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

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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

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[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).

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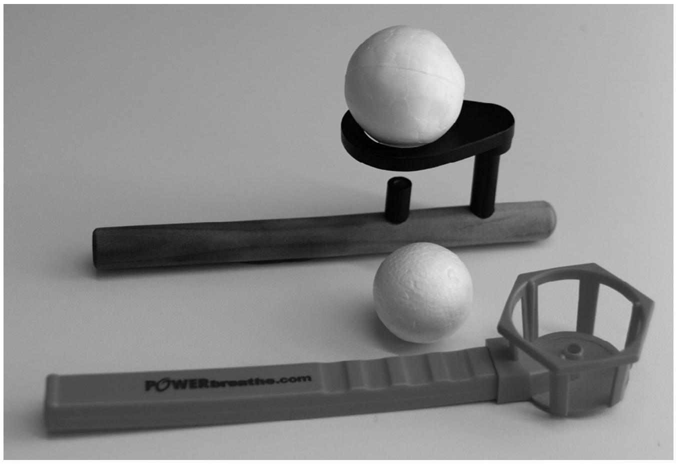

FIGURE 1. The two flow ball devices tested in this study: the floating ball game model (*top*) and the flow ball model (*bottom*).

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).

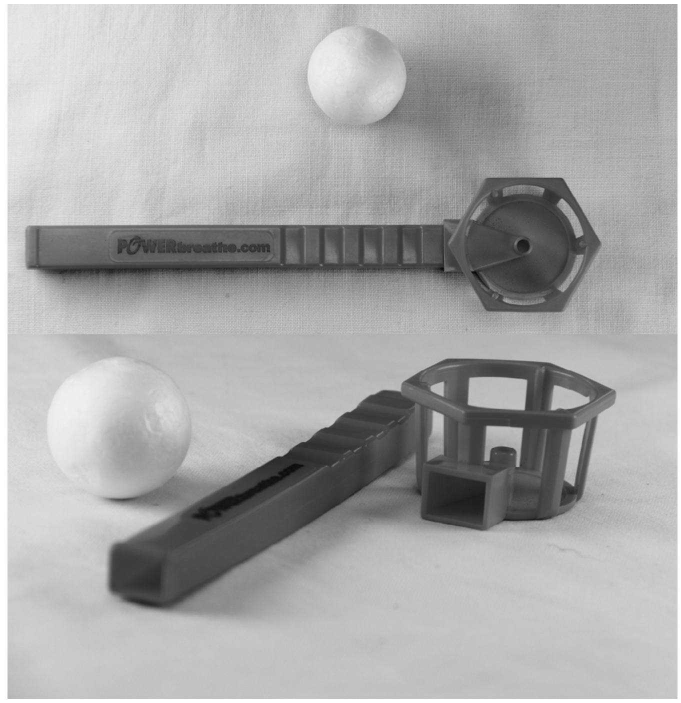

FIGURE 2. The flow ball device and its constituting parts (by POWERBreathe©).

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.