The Effects of Swim Training on Respiratory Aspects of Speech Production in Adolescents With Down Syndrome

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Reduced respiratory muscle strength in individuals with Down syndrome (DS) may affect speech respiratory variables such as maximum phonation duration (MPD), initiation volume, and expired mean airflow. Researchers randomly assigned adolescents with DS (N = 28) to either 12 weeks of swim training (DS-ST) or a control group (DS-NT). Repeated measures MANOVA demonstrated a significant increase in MPD for DS-ST participants from pretest to posttest, $t(11) = -3.44, p = 0.006$, that was not maintained at follow-up, $t(11) = 6.680, p < .001$. No significant change was observed for DS-NT participants across time, $F(2, 11) = 4.20, p = 0.044$. The lack of long-term change in DS-ST participants may be related to the relatively short training period.

Few published speech interventions feature individuals with Down syndrome (DS; Roberts, Price, & Malkin, 2007) despite suggestions that individuals with DS possess lower respiratory muscle strength than individuals without DS (Da Silva et al., 2010). Decreased respiratory muscle strength has been shown to influence speech production in different populations (Chiara, Martin, & Sapienza, 2007; Jones et al., 2006; Sapienza, 2008), and it is possible that the respiratory support needed for speech might be compromised among individuals with DS as well (Dodd & Thompson, 2001; Miller & Leddy, 1998).

Different factors have been advanced to explain why individuals with DS may experience reduced respiratory muscle strength (Da Silva et al., 2010). Increased obesity (Rubin, Rimmer, Chicoine, Braddock, & McGuire, 1998) and an inactive lifestyle (Shields, Dodd, & Abblitt, 2009) might both play a role while muscle hypotonia has also been found to varying degrees in this population (Gauld, Boynton, Betts, & Johnston, 2005; Miller, Leddy, & Leavitt, 1999; Ronchi, Antunes, & Fioretto, 2008). It is plausible that any lack of muscle tone and reduced ability

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to control muscle stiffness may affect the phonation, resonation, articulation, and/or prosody of speech (Miller et al., 1999). Indeed, the harshness, hoarseness, and gruffness of voice observed in individuals with DS (Groves & Gray, 1985; Van Riper & Erickson, 1996) could originate from the muscular fatigue caused by the excessive effort required to activate hypotonic laryngeal muscles (Pryce, 1994).

Respiratory Muscle Training

Respiratory muscle training (RMT) targets improvement in the efficiency of the respiratory system by strengthening the inspiratory and/or expiratory muscles (Celli, 1998; Kim & Sapienza, 2005; Weiner, Magadle, Beckerman, & Beray-Yanay, 2003). As such, RMT has been used to rehabilitate speech and voice disorders in diverse populations (Chiara et al., 2007; Sapienza, 2008). Jones et al. (2006) examined the effects of expiratory muscle training on a single participant diagnosed with dysarthria due to Lance Adams syndrome because they believed their participant’s perceptually deviant speech signs owed to deficits in respiratory laryngeal speech subsystems. Results indicated an increase in maximum phonation duration (MPD) for the vowel /a/ immediately after treatment finished although this increase was not sustained at follow-up. It remains undetermined whether individuals with DS, who may also have dysarthric speech profiles (Hamilton, 1993; Kumin, 2006; Miller & Leddy, 1998; Roberts et al., 2007) and deficits in respiratory laryngeal speech subsystems (Venail et al., 2004) stand to benefit from RMT aimed at influencing respiratory aspects of speech production (Sapienza, 2008).

Sports Training

Regular participation in certain endurance sports could provide a means to train the respiratory muscles (Voliantis et al., 2001; Wylegala, Pendergast, Gosselin, Warkander, & Lundren, 2007) while simultaneously combating obesity and physical inactivity (Ordonez, Rosety, & Rosety-Rodriguez, 2006). Limited sports training interventions, meeting recommended guidelines for health benefits, have been conducted on individuals with DS (Dodd & Shields, 2005). Aquatic exercise offers benefits for people with various disabilities (Yilmaz et al., 2009), and recent work on competitive athletes suggests that participation in swim training (ST) may also promote increased respiratory muscle strength (Wells, Plyley, Thomas, Goodman, & Duffin, 2005). ST allows for both variable loading and quantifiable intensity, which may achieve the same outcomes as the pressure threshold trainer devices currently used for RMT (Mickleborough et al., 2008). Whereas RMT devices often focus solely on either inspiration or expiration, ST offers near flow independent resistance to both inspiration and expiration and can be used for both endurance and strength paradigms (Lomax & McConnell, 2003).

Research has yet to examine the effects of ST on respiratory aspects of speech production among populations with voice and speech disorders. As with speech, swimming breathing patterns require phases of rapid inspirations and prolonged expirations (Hixon & Hoit, 2005). A swimmer’s immersion in the water during front-crawl forces her or him to coordinate breathing with stroke mechanics because physiological necessity often dictates when the former occurs, especially among inexperienced swimmers (Lomax & McConnell, 2003). It is possible, however, to
train swimmers to reach a level where they control their breathing and enter into what Mickleborough et al. (2008) labeled an “obligatory controlled frequency breathing pattern.” Such a trained respiratory pattern involves a more rapid inhalation with greater lung volumes and a relatively prolonged exhalation, which may lead to improved stroke mechanics and reduced drag by increasing buoyancy and contributing to an elevated body position in the water. Once a swimmer’s face rises above the water, rapid inspiration necessitates inspiratory muscle shortening at a higher velocity, placing increased demand upon the inspiratory muscles (Lomax & McConnell, 2003; Rodriguez, 2000).

By providing sufficient ST in terms of frequency, intensity, and duration (Dodd & Shields, 2005), it may be possible for individuals with DS to improve the capacity of the respiratory muscles and reach an ability level at which an obligatory controlled frequency breathing pattern occurs (Mickleborough et al., 2008). By increasing the endurance of the respiratory muscles, individuals with DS might be able to sustain their effort for longer without tiring (Wylegala et al., 2007). In terms of speech, this may translate into a decrease in inspiratory time and consequently a reduction in the pause time between utterances (Hixon & Hoit, 2005). ST focusing on breathing techniques may therefore be used not only to improve the performance of athletes (Mickleborough et al., 2008), but also aid individuals with DS who experience a compromised respiratory system and difficulty with speech production.

**Speech Respiratory Variables (SRV)**

Speech respiratory variables (SRV) such as maximum phonation duration (MPD), initiation volume, and mean expired airflow may be used to assess the impact of ST on individuals with DS as they provide an indication of respiratory support for speech (Solomon, Garlitz, & Milbrath, 2000). Voice pathologists stress the importance of measuring MPD in clinical settings as it is a relatively noninvasive measurement that provides an overall indication of vocal functioning (Speyer et al., 2008). MPD is measured as the greatest length of time over which phonation can be sustained for a vowel sound. Research shows MPD to be correlated with both expired mean airflow and initiation volume in different populations (Prathanee, Watthanathon, & Ruangjirachuporn, 1994). For a given phonation volume, different MPD values will be obtained depending on the airflow or time derivative of volume (Kent, Kent, & Rosenbek, 1987). Previous studies providing normative data on each of the SRVs have, however, demonstrated differences based on gender (Colton & Casper, 1990).

**Purpose**

The purpose of this study was to address (a) how adolescents with DS fare in comparison with normative data collected on individuals without DS with regard to three SRVs—MPD (sec), initiation volume (ml), and expired mean airflow (ml/sec); (b) the effects of a 12 week ST intervention on SRV in adolescents with DS (DS-ST) compared with a control group (DS-NT); and (c) whether DS-ST participants could pass the Swim to Survive Standard test based on the guidelines of the Royal Lifesaving Society of Canada (2009) following participation in the ST intervention.
Method

Procedures

Researchers recruited 28 participants (Mean Age = 14.6 years, SD = 1.9) through advertisement in a newsletter distributed to over 200 families of individuals with DS. Participants were randomly assigned to either a 12-week ST intervention (DS-ST; six females, eight males) or a control group (DS-NT; six females, eight males). Although DS-NT participants did not take part in any intervention during the course of the study, they continued with their usual daily activities. By chance, at baseline pretest, there was no significant difference in age between the randomly selected DS-ST (M = 14, SD =1.56) and DS-NT (M = 15, SD =1.98) participants (p = 0.171). Participants originated from a single Canadian city (White = 26; Asian-Canadian = 1; First Nation = 1) and diverse socioeconomic strata (SES; low SES = 2; medium SES = 14; high SES = 12).

Adolescents with DS were excluded from the study if they had any underlying health condition that prevented participation or if they belonged to any other exercise or speech interventions (Casey, Rasmussen, MacKenzie, & Glenn, 2010). No attempt was made to include or exclude participants based on prior swimming ability or on the distinction of mosaicism, translocation, or trisomy 21 while acquisition of participants IQ scores was also beyond the scope of this study. Researchers outlined testing procedures, potential benefits, associated risks, and the time required for the study in an information letter and discussion session prepared for participants and their parents and/or guardians—who provided signed informed consent. DS-NT participants were offered free of charge the same 12-week ST intervention following the completion of the research. The institutional research ethics board provided approval before the commencement of the study.

Measurements

Sustained Vowel /a/ Prolongation Test. All participants underwent the same measurement procedures for SRV at pretest, posttest, and 12 weeks following the completion of the ST intervention. The sustained vowel /a/ prolongation test assesses respiratory aspects of speech production including each participant’s MPD (sec), initiation volume (ml), and expired mean airflow (ml/sec) using a phonetic unit segment. For testing, each participant sat upright in a chair and was asked to perform relaxation, isovolume, and vital capacity maneuvers for calibration, according to standard kinematic method (Hixon et al., 1973). Participants were shown their respiratory response on a computer screen and instructed to sustain the vowel /a/ for as long as possible (Koike & Hirano, 1968) at a comfortable pitch and loudness into a facemask attached to a speech pneumotach (Parvo Medics TrueMax 2400), which had been calibrated with a 3-L syringe (5 repetitions) before testing. The pressure transducer transmitted data to the metabolic cart and measurement software. To ensure reliable measurement, each participant repeated the task three times (Speyer et al., 2008) with the longest MPD and its inspiration and expired mean airflow values used for further analysis (Iwata, Von Leden, & Williams, 1972; Prathanee et al., 1994; Terasawa, Hibi, & Hirano, 1987). The same technicians performed measurements for both groups.
and did not have a preestablished relationship with any participant or knowledge of group composition.

**Swim to Survive Standard.** The swimming ability level of all DS-ST participants was assessed at the beginning and end of the intervention based on the guidelines of the Royal Lifesaving Society of Canada (2009), which required participants to complete the following skills unassisted: roll into deep water, tread water for one minute, and also swim for 50 m. These standards were used to assess the effectiveness of ST, although the intervention began for all DS-ST participants regardless of whether they passed the pretest Swim to Survive Standard or prior swim experience.

**Swim Training Intervention**

DS-ST participants attended three one-hour sessions per week over a period of 12 weeks. Each ST session occurred in a competitive-size, indoor 25 m pool (78 °F) in the presence of certified lifeguards, three swim coaches who had all been certified by the Canadian national coaching certificate program (NCCP Level 1), and also three adolescent peer instructors with DS. To ensure maximum participation, nationally certified coaches implemented motivational strategies including verbal reinforcement (e.g., cheering and positive feedback) and physical praise (e.g., high-fives). Participants also trained in the same pool in swim lanes alongside members of a local competitive swim team to provide a visual image of an on-going sports training environment (Casey et al., 2010).

The intervention followed the competitive swim model adapted (Crowley, 2005; Maglischo, 2003). Coaches taught participants only one-stroke, front-crawl, and focused on breathing by emphasizing “1-2-3 Breathe” techniques to increase sustained expiration and short inspiration by training respiratory muscles. Flutterboards were provided for assistance. As recommended by Hixon and Hoit (2005) in the domain of speech, the load of RMT involved in learning to breathe was raised incrementally as the study progressed by gradually increasing the volume of training (Ordonez et al., 2006). Participants initially swam as little as 50 m or less per session assisted, but by the end of the intervention, completed approximately 1000 m per session. See Figure 1 for complete intervention plan.

**Data Analysis**

To assess the effects of the intervention on selected SRV, data were analyzed by a repeated measure multivariate analysis of variance (MANOVA) using SPSS statistical software (Statistical Package for Social Sciences 15.0, SPSS Inc., Chicago, IL) and R-project (R-project, R Development Core Team, Version 2.12.0). A repeated measure MANOVA allows us to analyze SRV as dependent variables as well as identifying patterns for three time points (pretest, posttest, and follow-up tests) simultaneously. MANOVA was used to examine the effects of time (pretest, posttest, follow-up), intervention (DS-ST, DS-NT), and gender (female, male) on SRV (MPD, initiation volume and expired mean airflow). A multivariate approach was preferred over a univariate approach (ANOVA) because the sphericity assumption was violated in our data. When the sphericity assumption is violated in a univariate analysis, it markedly affects the true Type I error rates and power. A MANOVA
<table>
<thead>
<tr>
<th>PHASE</th>
<th>WEEK</th>
<th>TASKS (see DRILLS)</th>
<th>DURATION (MIN)</th>
<th>VOLUME (Meters)</th>
<th>SPEED AND INTENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>Week 1 (First Stage)</td>
<td>1-2-3, Breathe at side of the pool</td>
<td>5 - 10 Min.</td>
<td>25 Meters (1 Length or 4 x width of pool)</td>
<td>Gradual Increase in Speed (Medium - Fast)</td>
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<td></td>
<td></td>
<td>Flutter Kicking with board (assisted)</td>
<td>5 - 10 Min.</td>
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<td>Instructor demonstrate / swimmers try</td>
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<td></td>
<td>Free Swim</td>
<td>5 - 10 Min.</td>
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<tr>
<td>Phase I</td>
<td>Week 2 (Second Stage)</td>
<td>1-2-3, Breathe</td>
<td>5 - 10 Min.</td>
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<tr>
<td></td>
<td></td>
<td>Flutter Kicking with board (assisted)</td>
<td>5 - 10 Min.</td>
<td>50 meters (2 Lengths or 6 x width of the pool)</td>
<td>Gradual Increase in Speed (Medium - Fast)</td>
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<td>Instructor demonstrate / swimmers try</td>
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<td>Component skills</td>
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<td></td>
<td></td>
<td>1. Dryland Arms</td>
<td>20 - 30 Min.</td>
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<td>2. Body Position</td>
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<td>3. Comfortable in water</td>
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<td>Free Swim</td>
<td>5 - 10 Min.</td>
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<tr>
<td>Phase I</td>
<td>Week 3 (First / Second Stage)</td>
<td>1-2-3, Breathe</td>
<td>20 - 30 Min.</td>
<td>100 meters (4 Lengths or 16 x width of the pool)</td>
<td>Gradual Increase in Speed (Medium - Fast)</td>
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<tr>
<td></td>
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<td>Flutter Kicking with board (assisted, if needed)</td>
<td>5 - 10 Min.</td>
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<td>Instructor demonstrate / swimmers try</td>
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<td>Component skills</td>
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<td></td>
<td></td>
<td>1. Dryland Arms</td>
<td>10 - 20 Min.</td>
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<td>2. Try deep end</td>
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<td>3. Body Position</td>
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<td>Free Swim</td>
<td>5 - 10 Min.</td>
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<tr>
<td>Phase I</td>
<td>Week 4 (First / Second Stage)</td>
<td>1-2-3, Breathe</td>
<td>20 - 30 Min.</td>
<td>100 meters (4 Lengths or 16 x width of the pool)</td>
<td>Gradual Increase in Speed (Medium - Fast)</td>
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<td></td>
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<td>Flutter Kicking with board (unassisted)</td>
<td>5 - 10 Min.</td>
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<td>Instructor demonstrate / swimmers try</td>
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<td>Component skills</td>
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<td>1. Dryland Arms</td>
<td>20 - 30 Min.</td>
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<td>2. Body position</td>
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<td>3. Try arms in water</td>
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<td>4. Try deep end</td>
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<td></td>
<td></td>
<td>Free Swim</td>
<td>5 Min.</td>
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<td>Phase II</td>
<td>Week 5 - 7 (First/ Second Stage)</td>
<td>1-2-3, Breathe</td>
<td>30 - 45 Min.</td>
<td>100 - 300 meters</td>
<td>Maintain Speed</td>
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<td>Flutter Kicking with board (unassisted)</td>
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<td>Instructor demonstrate / swimmers try</td>
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<td>Component skills</td>
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<td></td>
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<td>1. Dryland Arms</td>
<td>15 Min.</td>
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<td>2. Body position</td>
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<td>3. Try arms in water</td>
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<td>4. Comfortable in deep end</td>
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<tr>
<td>Phase III</td>
<td>Week 8 (Test Week)</td>
<td>Kicking-Breathing Test = 500 meters continuous</td>
<td>50 - 60 Min.</td>
<td>500 meters</td>
<td>Maintain Speed</td>
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<tr>
<td></td>
<td></td>
<td>1-2-3 Breath+ Flutter Kicking with board (unassisted)</td>
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<tr>
<td>Phase III</td>
<td>Week 9 - 11 (First/ Second Stage)</td>
<td>1-2-3 breathe</td>
<td>30 - 60 Min.</td>
<td>100 - 200 Meters</td>
<td>Maintain Speed</td>
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<td></td>
<td></td>
<td>Flutter Kicking</td>
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<td>3. Arms (For swimmers who passed week 8 test)</td>
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<tr>
<td>Phase III</td>
<td>Week 12 (Test Week)</td>
<td>Kicking-Breathing Test = 500 meters continuous</td>
<td>50 - 60 Min.</td>
<td>500 meters (20 Lengths)</td>
<td>Maintain Speed</td>
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<td></td>
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<td>1-2-3 Breath+ Flutter Kicking with board (For swimmers who did not pass week 8 test).</td>
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<td></td>
<td>Frontcrawl-Breathing Test = 200 meters continuous</td>
<td>50 - 90 Min.</td>
<td>200 Meters (3 Lengths)</td>
<td>Maintain Speed</td>
</tr>
</tbody>
</table>

**Figure 1** — Complete 12-week swim training intervention plan.
does not assume sphericity (Maxwell & Delaney, 2004; O’Brien & Kaiser, 1985). Using \( \alpha \) as the number of levels for repeated measures, the recommended sample size was 12 (\( \alpha + 10; \alpha = 2; 2 + 10 = 12 \)), indicating that with a final sample of 26 (DS-ST = 12; DS-NT = 14), we had a moderately large sample size to conduct MANOVA (Cohen, 1977; Stevens, 1990). ANOVA follow-up tests (planned comparisons) were later conducted to analyze findings further using the Bonferroni adjustment to maintain the Type I error rate at the 0.05 level.

**Results**

**Normative Data**

Table 1 shows the comparison between normative data collected on both sexes without DS (Finnegan, 1985; Peppard, Bless, & Milenkovic, 1988; Wilson & Starr, 1985; Yanagihara & Koike, 1967) and participants with DS at baseline pretest (nonage/gender matched). There were significant differences for both females and males in terms of MPD and initiation volume, but no significant differences for expired mean airflow. No significant differences were found between DS-ST and DS-NT participants in terms of MPD (\( p = 0.165 \)), initiation volume (\( p = 0.327 \)), or expired mean airflow (\( p = 0.642 \)) at pretest.

**Speech Respiratory Variables (SRV)**

Two DS-ST male participants completed the 12-week ST intervention and also the Swim to Survive Standard tests but did not attend post or follow up testing so were not included in the data set for SRV analysis. Table 2 presents the mean and standard deviation for MPD, initiation volume, and expired mean airflow for DS-ST and DS-NT participants at pretest, posttest, and follow-up for the sustained phonation /a/ test. A moderate correlation existed between SRV at each time point. Therefore, we conducted repeated measures MANOVA to evaluate the effects of ST on three SRV simultaneously. Results showed that the ST intervention did not have a significant effect on SRV, \( F(1, 22) = 1.83, p = 0.19 \). However, gender did have significant effect on SRV, \( F(1, 22) = 11.77, p = 0.0024 \), and the interaction effect of the ST intervention and gender was also significant, \( F(1, 22) = 5.75, p = 0.025 \), suggesting that the ST intervention affected the gender difference. Therefore, we examined further each dependent variable individually through repeated measures MANOVA.

**Maximum Phonation Duration (MPD)**

Repeated measures MANOVA demonstrated that the main effect of gender was not significant for MPD, \( F(2, 21) = 0.93, p = 0.088 \). The main effect of time was significant, \( F(2, 21) = 27.79, p < .001 \), as well as the interaction for time \( \times \) intervention, \( F(2, 21) = 13.25, p < .001, \eta^2 = 0.56 \). Further analysis revealed a significant effect of time for DS-ST, \( F(2, 9) = 22.71, p < .001 \), but no effect of time for DS-NT, \( F(2, 11) = 4.20, p = 0.044 \). Paired \( t \) tests between each time factor for DS-ST revealed a significant 1-tailed result between pre and posttests, \( t(11) = –3.44, p = 0.006 \). There was also a significant result between posttest and follow-up, \( t(11) = 6.680, p < .001 \).
Table 1  Normative Means and Standard Deviations for Speech Respiratory Variables During Sustained Phonation /a/ at a Comfortable Pitch and Loudness Compared With Participants With Down Syndrome

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source(s)</th>
<th>Norm Females Mean (SD)</th>
<th>DS Females (n = 12) Mean (SD)</th>
<th>Significance Females</th>
<th>Norm Males Mean (SD)</th>
<th>DS Males (n = 14) Mean (SD)</th>
<th>Significance Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Phonation Duration (sec)</td>
<td>Finnegan (1985)</td>
<td>19(4.84)</td>
<td>12(1.16)</td>
<td>p &lt; 0.001</td>
<td>22(6.22)</td>
<td>15(4.68)</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Initiation Volume (ml)</td>
<td>Yanagihara &amp; Koike (1967)</td>
<td>2146(345)</td>
<td>720(164)</td>
<td>p &lt; 0.001</td>
<td>3256(602)</td>
<td>877(209)</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Expired Mean Airflow (ml/sec)</td>
<td>Peppard, Bless, &amp; Milenkovic, (1988); Wilson &amp; Star (1985)</td>
<td>116(26)</td>
<td>131(23)</td>
<td>p = 0.171</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note. DS, Down syndrome; N/A, Not applicable; Finnegan (1985) examined females aged 12–17 years (n = 60) and males aged 12–17 years (n = 60); Yanagihari and Koike (1967) examined females aged 21–40 (n = 11) and males aged 30–43 (n = 11); Peppard, Bless, and Milenkovic (1988) examined females aged 16–30 (n = 10); Wilson and Starr (1985) examined males aged 19–26 (n = 25).
<table>
<thead>
<tr>
<th>Variable</th>
<th>Pretest Mean (SD)</th>
<th>Posttest Mean (SD)</th>
<th>Follow Up Mean (SD)</th>
<th>Pretest vs. Posttest Paired t (p-value)</th>
<th>Follow Up vs. Posttest Paired t (p-value)</th>
<th>Pretest vs. Follow-up Paired t (p-value)</th>
<th>Follow Up vs. Posttest Paired t (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS-ST MPD</td>
<td>12 (1.48)</td>
<td>15 (2.99)</td>
<td>15 (2.99)</td>
<td>-3.44 (0.006)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>DS-ST IV</td>
<td>749 (188)</td>
<td>805 (136)</td>
<td>684 (295)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>DS-ST EMA</td>
<td>122 (27)</td>
<td>152 (30)</td>
<td>156 (48)</td>
<td>-2.84 (0.015)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>DS-NT MPD</td>
<td>14 (4.97)</td>
<td>13 (5.34)</td>
<td>13.6 (5.06)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>DS-NT IV</td>
<td>853 (332)</td>
<td>808 (228)</td>
<td>857 (245)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>DS-NT EMA</td>
<td>166 (131)</td>
<td>158 (47)</td>
<td>166 (77)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

Note: DS-ST, Swim training group; DS-NT, Control group; MPD, Maximum phonation duration; IV, Initiation volume; EMA, Expired mean airflow; NS, No significance.
 Effects of Swim Training

No significance was found between pretest and follow-up test in MPD for DS-ST, $t(11) = 1.97, p = 0.075$. Therefore, MPD increased at posttest but returned to baseline at follow-up for the DS-ST group.

Initiation Volume

Using repeated measures MANOVA, the only main effect found to be significant was with regards to gender, $F(1, 22) = 10.02, p = 0.004$. The two-way interaction group $\times$ gender was also significant, $F(1, 22) = 4.34, p = 0.049$. Further analysis on the main effect of gender revealed no significant effect of gender for the DS-ST group, $F(1, 10) = 0.569, p = 0.468$, but a significant effect of gender for the DS-NT group, $F(1, 12) = 11.33, p = 0.006$. The mean scores also indicated initiation volumes were lower for females ($M = 720, SD = 165$) than for males ($M = 877, SD = 209$).

Expired Mean Airflow

Results indicated no significant findings for time, group, and/or gender.

Swim to Survive Standard

At pretest baseline only two DS-ST participants attained the Swim to Survive Standard. By the end of the study, however, all DS-ST swimmers passed the same test and swam 500 m with a flutter board by either eight or twelve weeks. Six participants also completed an additional 200 m front-crawl breathing every three strokes without the flutter board during the final week of the intervention.

Discussion

The purpose of this study was to (a) compare SRV data in adolescents with DS to normative data on the general population, (b) examine the impact of a ST intervention on SRV in adolescents with DS, and (c) assess whether adolescents with DS could pass the Swim to Survive Standard. Findings suggest that (a) adolescents with DS may have difficulty with initiation volumes and prolonged expiration for vowel /a/ at a normal expired mean airflow; (b) DS-ST participants improved MPD significantly compared with DS-NT participants, although this improvement was not sustained at follow-up; (c) by the end of the study, all DS-ST participants completed the Swim to Survive Standard test.

Implications of the Study

Findings from the comparison of SRV in adolescents with DS to normative data on individuals without DS concur with previous research, indicating that individuals with DS may have a compromised respiratory system for speech (Dodd & Thompson, 2001; Miller & Leddy, 1998; Roberts et al., 2007). Adolescent participants fell significantly below normative values for both MPD (Finnegan, 1985) and initiation volume (Yanagihara & Koike, 1967), although this was not the case for expired mean airflow (Peppard et al., 1988; Wilson & Starr, 1985). These results support findings suggesting that individuals with DS have significantly reduced respiratory
muscle strength compared with the norm (Da Silva et al., 2010). This may not impact attempts to produce short utterances as at normal loudness, a mere 25% of total lung capacity is sufficient for normal expiration (Lass, 1996). For longer speech, however, individuals with DS must use muscles actively to inhale more deeply as the inspiration phase increases with lung volumes ranging from four to five liters (Bailey & Hoit, 2002). Therefore, compared with people without DS, adolescents with DS may be more inclined to produce short rather than long utterances. Adolescent boys with DS did have significantly greater initiation volume than girls with DS, although this may be expected in light of findings that show males tend to have 20–25% more lung capacity than females do (Plowman & Smith, 2007).

The randomized control trial showed that DS-ST participants may increase MPD following involvement in an ST intervention. Similarly, Jones et al. (2006) demonstrated that with sufficient training, individuals with dysarthric speech profiles may learn to sustain the expiration phase needed for improved speech production. In our study, a clinically significant increase in MPD may suggest that swimmers with DS learned how to use their abdominal and intercostals muscles to control the exhalation and force length for both swimming and for sustained phonation by posttest. Although participants are liable to modify their behavior as a result of involvement in the study, researchers believe these changes are more likely to be related to the intervention rather than extraneous factors such as repeated testing, familiarity with testing procedures, experimental setting, or the experimenter (Ramig et al., 2001). No change was documented for the randomly selected control group who worked with the same experimenters during measurements even if DS-NT participants did not have as much experience in the research environment as DS-ST participants by the end of the intervention.

Findings demonstrated no overall significant change in initiation volume or expired mean airflow for the DS-ST group following training. The lack of significant change in initiation volume for DS-ST participants may be due to lack of ST experience highlighted by the pretest Swim to Survive Standard results. It is possible that the 12-week training period was too short for participants to reach a sufficient ability level for what Mickleborough et al. (2008) deemed an “obligatory controlled frequency breathing pattern” to occur.

**Limitations of the Study**

A primary issue with interpretation of sustained vowel /a/ performance is the availability of good quality normative data. The lack of aged matched data and more recent normative values must be taken into consideration when interpreting results, especially in light of changes in physical activity and obesity levels among the general population over the past twenty years (Haslam & James, 2005). Consequently, more research may be warranted in this area, especially among adolescents. Nevertheless, collection procedures and instrumentation in this current study largely followed methods used to obtain normative data on large samples of individuals without DS in the past (Kent, Kent, & Rosenbek, 1987). Furthermore, for sustained vowel /a/ tasks, the basic procedure is the same regardless of the specific software used to display the waveforms and measure the durations. As such, the normative data reported is still considered practically useful in the clinical setting (Rvachew, Hodge, & Ohberg, 2005).
The criterion for implementing RMT among individuals with voice disorders has not yet been ascertained experimentally in the area of speech (Sapienza, 2008). More information on participants’ speech profiles would allow for a greater understanding of the effectiveness of the intervention as findings from strength training paradigms imply that individuals who commence training programs at a lower level of function may have a larger capacity for improvement (Powers & Howley, 2000). This study did not have access to individual speech profiles, and participants were not selected based on the presence or otherwise of speech impairments or degree of dysarthria even though researchers knew participants had prior involvement in speech therapy.

Exercise has been shown to affect cognitive abilities, sleep, and mood in the past—all of which have been shown to improve the concentration of participants (Reid et al., 2010). Therefore, changes in these particular variables and not the measures tested may have contributed to the final outcomes. The ST environment may have played a role as the indoor pool temperature was lower than is sometimes the case when working with people with disabilities. In addition, researchers did not directly measure respiratory muscle strengthening so the absence of significant long-term change in SRV may have resulted from a lack of change in DS-ST participants’ muscle strength. The length of study suggests that change in MPD following ST may be attributed to enhanced neural recruitment rather than changes in muscle fiber size (Wilmore & Costill, 2005). Jones et al. (2006) proffered an alternative explanation, however, by highlighting how detraining may occur rapidly in populations with compromised muscle structure and physiology (Baker, Davenport, & Sapienza, 2005).

**Recommendations for Future Research**

Training for a longer duration could have possibly increased the number of adaptations to the expiratory muscles among DS-ST participants. Therefore, ST may warrant further exploration as an alternative therapy for training the respiratory system for the purposes of speech production in place of measures already recommended in this population (Kumin, 1994; Rosin & Swift, 1999). A competitive ST program may prove cheaper and more readily available than current handheld RMT devices (Sapienza, 2008). Individuals with disabilities may also garner additional benefits from ST that extend beyond certain respiratory aspects of speech production (Yilmaz et al., 2009). It is plausible that ST may have provided further health benefits including decreased obesity (Ordonez et al., 2006). To explore the potential of ST further in this population, researchers recommend additional investigation into appropriate methods for teaching people with various disabilities how to swim. This study focused on one-stroke only at an early stage of athlete development to promote consistency and repetition among swimmers with DS. It differed from traditional swim programs such as the Red Cross Learn to Swim model (Reid & O’Neill, 1989) or the YMCA Learn-to-Swim program (Burpee & McCuiag, 1993), which favor the acquisition of many skills first or learning many strokes simultaneously.

Although no long-term significant changes in SRV followed the intervention, all participants with DS attained the Swim to Survive Standard test. At the end of this study, all participants, including members of the DS-NT group, who were
offered the same program after the completion of the initial study, wanted to con-
tinue their success in a sports training environment as all had passed the Swim to
Survive Standard \((n = 26)\). This resulted in the formation of the Calgary Dolphins
competitive swim club that has since been recognized as a nonprofit parent run
body under the national governing organization of sport, Swim Canada. Further
research may examine whether a sustainable program of this nature offers long-
term benefits for individuals with DS and other disabilities.

**Conclusion**

This study suggests adolescents with DS may have difficulty with certain respira-
tory aspects of speech production compared with individuals without DS. The ST
intervention did not result in any significant long-term change in SRV according to
results from the randomized control trial. However, DS-ST participants increased
their MPD significantly between pre and posttest, although this was not sustained
at twelve weeks follow-up. The lack of long-term change may be explained by the
relatively short duration of the intervention especially in light of the participants’
lack of ST experience. Future studies may consider training periods of longer
duration to counter possible detraining effects and the likelihood of participants
reaching an ability level where an obligatory breathing pattern occurs.

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