Real-Time Visual Feedback of Airflow in Voice Training: Aerodynamic Properties of Two Flow Ball Devices

*,†Filipa M.B. Lã, ‡Greta Wistbacka, §Pedro Amarante Andrade, and ¶,**Svante Granqvist, *†Coimbra, Portugal, ‡Turku, Finland, §Plymouth, UK, and ¶ and **Stockholm, Sweden

Summary: Objectives. Flow ball devices have been used as teaching tools to provide visual real-time feedback of airflow during singing. This study aims at exploring static back pressure and ball height as function of flow for two devices, marketed as flow ball and floating ball game.

Study Design. This is a comparative descriptive study.

Methods. A flow-driven vocal tract simulator was used to investigate the aerodynamic properties of these two devices, testing them for four different ball sizes. The flow range investigated was between 0 and 0.5 L/s. Audio, flow, pressure, and ball height were recorded.

Results. The flow pressure profiles for both tested devices were similar to those observed in previous studies on narrow tubes. For lifting the ball, both devices had a flow and a pressure threshold. The tested floating ball game required considerably higher back pressure for a given flow as compared with the flow ball.

Conclusions. Both tested devices have similar effects on back pressure as straws of 3.7 and 3.0 mm in diameter for the flow ball and the floating ball game, respectively. One might argue that both devices could be used as tools for practicing semi-occluded vocal tract exercises, with the additional benefit of providing real-time visual feedback of airflow during phonation. The flow threshold, combined with the flow feedback, would increase awareness of flow, rather than of pressure, during exercises using a flow ball device.

Key Words: Flow ball–Floating ball game–Real-time visual feedback of airflow–Semi-occluded vocal tract–Voice training.

INTRODUCTION

Phonation into narrow tubes has been substantially used in voice training. For example, resistant straws have been used to promote vocal economy, ie, the production of normal vocal intensity with less mechanical trauma to the vocal folds' tissues. Previous investigations have suggested that such effect is achieved by engaging the vocal tract to transforming aerodynamic energy into acoustic energy by means of a back pressure created when phonating into a narrow tube.[1] Glass tubes submerged in water have also been applied in clinics to treat, for example, hypernasality, hypo- and hyper-phonation, and vocal nodules.[2] Although not yet described in the literature, there are other types of devices that can be explored as tools to train efficient voice use. For example, the flow ball (FB) is a device available for respiratory training. This type of device is claimed to be beneficial for respiratory training, especially for wind instrumentalists and singers.[a,b] Different devices can be found in the market. They contain a squared plastic tube that connects to a plastic basket with a narrow passage. The latter has a hole in the middle through which air passes when exhaling through the device, lifting a small polystyrene ball that comes with it. Other devices can be found in early learning centers, referred to as floating ball games (FBG) (Figure 1).

The use of the FB as a voice training device was implemented for the first time in singing lessons by author FL several years ago. This idea emerged from the fact that this device could facilitate the visualization of flow via inspecting the ball height when phonating. Simultaneously, it also provides the potential effect of a semi-occlusion of the vocal tract. Students practicing with it realize the easiness of phonation when changing airflow according to the frequency and the intensity of each note in an exercise or when singing a musical phrase. This visualization of breath management (ie, *appoggio*)[3] is of paramount importance for a classical trained singing to avoid timbre changes associated with pressed phonation, especially when singing fortissimo. Classically trained singers are expected to be able to change frequency and intensity of tones keeping the same phonation mode. Pressed phonation involves a high adduction force, and consequently low flow amplitudes, ending in greater vocal effort when compared with flow phonation.[4] The latter promotes vocal economy as an increased acoustic output is achieved with lower subglottal pressure (P_{sub}) and a more moderate adduction.[4] Adding to FL's anecdotal experience results of a preliminary investigation on the effects of FB use on voice revealed a decrease in contact quotient immediately after its use for professional singers performing a *messa di voce* at different pitches.[5] Positive experiences have also been reported by singing students using the FB as a respiratory exercising tool and as a phonatory training device.[5] Instructions on its use include the following: (1) holding the proximal end firmly between the lips while phonating into the tube; and (2) maintaining control of

Accepted for publication September 23, 2016.

From the *Center for Social Sciences, University of Coimbra, Portugal; †Institute of Interdisciplinary Research, University of Coimbra, Portugal; ‡Faculty of Arts, Psychology and Theology, Abo Akademi University, Turku, Finland; §Faculty of Culture and Language Sciences, University of St Mark & St John, UK; ¶Division of Speech and Language Pathology, Department of Clinical Science, Intervention and Technology (CLINTEC), Karolinska Institutet (KI), Stockholm, Sweden; and the **Basic Science and Biomedicine, School of Technology and Health (STH), Royal Institute of Technology (KTH), Stockholm, Sweden.

Address correspondence and reprint requests to Filipa M.B. Lã, Centre for Social Sciences, University of Coimbra, Largo D. Dinis, Apartado 3087, 3000-995 Coimbra, Portugal. E-mail: filipala@ces.uc.pt

[a] http://www.thomann.de/intl/thomann_flowball.htm?sid=2df448726396b313dfcd22787ec1f2d4 (accessed July 12, 2016, 16: 51).

[b] http://www.powerbreathe.com/flowball-blue (accessed July 12, 2016, 16:51).

Journal of Voice, Vol. ■■, No. ■■, pp. ■■-■■
0892-1997
Published by Elsevier Inc. on behalf of The Voice Foundation.
http://dx.doi.org/10.1016/j.jvoice.2016.09.024

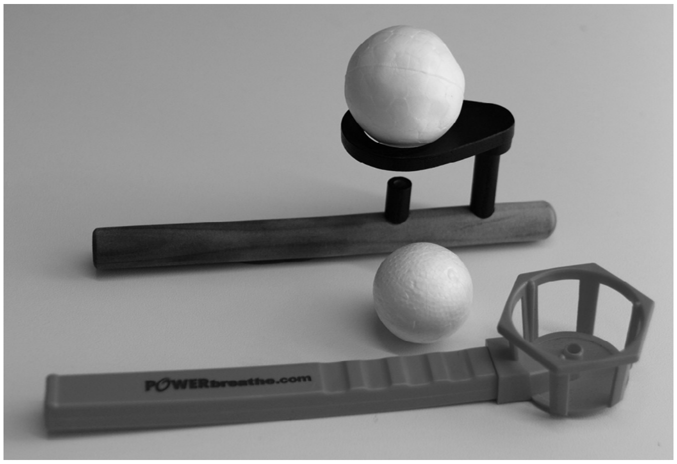

FIGURE 1. The two flow ball devices tested in this study: the floating ball game model (*top*) and the flow ball model (*bottom*).

breath and phonation so that the ball is kept in the airstream while phonating. This is possible as the ball stays near the center of the airstream due to the pressure being the lowest where the air speed is the highest (ie, Bernoulli effect).

The results of previous studies suggest that the provision of meaningful and quantitative feedback in a singing lesson encourages the development of consistent subsequent repetitions of the same neuromotor behavior, ie, "Knowledge of Results."[6] Misunderstanding of the information prior to and after providing feedback might be avoided if the feedback is immediate.[6] Moreover, phonation habits seem to change quicker in a singing lesson when using visual feedback (eg, electrolaryngographic displays) together with verbal instructions.[7,8] Visual feedback also assists in the development of student's independence, self-correction, self-evaluation, and appraisal skills, promoting cognitive and associative stages of learning.[9]

Finally, the FB might also add the benefits of a semi-occluded vocal tract, as phonation into a narrow tube is required. As suggested earlier, phonation into narrow tubes increases the static back pressure (P_{back}) (ie, analogous to intraoral pressure) in the vocal tract for a given flow.[10] These authors measured the back pressure–flow (P_{back}–U) relationship for different tube lengths and diameters commonly used in voice training, concluding that a change in tube diameter would affect the flow resistance more than a corresponding relative change in tube length. This has later been confirmed by Smith and Titze, who based on flow theory and empirical data suggested two models for the pressure–flow relationship.[11]

This paper aims at exploring the physical properties of two different flow ball devices, the FB and the FBG, in terms of relationships among P_{back}, air flow (U), and ball height (h_B).

METHODS

The flow ball (FB)

For the purposes of this experiment, two flow ball devices were investigated. The first device, FB, consisted of a 140-mm long tube with a rectangular cross section of 7 × 10 mm. A basket with a narrow, upward facing opening of 3.9 mm in diameter[12] was attached to the tube. The device was supplied with a polystyrene ball of Ø 29 mm (Figure 2).

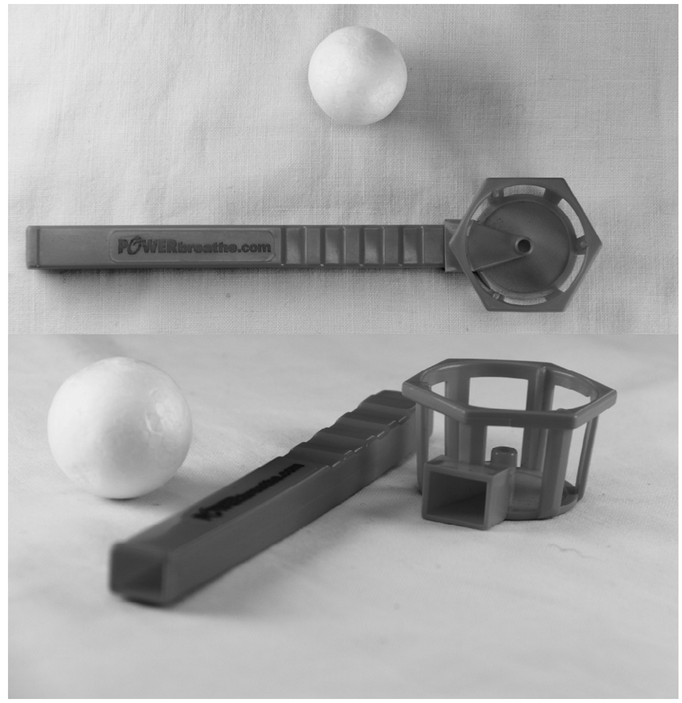

FIGURE 2. The flow ball device and its constituting parts (by POWERBreathe©).

The floating ball game (FBG)

Another device was tested, the FBG made of wood. With a total length of 147 mm, this device had an inner longitudinal tube with Ø 7 mm. At a distance of 95 mm along the length of this tube, a smaller tube with 20 mm length and 3.5 mm inner Ø was inserted perpendicularly. In this particular tested specimen, the smaller tube was inserted deep into the tunnel so that it created a narrow passage between the two attached tubes. On the wood shaft, there was a ring also made of wood where the ball was placed. The FBG was provided by a polystyrene ball of Ø 34.5 mm (Figure 3).

Experimental setting

The P_{back}–U characteristics of these flow ball devices were measured with a flow-driven vocal tract simulator similar to the one used in a previous study.[6] A ruler was kept next to the devices during video recordings in order to calibrate h_B. An air pressure of approximately 100 kPa was supplied from a pressurized air cylinder to a mass flow controller (Alicat Scientific Model MCR-50SLPM-TFT), connected to a 60-mL size syringe set with an inner cavity volume of 36 mL.[6] A pressure transducer (8-SOP MPXV7007DP-ND NXP Freescale Semiconductor, Petaling by Digi-Key Electronics, UK)[c] was attached to the syringe and FB and FBG were placed at the end, sealed with plasticine. A representation of this experimental setting is shown in Figure 4.

[c]http://www.digikey.co.uk/en/supplier-centers/n/nxp-semiconductors.

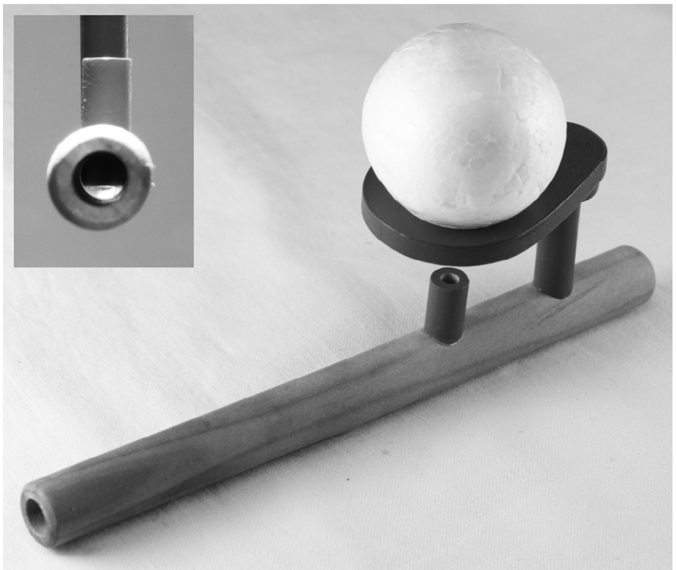

FIGURE 3. The floating ball game device and its constituting parts. The narrow constriction at the connection between the two tubes can be visualized by a strong light from above (*upper left image*).

TABLE 1.
Sizes and Weights of the Balls Tested in This Study

Ball Number	Diameter (mm)	Weight (g)	Density (g/cm^3)
1	29.0	0.304	0.0461
2	34.5	0.347	0.0371
3	37.2	0.652	0.0600
4	48.1	1.595	0.0878

Balls # 1 and #2 were supplied with the flow ball and the floating ball game, respectively.

Recordings and analysis

The experiments were recorded using a Canon (Canon, Tokyo, Japan) 700D digital camcorder with a Canon EF-S 18–200 mm lens. Video recordings of h_B were carried out at a rate of 25 frames per second, at a resolution of 1920×1088 pixels. In order to determine the range for h_B to be recorded, typical singing exercises with the FB device were performed by author FL prior to the experiments. A range of h_B of 2–7 cm was used to determine the range of U needed.

Audio, U, and P_{back} signals were recorded at a sampling rate of 16 kHz using the Soundswell signal workstation (Version 4.00 Build 4003, Core 4.0, Hitech Development AB, Stockholm, Sweden) and a DSP board (Loughborough Sound Images plc, Loughborough, UK) allowing DC input. The transducer for P_{back} was calibrated using a U-tube manometer. A visible clap of the hands was used to synchronize audio, U, and P_{back} with the video. The audio was also recorded for documentation purposes. Based on the h_B observed in the singing exercises, a U range of 0–0.5 L/s was used. This was supplied over 90 seconds by the custom-made software *Mjau* (by author SG).

The h_B was measured from the digital video recording using a *Matlab* (Mathworks, Natick, Massachusetts, USA) script. An area of the video containing only the ball and the neutral background was selected. The top edge of the ball was detected by looking for the increased pixel brightness caused by the white ball. Also, two positions on the ruler were associated with pixels in the video, enabling absolute calibration of h_B. This procedure resulted in 25 measurements per second of h_B.

The P_{back} and U signals were calibrated and down-sampled to 25 Hz using the custom-made *Sopran* software (by author SG) and synchronized with the h_B measurement. Thus, the experiment resulted in a data file at 25 Hz sampling rate, with channels containing U, P_{back}, and h_B. The signals were low-pass filtered to smooth the graphs plotted using *Matlab*.

This procedure was performed for the recordings of the two devices tested with four balls of different sizes (Table 1), as well as for recordings made without the balls. When recording the P_{back}–U characteristics without the ball, the experiments were not video-recorded. Although the balls that originally come with the devices are similar in shape and size, four different ball sizes were tested as they might be replaced by other sizes when the original ones are damaged or lost. In addition, singing teachers might want to change P_{back} and U relationships using the same device, thus using different ball sizes to achieve such combinations.

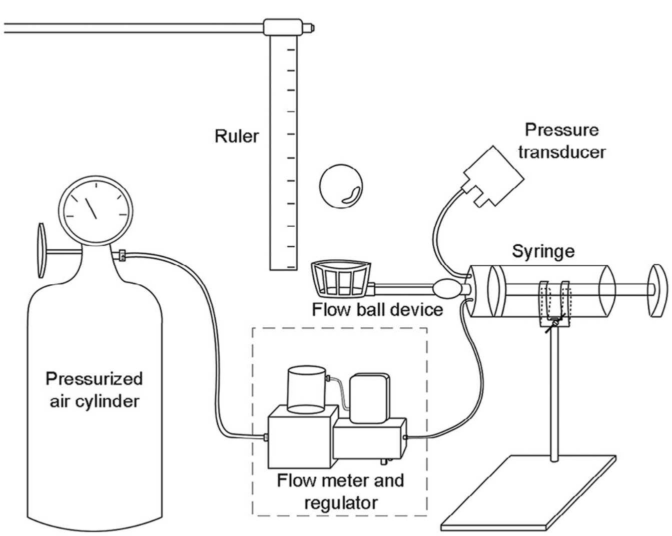

FIGURE 4. Schematic representation of the experimental setup.

Straw dimension adaptations

The P_{back}–U relationship appeared to be similar to that of a straw; thus, adaptations to the Smith and Titze's basic flow model (Equation 1) and modified flow model (Equation 2) were attempted to compute equivalent straw diameters and lengths. For these adaptations, both the solver add-in in *Microsoft Excel* (2010, Albuquerquer, New Mexico, USA) and a brute force method implemented in *Matlab* were tested.

$$p_{back} = \left(1.446 \cdot 10^{-6} \cdot \frac{\rho}{D^4}\right)U^2 + \left(0.1752 \cdot \frac{\mu L}{D^4}\right)U \qquad (1)$$

$$p_{back} = \left(3.7631 \cdot 10^{-7} \cdot \frac{L}{D^{4.4997}} + 1.0268 \cdot 10^{-6} \cdot \frac{1}{D^{4.0416}}\right) U^2 + \left(3.9913 \cdot 10^{-9} \cdot \frac{L}{D^{5.0089}} + 8.0169 \cdot 10^{-7} \cdot \frac{1}{D^{3.7696}}\right) U \quad (2)$$

where P_{back} is the flow-dependent back pressure from the tube in Pa, ρ is the density of air (1.225 kg/m^3), D is the tube diameter in m, U is the flow in L/s, μ is the dynamic viscosity of air ($1.983 \cdot 10^{-5}$ Pa·s), and L is the length of the tube in m.

RESULTS

The FB

Figure 5 shows the results for the FB with all balls tested. A P_{back}–U relationship similar to that of the FB without the ball was found when adding all balls, except for the range between 0 and 0.1 L/s for the smallest ball. With respect to this ball, it stayed in the basket covering the hole until 0.1 L/s where it started to bounce. At 0.2 L/s, it started to lift off. For higher flows, the h_B seemed to increase linearly with U, reaching 10 cm at 0.4 L/s. Another way of looking at the results is considering how the h_B depends on the P_{back}; about 5 cmH$_2$O was required for the ball to lift off. However, the relationship between h_B and P_{back} did not appear to be linear.

For ball #2, the results were almost identical, the main difference being the absence of the hump in the P_{back}–U profile. For the considerably larger ball, ball #3, the threshold for lift off was increased to about 0.3 L/s and 10 cmH$_2$O. For ball #4, lift off occurred beyond 0.5 L/s and a P_{back} of about 25 cmH$_2$O.

The FBG

Figure 6 shows the results for all balls tested using the FBG. No humps were found in the P_{back}–U profile for this device; the balls never covered the hole.

Considering ball #1, the h_B revealed a similar behavior as to the FB, but a slightly higher U was required for lift off: about 0.25 L/s. For higher U, the h_B appeared to relate linearly with increasing U. However, the P_{back} required for lift off was about 20 cmH$_2$O, hence four times higher than for the FB.

Ball #2 required a slightly higher U for lift off as compared with ball #1: about 0.27 L/s. A linear relationship between U and h_B was still observed. The P_{back}–h_B relationship for this ball revealed a threshold P_{back} of about 20 cmH$_2$O for lift off.

Ball #3 required high U and P_{back} for lift off: >0.4 L/s and 50 cmH$_2$O.

Ball #4 did not lift off for the flows used in this study.

While carrying out the recordings, a bouncing of the ball in the airstream was observed. When inspecting these oscillations closely, it was found that they occurred at a frequency of 1.5–2 Hz, as exemplified in Figure 7.

Straw dimension adaptations

When adapting the recorded data to the modified flow model provided by Smith and Titze, the *Excel* solver method did not converge to an optimum. The brute force method implemented in *Matlab* found an optimum match for a straw with a negative length, which is of course unrealistic. Using the basic flow model, *Excel* and *Matlab* provided nearly identical optima and resulted in a positive straw length. The predictions of P_{back} by the basic model matched measured data with an average error of 0.14 and of 0.17 cmH$_2$O for the FB and FBG, respectively (Table 2).

Figure 8 compares the measured results for P_{back}–U relationships for both FB and FBG with no balls; the predictions were made applying the basic flow model.

DISCUSSION

The present investigation aimed at describing the physical properties of a device recently implemented in singing lessons. The

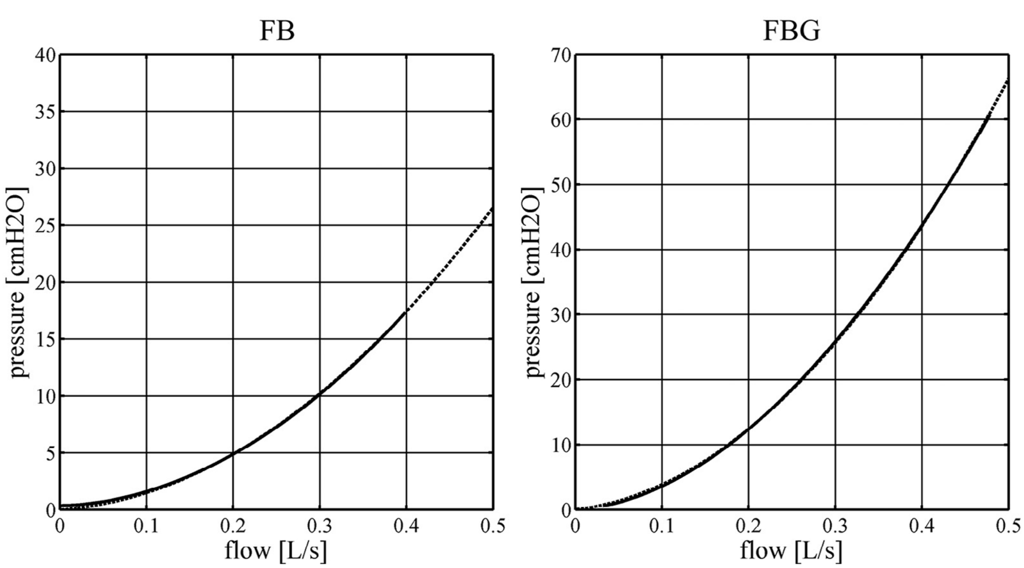

FIGURE 5. Back pressure and flow relationship for the flow ball (FB) and floating ball game (FBG) devices (*solid lines*) and for the adaptation of the basic flow model to the data represented in Table 2 (*dashed lines*).

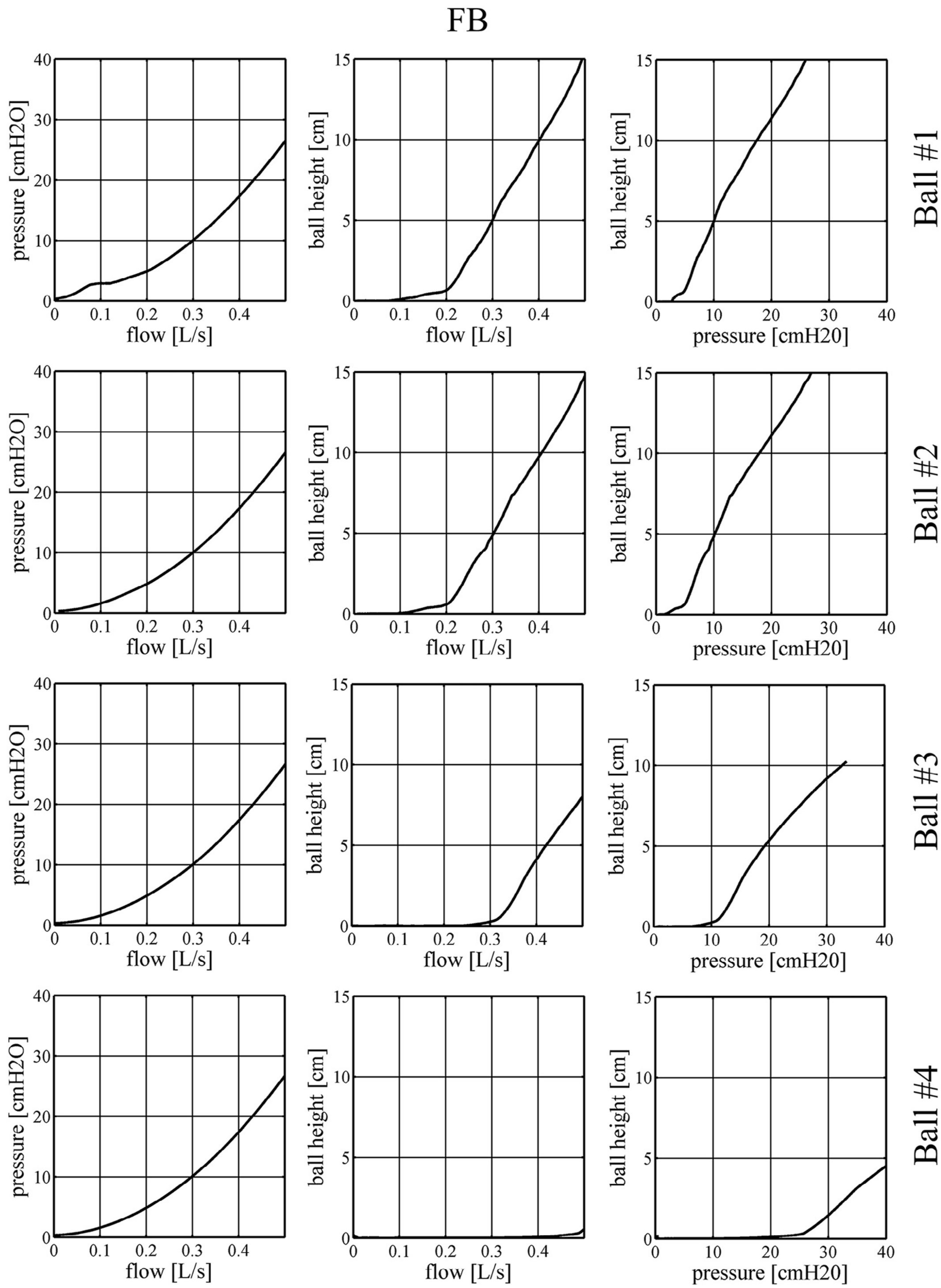

FIGURE 6. Results for the flow ball device (FB). The following relationships are represented for the four tested ball sizes: back pressure and flow (*left panel*), ball height and flow (*middle panel*), and back pressure and ball height (*right panel*).

FB and an FBG with four ball sizes were compared. Relationships among P_{back}, U, and h_B were investigated.

Both devices showed similar P_{back}–U profiles to that of a straw, although with different dimensions. Both FB and FBG had thresholds for the ball to lift off regarding U and P_{back}. The U thresholds were similar, but the P_{back} threshold for the FBG was considerably higher than for the FB. The FBG had a narrower opening, hence a P_{back}–U profile that resembles a considerably thinner straw. The FBG device provides an almost 2.6 times higher P_{back} as compared with the FB for the same U.

Previous studies on the effects of phonating into a glass tube and a stirring straw have found a decreased glottal adduction, presumably as a direct physiological result of the increased pressure in the vocal tract.[13] Increasing the oral pressure, maintaining P_{sub} and glottal resistance, would reduce the transglottal pressure and U. This would be true both for straws and for both FB

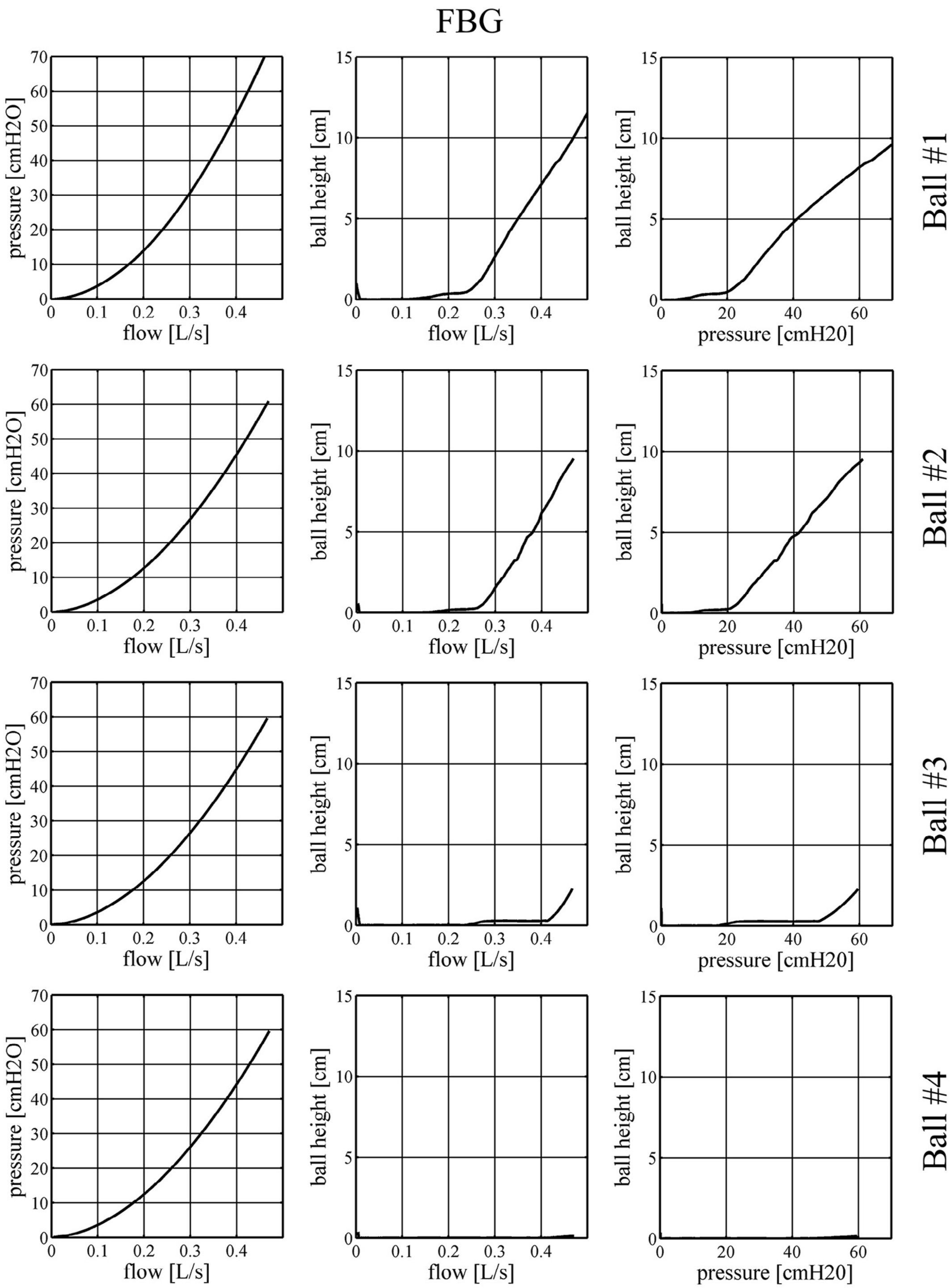

FIGURE 7. Results for the floating ball game device (FBG). The following relationships are represented for the four tested ball sizes: back pressure and flow (*left panel*), ball height and flow (*middle panel*), and back pressure and ball height (*right panel*).

and FBG due to their similar P_{back}–U profiles. However, the results of this and previous investigations[10] suggest that even small changes in tube diameter might have a considerable effect on P_{back}, emphasizing the need for awareness of the physiological effects of P_{back} during voice training.

The predictions of tube lengths based on the two flow models by Smith and Titze varied considerably.[11] It appears that although the models work well for predicting a P_{back} from tube dimensions, they are numerically ill-conditioned when applied backwards, ie, when trying to predict tube length from P_{back} data. It has been shown that a change in relative tube length affects the P_{back} to a much lesser degree than the corresponding relative change in tube diameter[10]; a relatively large change in tube length only affects the P_{back} slightly. When the P_{back}–U relationship is applied backwards, this results in a slight change in P_{back} data that may lead to a large change in the estimation of the tube

TABLE 2.
Estimated Diameters and Lengths for Straws With Equivalent Back Pressure and Flow Profiles to the Ones Found for the Flow Ball (FB) and the Floating Ball Game (FBG) Devices, Applying the Basic and the Modified Flow Models by Smith and Titze

	Basic Flow Model		Modified Flow Model	
Device	Diameter (mm)	Length (mm)	Diameter (mm)	Length (mm)
FB	3.7	31	2.7	–112
FBG	3.0	33	2.3	–85

Note the unrealistic negative lengths that resulted from applying the modified flow model.

length. With that in mind, the equivalent tube lengths found in this paper should be considered as rough estimations. It is true that a straw with the suggested dimensions will have a similar P_{back}–U profile as the flow ball devices, but other tube dimensions may also have similar profiles.

A finding from the video recordings was that the ball occasionally started to oscillate, sometimes at an amplitude so high that it fell out of the airstream. Looking closer at these oscillations, they occurred in the frequency range between 1 and 2 Hz. Thus, it appears as if the device with the ball in the air has similarities with a resonant system, with a resonant frequency near 1–2 Hz. If the singer would provide a flow with oscillations in this frequency range, corresponding to 60–120 BPM, these oscillations would be amplified and the ball could fall out of the airstream. One could argue that this property of the device would promote the use of a steady flow with a more legato-like phonation, eg, during *messa di voce* or arpeggio exercises.

The h_B provides visual feedback of the amount of airflow used. Thus, a flow ball device could be used as a U meter. Different

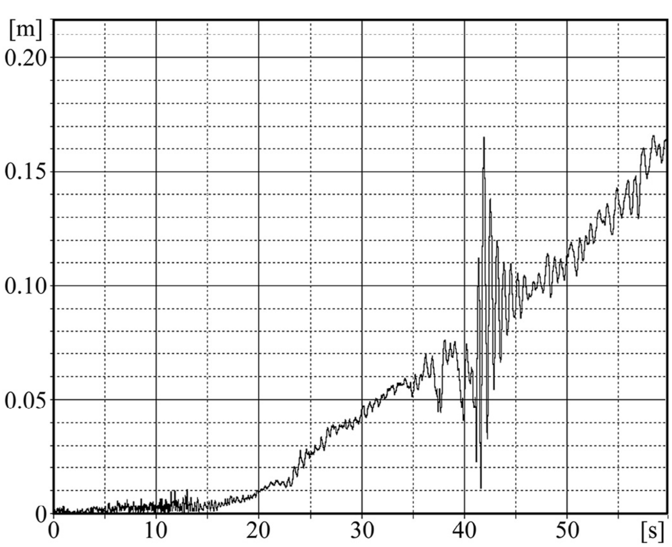

FIGURE 8. Graphic representation of the ball height as a function of time during one recording of the flow ball device with its supplied ball (ie, ball #1). At approximately 42 seconds, the ball height oscillates at a frequency of 1.6 Hz.

phonation types could be visualized through the amount of U the singer would apply. The h_B range of 0–10 cm for the FB would correspond to U of 0.2–0.4 L/s. It could be speculated what behavioral changes this might lead to. At a glottal level, high flow and low transglottal pressure correspond to a low flow resistance, ie, a small amount of adduction. Using the FB, the singer could choose between applying a high P_{sub} and using less adduction to achieve a sufficiently high U. The lift of the ball and its maintenance in the airstream could therefore encourage use of less adduction, promoting the awareness that pressure and flow are different dimensions that can be changed separately. From a pedagogical point of view, this seems also worthwhile because the student could be encouraged to explore the sensation of achieving maximum flow with a complete glottal closure. This type of phonation, ie, flow phonation, has been associated with an improved vocal function, as it requires lower P_{sub} and moderate degree of adduction force.[4,14]

Moreover, the combination of visual feedback with verbal instructions can assist both teacher and student in achieving a common vocabulary voided of multiple translations of sound quality into words.[15,16] Additionally, the different types of learners in a singing lesson (ie, intellectual, aural, kinesthetic, and visual) call for the need for applying different types of feedback and a teaching model distant from the "one model fits all."[17]

In summary, the results here discussed confirm that flow ball devices have a similar P_{back}–U profile as narrow tubes. However, when applied to singing lessons, the flow ball device provides visual real-time feedback of airflow during phonation.

CONCLUSIONS

The results of this study suggest that flow ball devices seem to be useful pedagogical tools for singing practice. On the one hand, they provide real-time visual feedback of airflow. The ball height can be used as an indication of the amount of airflow that is being used, an essential element in singing training. Flow phonation is the most advantageous phonation type in terms of ease of phonation, thus being emphasized when training voices.[18] In addition, as previous results have suggested, visual feedback (when combined with verbal feedback) might have a significant positive effect on student's development. It is, however, important to emphasize that different flow ball devices might have different lift off, flow/pressures, and aerodynamic properties. Therefore, it seems worthwhile to assess these characteristics before using them and to make sure that they correspond to the needs of the intended exercises.

Acknowledgments

FL would like to acknowledge the support from dept of Speech, Music and Hearing at KTH and also the Voice Foundation and the National Association of Teachers of Singing for the Van Lawrence Award in 2015, which made this collaborative research study possible.

REFERENCES

1. Titze IR. Voice training and therapy with a semi-occluded vocal tract: rationale and scientific underpinnings. *J Speech Lang Hear Res.* 2006;49:448–459.

2. Simberg S, Laine A. The resonance tube method in voice therapy: description and practical implementations. *Logoped Phoniatr Vocol*. 2007;32:165–170.
3. Lã FMB, Gill BP. Physiology and its impact on the performance of singing. In: Welch G, Howard D, Nix J, eds. *The Oxford Handbook of Singing*. Oxford: Oxford University Press; 2015:1–19. Vol Oxford Handbooks Online. Available at: http://www.oxfordhandbooks.com/view/10.1093/oxfordhb/9780199660773.001.0001/oxfordhb-9780199660773-e-23.
4. Sundberg J. *The Science of the Singing Voice*. Dekalb, Illinois: Northern Illinois University Press; 1987.
5. Lã FMB, Granqvist S. Semi-occluded vocal tract gestures with real-time feedback of airflow: impacts on voice during vocal training. 43rd Voice Foundation Annual Symposium: Care of the Professional Voice, Philadelphia, USA; 2014.
6. Welch GF, Howard DM, Himonides E, et al. Real-time feedback in the singing studio: an innovatory action-research project using new voice technology. *Music Educ Res*. 2005;7:225–249.
7. Lã FMB. Teaching singing and technology. In: Basa KS, ed. *Aspects of Singing II—Unit in Understanding—Diversity in Aesthetics*. Nürnberg: Vox Humana; 2012:88–109.
8. Herbst CT, Howard DM, Schlömicher-Thier J. Using electroglottographic real-time feedback to control posterior glottal adduction during phonation. *J Voice*. 2010;24:72–85.
9. Lennon M, Reed G. Instrumental and vocal teacher education: competences, roles and curricula. *Music Education Research.* 2012;14:285–308.
10. Amarante Andrade P, Wistbacka G, Larsson H, et al. The flow and pressure relationships in different tubes commonly used for semi-occluded vocal tract exercises. *J Voice*. 2016;30:36–41.
11. Smith SL, Titze IR. Characterization of flow-resistant tubes used for semi-occluded vocal tract voice training and therapy. *J Voice*. 2016. In Press.
12. Jørgenson H. Strategies for individual practice. In: Williamon A, ed. *Musical Excellence*. Oxford: Oxford University Press; 2004:85–104.
13. Guzman M, Laukkanenm AM, Krupa P, et al. Vocal tract and glottal function during and after vocal exercising with resonance tube and straw. *J Voice*. 2013;27:19–34.
14. Gauffin J, Sundberg J. Spectral correlates of glottal voice source waveform characteristics. *J Speech Hear Res*. 1989;32:556–565.
15. Nair G. *Voice—Tradition and Technology: A State-of-the-Art Studio*. San Diego, CA: Singular Publishing Group; 1999.
16. Lã FMB. Learning to be a professional singer. In: Papageorgi I, ed. *Advanced Musical Performance: Investigations in Higher Education Learning*. Aldershot: SEMPRE Studies in the Psychology of Music, Ashgate Press; 2014:265–287.
17. McCoy S. *Your Voice: An Inside View—Multimedia Voice Science and Pedagogy*. Princeton: Inside View Press; 2004.
18. Gartner-Schmidt J. Flow phonation. In: Behrman A, Haskell J, eds. *Exercises for Voice Therapy*. San Diego, CA: Plural Publishing; 2008: 24–26.