the search of participants. This limited the study in matching the actors with the dancers to eliminate factors such as sex and age. Future research can include older non-professional actors to avoid this limitation. Secondly, stress, time pressure and an extensive voice assessment protocol before and after the performance could have induced that the participants sometimes did not fully complete the whole questionnaire. It should be mentioned that the time elapsed between the pre recording and the performance is not the same as the time between the performance and post recording (30 versus 10 minutes). Actors usually needed time to prepare their show and were therefore unable to perform the test at a later time. A third limitation is the diverse test environment. Before every analysis of the samples, a quality control of the recordings was performed. Recordings with bad signal-to-noise ratio were excluded (n = 1). Nevertheless, there could be a little impact of noise and the acoustically not favorable test setting on the objective measurements.[28] In a future study design the long-term impact of a series of performances could be investigated as well.

CONCLUSION

Comparing the vocal quality between professional actors, non-professional actors and professional dancers, professional actors have better scores on the fundamental frequency measurements, compared to non-professional actors and dancers, showing more refined vocal capacities. Professional dancers on the other hand show worse AVQI scores than non-professional actors. A significant impact of a single performance was nonexistent within the three groups. Hence, neither vocal load, stress or physical effort change the vocal quality after a single performance. Whether these factors have a long-term influence is subject for further research. Finally, the results showed poor vocal habits in professional theater actors, which emphasizes the importance of vocal education.

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