# Effects of Directional Exercise on Lingual Strength

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**Purpose:** To examine the application of known muscle training principles to tongue strengthening exercises and to answer the following research questions: (a) Did lingual strength increase following 9 weeks of training? (b) Did training conducted using an exercise moving the tongue in one direction result in strength changes for tongue movements in other directions? (c) Were differential training effects observed for participants completing exercises sequentially (in isolation) versus concurrently (several exercises in combination)? (d) Were strength gains maintained after exercise was discontinued?

**Methods:** Participants were 39 healthy adults assigned to sequential or concurrent lingual strength training. Lingual exercise (elevation, protrusion, and/or lateralization) was conducted for 9 weeks, with lingual strength and cheek strength (control variable) assessed weekly.

**Results:** All lingual strength measures increased with training, but cheek strength remained unchanged. Training effects were not related to training condition (sequential vs. concurrent), nor were specificity effects observed for direction of exercise. Significant decreases in lingual strength were noted 2–4 weeks after exercise was discontinued.

**Conclusions:** The findings replicate those of earlier studies demonstrating that lingual strength may be increased with a variety of exercise protocols and confirm that detraining effects may be observed when training is discontinued. The findings further suggest that the lingual musculature may demonstrate less dramatic training specificity than what has been reported for skeletal muscles.

**KEY WORDS: oral motor exercise, tongue strength, specificity, detraining**

Oral motor exercise (OME) for the purpose of improving speech and swallowing function is a widely used clinical practice in speech-language pathology (Lof & Watson, 2008). Examples of nonspeech OME include moving the articulators against resistance to increase strength, stretching the articulators to improve range of motion, and sequencing multiple oral movements to improve coordination.

A frequent criticism of nonspeech OME is that these training methods often do not adhere to accepted principles of muscle training (Burkhead, Sapienza, & Rosenbek, 2007; Cerny, Sapienza, Lof, & Robbins, 2007; Clark, 2003). For example, the training specificity principle arises from the robust finding in the exercise science literature that improvements in performance are most dramatic for movements that closely match the exercise (Jones, McCartney, & McComas, 1986; Schmidt & Lee, 1998; Schmidt & Wrisberg, 2000). Training specificity predicts that OME conducted with nonspeech or nonswallowing movements will not result in significant functional changes in speech or swallowing function, respectively, yet most OMEs do not involve speech or swallowing movements.

A related concern surrounding the use of OME is that the primary principles available to guide the development of training protocols arose from observations of limb musculature (e.g., Clark, 2003). Because the musculature of the speech and swallowing mechanism differs from other skeletal muscles in key ways, including fiber types and attachment patterns (Barlow & Farley, 1989; Clark, 2003; Luschei, 1991), it is possible that this musculature responds differently to training. For example, the rates at which muscle groups gain strength with training and lose strength when training is discontinued have been described for various limb muscles, but similar descriptions are largely lacking for the orofacial musculature.

Finally, popular clinical resources (e.g., Gangale, 2001) often overlook the small number of OME training protocols with demonstrated benefit (e.g., Robbins et al., 2007). For example, the procedures described often utilize exercises and/or training schedules that have not been subjected to efficacy study (see Clark, 2003, for review).

The present study systematically examined specific training principles within the context of OME. The study parallels similar studies examining training of the respiratory musculature (e.g., Baker, Davenport, & Sapienza, 2005), providing information critical to our understanding of the neuromuscular systems supporting speech and swallowing.

## Training Specificity

The tongue is a common target of OME, presumably due to the critical role it plays in both speech production and deglutition. Only recently, however, have the effects of lingual strengthening been the subject of systematic research. The literature now includes evidence that tongue exercise increases lingual strength in healthy young (Lazarus, Logemann, Huang, & Rademaker, 2003) and aging (Robbins et al., 2005) individuals and also results in improved swallowing function (Robbins et al., 2007).

Of particular note in this line of research is the nature of the lingual exercise utilized during strength training. A single exercise involving elevation of the tongue against the hard palate, a nonswallowing movement, resulted in improved swallowing function (Robbins et al., 2007). These findings are inconsistent with the training specificity principle and suggest that the lingual musculature may demonstrate atypical responses to strength training. Indeed, the unique physiology of the tongue musculature (Luschei, 1991) may permit these muscles to defy specificity principles. The tongue, as a muscular hydrostat, generates force as a result of muscle fibers contracting against each other to produce hydraulic pressure within a confined area. In contrast, skeletal muscles typically contract against a joint to generate force. Because most tongue movements, regardless of direction, require contraction of several tongue muscles simultaneously to generate hydraulic pressure, tongue exercises may result in functional strength changes for untrained lingual movements.

The present study directly examined specificity of training in the lingual musculature by measuring changes in lingual strength resulting from three different directions of tongue exercise. Whereas training specificity predicts that strength changes will be greatest for lingual movements matching the tongue exercise, a competing hypothesis predicts that, because of the unique physiology of the tongue musculature, generalized strength gains will be observed regardless of the exercise completed.

## Isolated Versus Combined Exercise

As noted previously, the studies demonstrating improved swallowing function following tongue exercise utilized a single exercise involving tongue movement in one direction only. This method, however, is not typical of clinical practice. Instead, clinicians often provide patients with lists of several tongue exercises to complete, often targeting lingual protrusion and lateralization in addition to elevation (e.g., Gangale, 2001). Previous research has demonstrated lingual strength gains when multiple exercises are trained (Lazarus et al., 2003). The present study expanded this line of inquiry to examine differential effects of isolated and combined exercise.

## Detraining

A common observation in the strength training literature is that strength gained as a result of training gradually returns to pre-training levels when training is discontinued (e.g., Andersen, Andersen, Magnusson, & Aagaard, 2005; Blazevich, 2006; Elliott, Sale, & Cable, 2002). Of particular interest are detraining effects in muscle groups contributing to speech production and swallowing function, as these muscle groups are often targeted for strength training during speech and swallowing rehabilitation. Given that treatment duration is finite, understanding how these muscle groups are likely to respond when treatment (exercise) is discontinued may inform discharge planning and aftercare. Unfortunately, studies of detraining effects in the speech and swallowing musculature are largely lacking. One recent study examining strength training of expiratory muscles (Baker et al., 2005) reported detraining effects observed at 4 and 8 weeks post-training. Expiratory strength declined significantly during the detraining periods but did not return to pre-training levels, a pattern similar to that observed in limb musculature (e.g., Andersen et al., 2005). The present study examined detraining effects in the lingual musculature.

## Research Questions and Hypotheses

*Question 1: Did lingual strength increase following 9 weeks of training?* The present study attempted to replicate previous findings demonstrating increases in lingual strength as a result of training (Clark, Barber, & Irwin, 2004; Lazarus et al., 2003; Robbins et al., 2005, 2007). It was hypothesized that significant increases in strength would be observed for each of the trained movements.

*Question 2: Did strength training moving the tongue in one direction result in strength changes for tongue movements in other directions?* This question addresses the issue of training specificity. It was hypothesized that all tongue exercises would result in measurable gains in strength for all lingual movements but that the greatest increases in strength would be observed for the tongue movement that was directly trained.

*Question 3: Were differential training effects observed for participants completing exercises sequentially (in isolation) versus concurrently (several exercises in combination)?* It was hypothesized that participants undergoing training for a single exercise with a high number of repetitions would show larger and faster gains in strength compared with participants undergoing training on three exercises with fewer repetitions (per exercise).

*Question 4: Were strength gains maintained after exercise was discontinued?* It was hypothesized that, similar to expiratory and limb muscle groups, the lingual musculature would demonstrate measurable detraining effects but that strength would not return to baseline within 4 weeks of detraining.

# Methods

## Participants

Thirty-nine healthy adults participated in the study (17 males and 22 females, $M$ = 37.8 years, range = 18–67 years). All participants had negative histories for speech or swallowing impairment. A screening conducted prior to beginning the training study verified that all participants demonstrated adequate orofacial structure and function for completing the assessment and training tasks. Specifically, all participants exhibited dentition capable of stabilizing a small block between the molars, bilaterally, and between the incisors. Additionally, all participants exhibited lingual range of motion adequate to exert pressure against the palate, lateral molars, and incisors. Finally, all participants exhibited normal lingual elevation strength as evidenced by lingual elevation pressures within the range described in previous studies involving healthy adults (Solomon & Munson, 2004; Youmans & Stierwalt, 2006).

Participants were assigned to the sequential ($n$ = 29) or concurrent ($n$ = 10) training condition. This proportion was selected to equalize the number of participants within each of the three sequential exercise conditions and the one concurrent exercise condition (see Procedures section). Randomization of assignment was achieved by designating assignments 1–10 as concurrent training, and assignments 11–20, 21–30, and 31–39 as the respective sequential training conditions. A random number generator was then utilized to assign each participant a number (1–39) that thus specified the assigned training condition.

Two participants (1 male, 1 female) participated in the first 3-week exercise block only. One of these participants developed a tooth abscess causing significant pain associated with exercise. The other participant's schedule would not accommodate the time commitment required for the experiment.

## Procedures

The experimental procedures were approved by the Institutional Review Board. Participants were made aware of the purpose of the study, but specific information about which muscle groups were of highest interest was withheld; participants knew only that they would be randomly assigned to an exercise condition and that training protocols would vary across participants. Volunteer compensation ($50.00) was based solely on participation, not on amount of strength gained.

Training consisted of three lingual exercises involving elevation, protrusion, or lateralization. The elevation exercise required pressing the tongue against the hard palate, just posterior to the alveolar ridge with maximum effort. During the elevation exercise, the jaw was in a neutral position with the lips closed or slightly parted. Protrusion exercises utilized a tongue blade positioned between the upper and lower incisors. The participants pushed the tongue forward against the tongue blade. Participants were instructed to use their fingers as necessary to provide additional stabilization to the tongue blade (see Figure 1). Similarly, a tongue blade was positioned between the upper and lower premolars for the lateralization exercise (Figure 2), with participants instructed to push against the blade with the side of the tongue. Each repetition involved a contraction sustained approximately 1 s and repeated at a comfortable rate, typically 1½–2 s per repetition.

Under all conditions, participants completed 30 repetitions of lingual exercise 7 days per week. Participants were instructed to complete exercises in sets of 10 repetitions with a brief rest interval between each of the three sets. Participants in the sequential training group performed three sets of 10 elevation, protrusion, or lateralization exercises. Lateralization exercises were performed

**Figure 1.** Protrusion exercises utilizing a tongue blade. The tongue blade is positioned between the incisors with additional stability provided by the finger.

five times on the right and five times on the left during each set. Participants completed a single exercise for 3 weeks, followed by 3 weeks of the second exercise and then 3 weeks of the final exercise, for a total of 9 weeks of training. Order of exercise (elevation, protrusion, and lateralization) was counterbalanced across participants.

Participants in the concurrent training group performed one set each of 10 elevation, protrusion, and lateralization exercises each day. These participants completed all three exercises concurrently for the entire 9-week training period.

Initial training took place during the final baseline assessment session. Participants were instructed in how to complete all three exercises but were cautioned that they might not be assigned all of the exercises in any one training block. Because the exercises closely matched the assessment measures (see *Dependent Measures* section), extensive training was not required for participants to demonstrate correct execution of all exercises. In addition to the initial training, examiners reviewed all exercises with the participants each week and asked the participants to demonstrate how they were completing the exercise(s). Appropriate corrective feedback was provided as necessary; however, such feedback was rarely required. All participants maintained exercise logs that were submitted to the examiners each week.

**Figure 2.** Lateralization exercises utilizing a tongue blade. The tongue blade is positioned between the molars with additional stability provided by the finger.

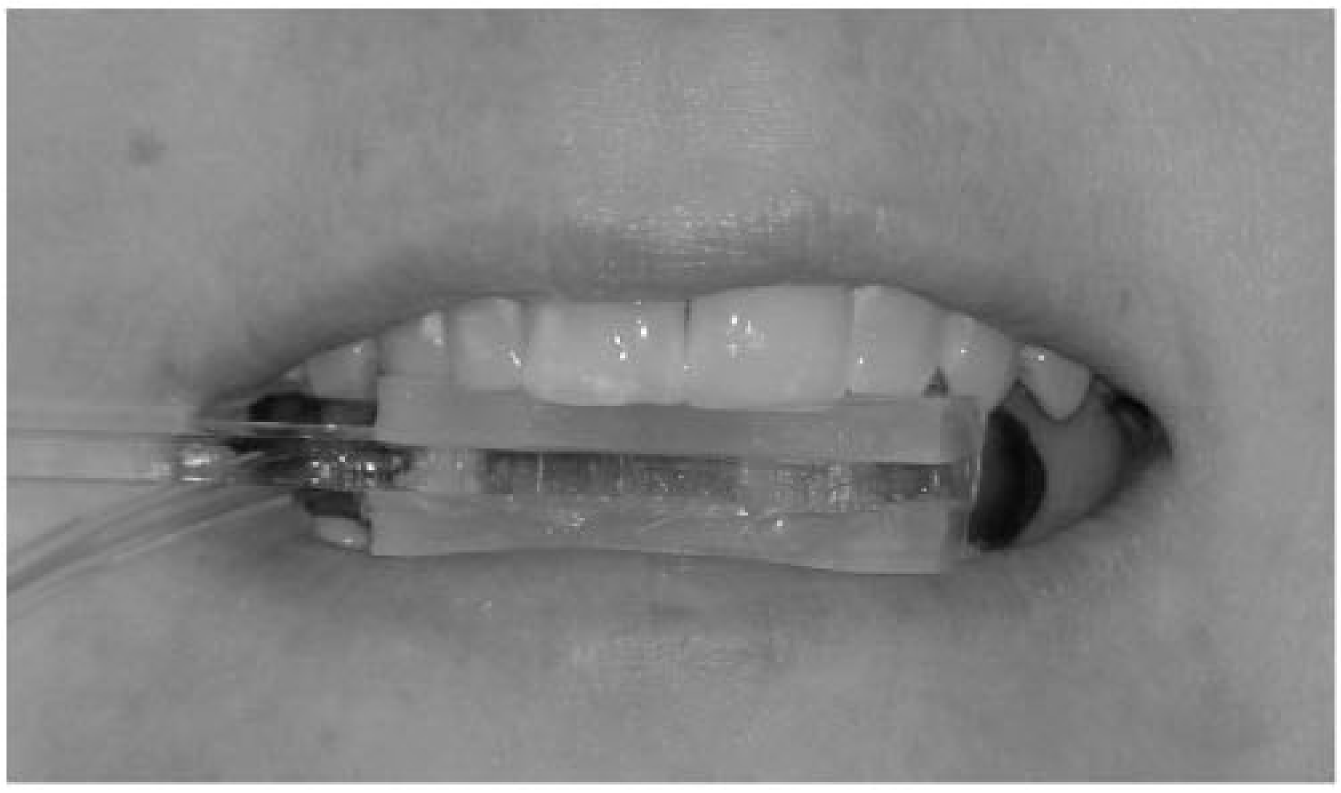
Nineteen participants volunteered to complete the detraining protocol. Because no additional compensation was available to those who returned for final testing, many participants declined to participate in the detraining protocol. Lingual strength measures were obtained from these participants an average of 23.2 days (range = 18–31 days) following discontinuation of exercise.

## Dependent Measures

Measures of lingual strength obtained during elevation, protrusion, and lateralization were the primary outcomes of interest. Secondary outcome measures of buccal strength were also obtained as an untrained control condition.

The strength measures were obtained using the Iowa Oral Performance Instrument (IOPI Northwest, Carnation, WA; Blaise Medical, Nashville, TN), which measures pressure generated against a soft, air-filled bulb. Lingual elevation strength was obtained using standard IOPI procedures (Robin, Somodi, & Luschei, 1991) with the bulb positioned longitudinally along the hard palate. Participants were instructed to elevate the tongue against the bulb with maximum effort. The maximum peak pressure generated across three trials was recorded as the strength measure. For the lingual protrusion and lateralization measures, the IOPI bulb was attached to a tongue-bulb holder (Clark, Solomon, O'Brien, Calleja, & Newcomb, 2008). This holder provides a firm, smooth surface to which the bulb is attached with double-sided surgical tape. It also includes a cushioned bite surface, made from medical-grade silicone rubber, upon which the teeth rest to provide stability to the holder. For tongue lateralization, the holder is positioned between the upper and lower premolars with the tongue bulb facing medially toward the tongue (see Figure 3). Participants were instructed to push the tongue to the side against the bulb with maximum effort. Similarly, for the protrusion measures, the holder was positioned between the upper and lower incisors with the tongue bulb placed toward the tongue (see Figure 4). Finally, the control measure of cheek strength was obtained with the bulb holder in the lateral position, with the modification of the bulb facing

**Figure 3.** Lingual protrusion strength measure. The participant pushes the tongue forward against the Iowa Oral Performance Instrument (IOPI) bulb secured to the lateral bulb holder.



laterally toward the buccal surface (see Figure 5). For this measure, participants were instructed to squeeze the bulb with the cheek with maximum effort. All trials were "motivated," with the examiner cheering "Push, push, push!" or "Squeeze, squeeze, squeeze!" For all measures, the maximum value across three trials was used. No feedback was provided to the participants regarding the strength measures recorded.

Strength measures were obtained on three separate occasions prior to training, to establish a stable baseline. The average interval between baseline measures was 4.3 days (*SD* = 2.8; range = 1–14 days). Although mean strength did not differ significantly across the baselines for any of the measures, the third baseline showed a trend to be numerically highest (Clark, Solomon, Newcomb, O'Brien, & Calleja, 2007). Thus, to minimize the contribution of learning effects, the third baseline measure for each participant was included in the final analyses. Strength measures were also obtained during each of the 9 weeks of training, with the measures obtained at the end of each 3-week training block included in the analyses addressing the research questions. Finally, measures of lingual strength were obtained following detraining for a subset of the participants. Examiners obtaining the strength measures were blinded to the participants' assigned training condition.

**Figure 4.** Lingual lateralization strength measure. The participant pushes the tongue laterally against the IOPI bulb secured to the lateral bulb holder.

**Figure 5.** Cheek compression strength measure. The participant squeezes the cheek inward against the IOPI bulb secured to the lateral bulb holder.

## Design and Statistical Analyses

Effects of training were examined with a repeated-measures analysis of variance (ANOVA). Independent variables included three within-subject variables: Movement assessed (e.g., lingual elevation, protrusion, lateralization, and cheek compression), exercise condition (e.g., elevation, protrusion, or lateralization exercises), and training point (e.g., baseline, 9-week training point, or detraining). The between-subjects variable was training condition (e.g., sequential or concurrent). The dependent measure was amount of pressure exerted during the movement (see earlier in this paragraph). A significance level of $p$ = .008 was selected for all statistical analyses to accommodate six significance tests across the four research questions.

# Results

## Participant Compliance

The examiners reviewed the training logs submitted by the participants each week. Twenty-four of the participants (61.5%) reported 100% compliance. Thirteen participants (33.3%) reported missing between 1 and 5 training days across the 9-week training period. In these cases, the training days missed did not number more than two in a given week or more than four within a 3-week training block. The remaining 2 participants reported missing 11 and 16 training days. The performance of these two participants was visually inspected and found to be consistent with the overall pattern of findings described in the sections that follow; thus, the data from these participants were included in the final analyses.

## Preliminary Analyses

Preliminary analyses were conducted to determine whether strength measures differed for right and left lingual lateralization and for right and left cheek lateralization. Separate repeated-measures $t$ tests revealed no significant differences between right and left tongue lateralization, $t(167) = 0.99$, $p = .324$, or right and left cheek compression, $t(167) = 1.8$, $p = .06$. Thus, all remaining analyses utilized a single lateralization and cheek compression measure computed by averaging the right and left measures for the respective variables.

## Training Effects

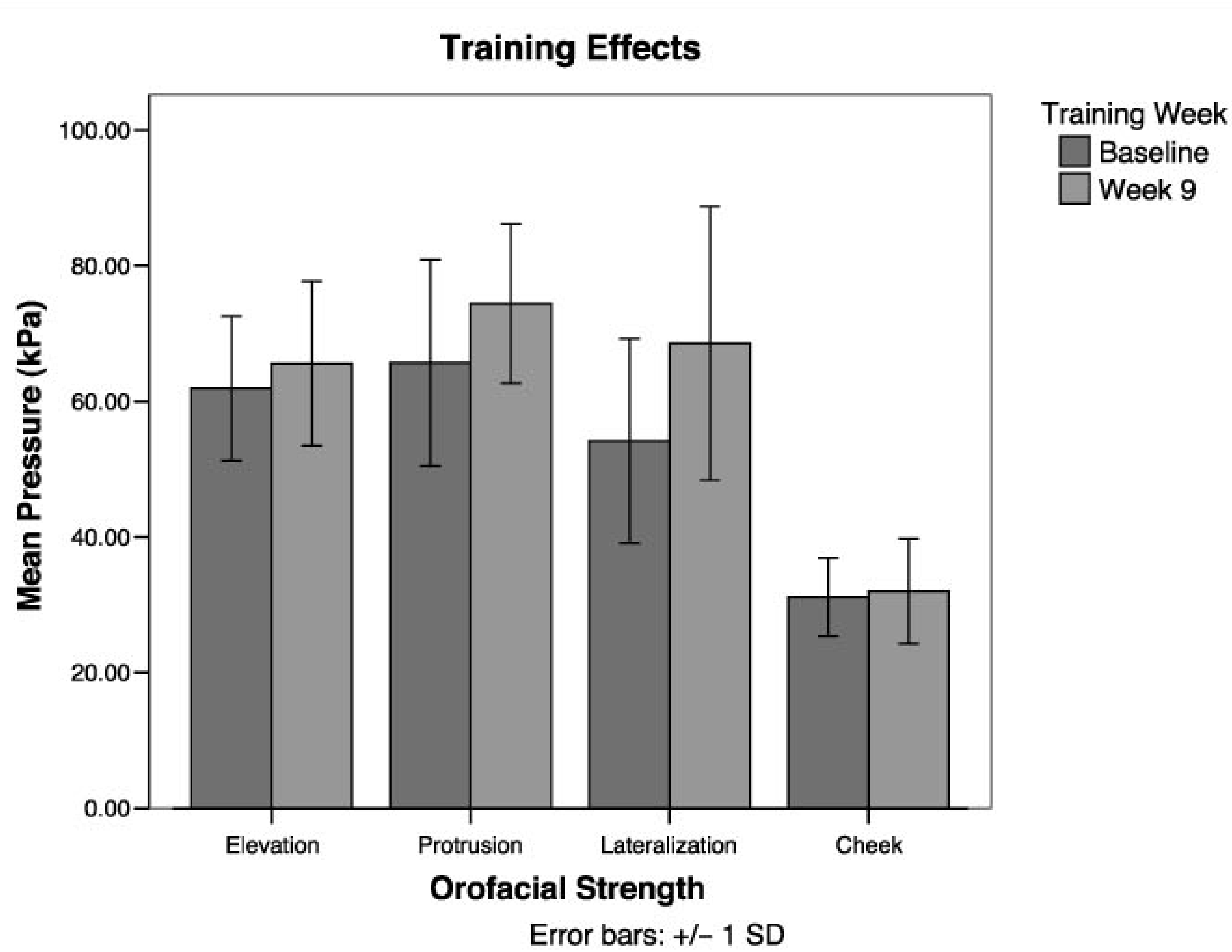
The first research question addressed the effects of 9 weeks of lingual exercise on orofacial strength. The repeated-measures ANOVA revealed significant main effects of training, $F(1, 36) = 58.6$, $p < .001$, and measure type, $F(3, 108) = 147.9$, $p < .001$, as well as significant interaction effects, $F(3, 108) = 42.0$, $p < .001$.

Figure 6 illustrates that although significant increases in strength were observed for all three lingual measures, the size of increase varied across measures. Post hoc analyses of the changes in lingual strength revealed that the 6% change in elevation strength—while significant, $t(36) = 3.47$, $p < .001$—was of lesser magnitude than the changes observed in lingual lateralization and protrusion, which increased by an average of 26.6%, $t(36) = 6.52$, $p < .001$, and 13.4%, $t(36) = 4.86$, $p < .001$, respectively. The degree of strength change of lateralization and protrusion did not significantly differ. Cheek compression strength did not increase significantly during the 9-week training period, $t(36) = 0.97$, $p = .340$.

## Specificity Effects

Two hypotheses were tested with respect to specificity of training. First, to examine the effects of exercise condition (elevation training, protrusion training, and lateralization training) on overall lingual strength, data from baseline and the third weeks of training for each

**Figure 6.** Each of the lingual strength measures increased following 9 weeks of training. Cheek compression strength remained unchanged.



exercise were subjected to individual paired $t$ tests. Data from the concurrent training group were not included in this analysis. Each of the training conditions resulted in overall lingual strength increases, as detailed in Table 1.

To further assess specificity of training, the elevation, protrusion, and lateral strength measures were subjected to repeated-measures ANOVAs. Of particular interest to this research question were main effects of exercise condition, identifying if any one exercise was most effective for increasing lingual strength, and the Exercise Condition × Measure Type interaction, revealing whether each exercise had differential effects on the various lingual strength measures. Neither a significant main effect of exercise condition, $F(2, 56) = 0.013$, $p = .987$, nor a significant interaction effect, $F(4, 112) = 0.993$, $p = .415$, was observed. Figure 7 illustrates that the increases for the strength measures did not differ according to which exercise was trained.

## Training Condition Effects

The third question addressed the effects of completing the three exercises individually in sequential 3-week training blocks versus a single 9-week block in which all three exercises were completed concurrently. An independent-sample $t$ test was conducted on the strength measures obtained at the end of training to determine the effects of training condition. Post-training strength measures did not differ for sequential versus concurrent training, $t(37) = -0.397$, $p = .694$.

We hypothesized that training participants on a single exercise at a higher number of repetitions would increase strength of the targeted movement more efficiently than training them on multiple exercises simultaneously. To test this hypothesis, the data obtained at Training Week 3 were analyzed to compare the mean strength of participants undergoing training on only one of the exercises with that of the participants undergoing training on all three exercises. Separate $t$ tests were conducted on the data pairs, revealing no significant effects of training condition on lingual elevation, $t(38) = 0.182$, $p = .67$; protrusion, $t(38) = 4.38$, $p = .04$; or lateralization, $t(38) = 0.345$, $p = .56$. Figure 8 illustrates that although the condition effect approached significance for lingual protrusion, the difference was actually in the opposite direction than hypothesized. Training participants on all three exercises concurrently resulted in numerically higher protrusion strength scores than training participants on protrusion in isolation.

## Detraining Effects

The final research question considered the effects of detraining. A repeated-measures ANOVA revealed a significant main effect of detraining, $F(2, 112) = 12.06$, $p < .001$. Follow up contrasts revealed that strength measures were significantly greater immediately post-training relative to measures obtained at baseline and after training was discontinued. Baseline and detraining measures did not differ significantly (see Figure 9).

# Discussion

The present study revealed that healthy adults demonstrated substantial gains in lingual strength after 9 weeks of strength training. Because the experiment included weekly strength measures of an untrained movement (cheek compression) that did not change over the training period, the observed lingual strength increases do not appear to be attributable solely to learning effects or to overall energizing effects. That the amount of strength gained would vary so greatly across the various lingual measures was not predicted a priori.

The gains observed for lingual protrusion and lateralization (13.4% and 26.6%, respectively) were consistent with previous findings. In earlier studies, young healthy adults increased lingual elevation strength by 12% (Lazarus et al., 2003) and 27% (Clark et al., 2004) after 1 month of training, whereas healthy elders demonstrated 17% gains after 6 weeks of training. Surprisingly,

**Table 1.** Exercise condition effects: Overall lingual strength at baseline versus 3 weeks of training with elevation, protrusion, or lateralization exercise.

| Variable | Baseline | Elevation training | Protrusion training | Lateralization training |
|---|---|---|---|---|
| Mean lingual strength (kPa) collapsed across measures[a] | 59.63 (14.12) | 66.65 (14.5) | 66.46 (14.13) | 66.45 (14.91) |
| Range (kPa) | 34.3–88.0 | 55.0–77.0 | 49.0–76.0 | 52.0–95.0 |
| $t$ (86) | n/a | 6.26 | 5.29 | 5.51 |
| $p$ | n/a | .000 | .000 | .000 |

*Note.* n/a = not applicable.

[a]Values in parentheses indicate standard deviations.

**Figure 7.** The lower bars depict hypothetical findings consistent with the presence of specificity effects. The actual results depicted in the upper bars do not demonstrate a specificity effect, as the degree of strengthening observed for each of the lingual movements was not influenced by the specific exercise completed.

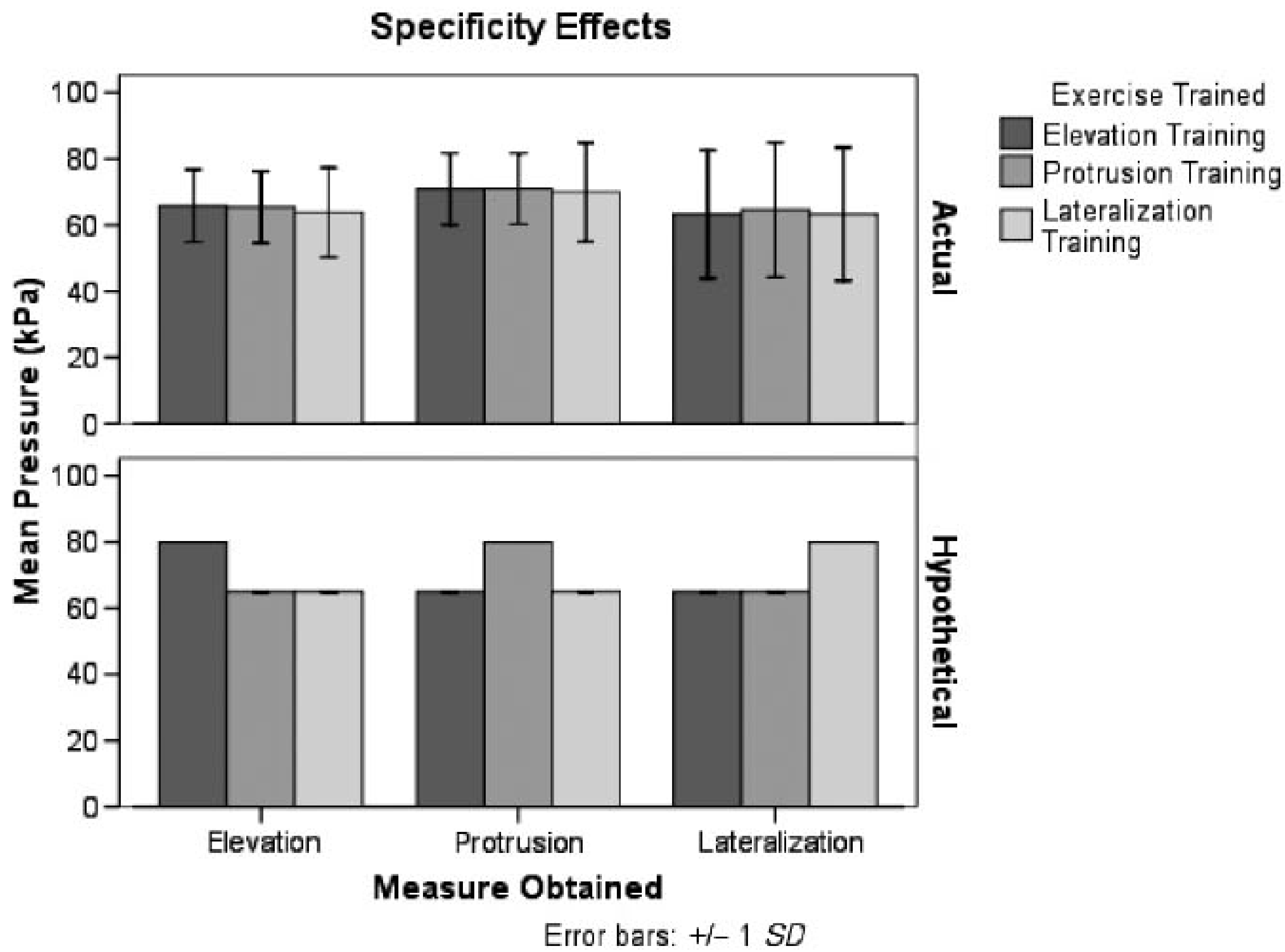



**Figure 8.** Sequential (isolated) and concurrent (combined) exercise increased each lingual strength measure similarly.

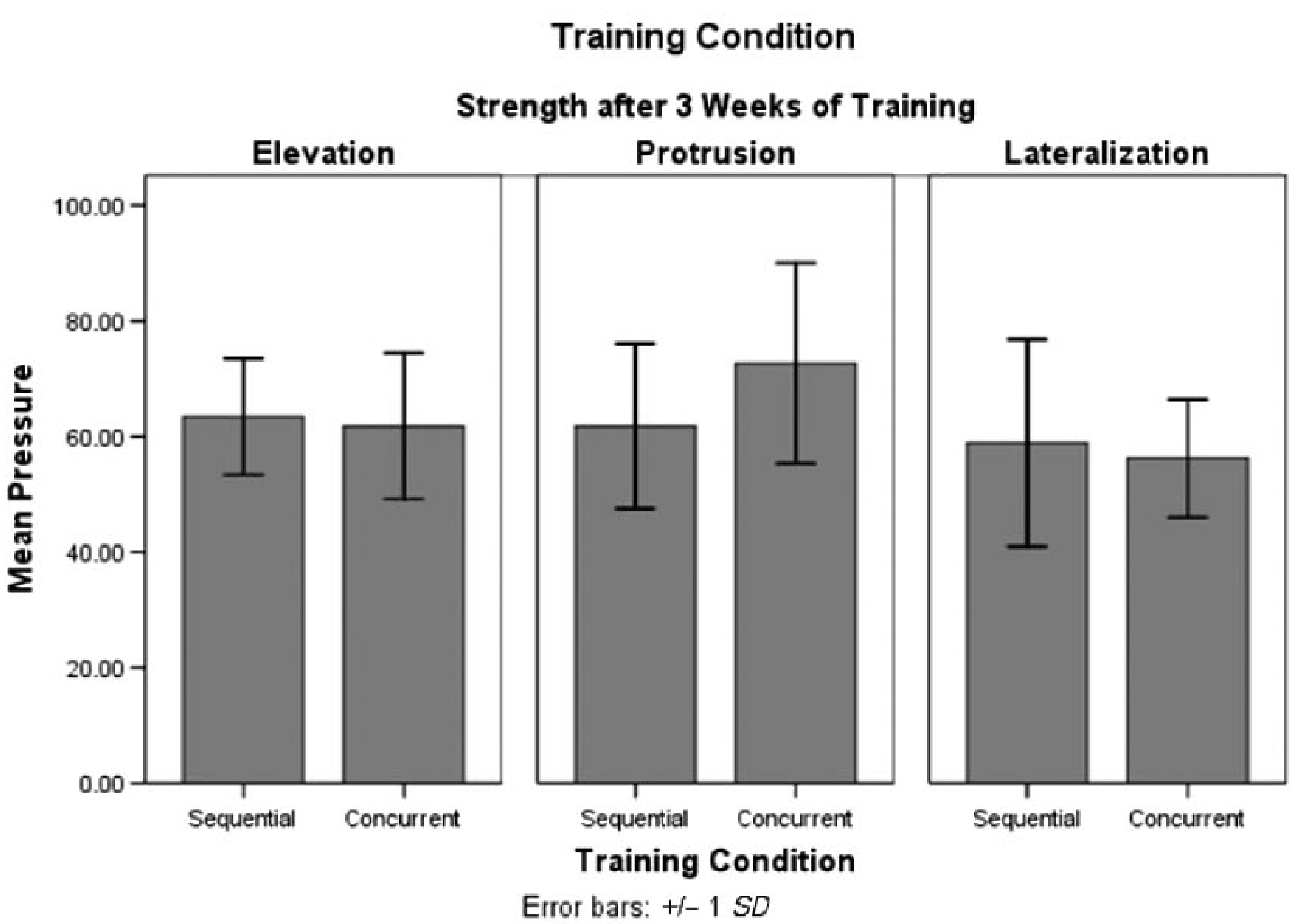
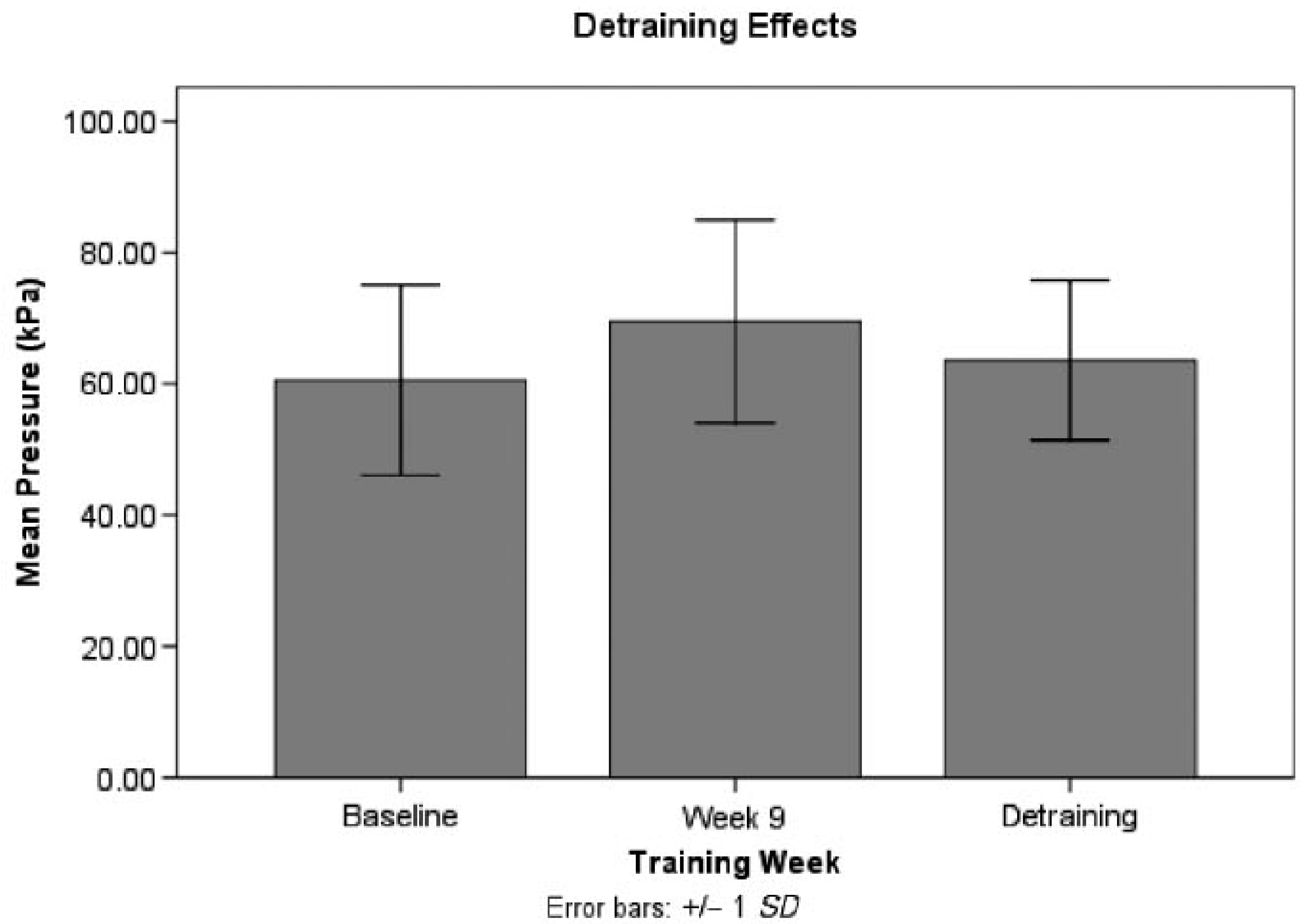


**Figure 9.** Detraining effects. Lingual strength, averaged across all measures, significantly decreased during the detraining period. Strength measures obtained at baseline and following detraining were not significantly different.




participants in the present study demonstrated only 6% gains in lingual elevation strength, which was not only less than gains noted by previous researchers but was also considerably less than the gains demonstrated for other lingual movements in this study. No immediate explanation is available for this pattern of results. The training protocol in the present study differed slightly from previous lingual training studies. Participants in the Lazarus et al. (2003) study completed lingual exercise 5 days per week, whereas participants in the Clark et al. (2004) study exercised 3 days per week. In the present study, participants exercised every day. It is possible that the muscles primarily responsible for lingual elevation (e.g., genioglossus, styloglossus) respond better to a lower-dose treatment protocol than was utilized in this experiment. Because measures of protrusion and lateralization strength were not obtained in the earlier studies, it is unknown if similar dosage effects exist for these exercises. Future research may reveal differential dosage effects for individual articulators as well as different movements of single articulators.

## Training Specificity

We hypothesized that training participants on a single exercise would increase strength of all lingual movements and that the largest gains in strength would be observed for the trained movement. Only the first of these hypotheses was supported by our findings. Although all of the exercises increased overall lingual strength equally, none of the lingual strength measures were preferentially affected by targeted exercise. In fact, for lingual protrusion and lateralization, had the differential effects proven statistically significant, the direction of the differences would not have been in the predicted direction. Our findings failed to provide evidence of training specificity for the lingual movements targeted.

Our findings are consistent with the view that the biomechanical properties of the lingual musculature may allow these muscle groups to demonstrate training patterns atypical of other skeletal muscles with respect to specificity. The present study provides explanatory power for the findings of other researchers demonstrating that lingual strengthening improves swallowing function (Robbins et al., 2007). Although a number of studies have demonstrated a relationship between lingual strength and swallowing function (e.g., Clark, Henson, Barber, Stierwalt, & Sherrill, 2003; Reddy, Costarella, Grotz, & Canilang, 1990; Robinovitch, Herschler, & Romilly, 1991), Clark et al. (2003) found that strength ratings incorporating tongue movements in several directions, including elevation, protrusion, and lateralization, better predicted oral phase swallowing function than did strength measures obtained during lingual elevation alone. The current findings suggest that lingual protrusion and lateralization may show greater strength gains in response to training compared with lingual elevation. Thus, although the Robbins et al. (2007) study did not measure lingual protrusion and lateralization strength, we might speculate that the strength of these movements also increased during training and that perhaps these gains were more dramatic than those noted for elevation. Taken together with the Clark et al. (2003) findings, it might be predicted that the gains in overall lingual strength, including elevation, protrusion, and lateralization, would more adequately account for improved swallowing function than increases in lingual elevation strength alone.

Additional research is needed not only to replicate the current findings but also to explore other training contexts where specificity might be observed for lingual muscles. For example, it is a well-established specificity principle that strength and endurance require unique training protocols (Kutz, 2002), a principle that our laboratory has begun to examine with respect to training the lingual musculature (Clark et al., 2004).

## Isolated Versus Combined Exercise

One of the goals of the present study was to explore whether the exercise conditions typical of clinical practice and of lingual exercise research result in similar training effects. We found that training participants on a single exercise at a high repetition rate, typical of research protocols (Robbins et al., 2005, 2007) and training multiple exercises at a lower repetition rate per exercise, typical of clinical practice, resulted in similar strength gains. This finding is consistent with those of Lazarus et al. (2003), who reported gains in lingual elevation strength when healthy young adults completed 4 weeks of elevation, protrusion, and lateralization exercises. The present study expands on this earlier study by reporting strength increases for protrusion and lateralization, which were not measured by Lazarus et al.

The fact that participants in both training groups demonstrated similar strength gains lends support to the ecological validity of earlier studies using a single exercise, thus providing clinicians with more sound rationale for generalizing the training outcomes reported by Robbins et al. (2005, 2007) to the more typical clinical practice of using multiple lingual exercises. This is particularly relevant for patients who may find a variety of lingual exercise more interesting and/or tolerable than a single exercise and may thus be more compliant with training protocols. Conversely, the current findings suggest that even when only a single tongue exercise is utilized, generalized gains in lingual strength may be expected. This is pertinent for patients whose cognitive limitations may preclude a complex exercise protocol. In sum, these findings, particularly if replicated in patient populations, may provide clinicians with more treatment options.

## Detraining

A critical issue in rehabilitation is the retention of skills and abilities gained as a result of intervention. This is of particular concern for strength training, where gains result specifically from requiring muscle groups to exert forces beyond what is necessary for everyday movements. Given the demonstrated relationships between lingual strength and swallowing function (Clark et al., 2003; Reddy et al., 1990; Robinovitch et al., 1991; Youmans & Stierwalt, 2006) and the finding that increasing lingual strength can improve swallowing function (Robbins et al., 2007), it is relevant to question the nature of detraining effects in the lingual musculature and the potential impact of detraining on swallowing function.

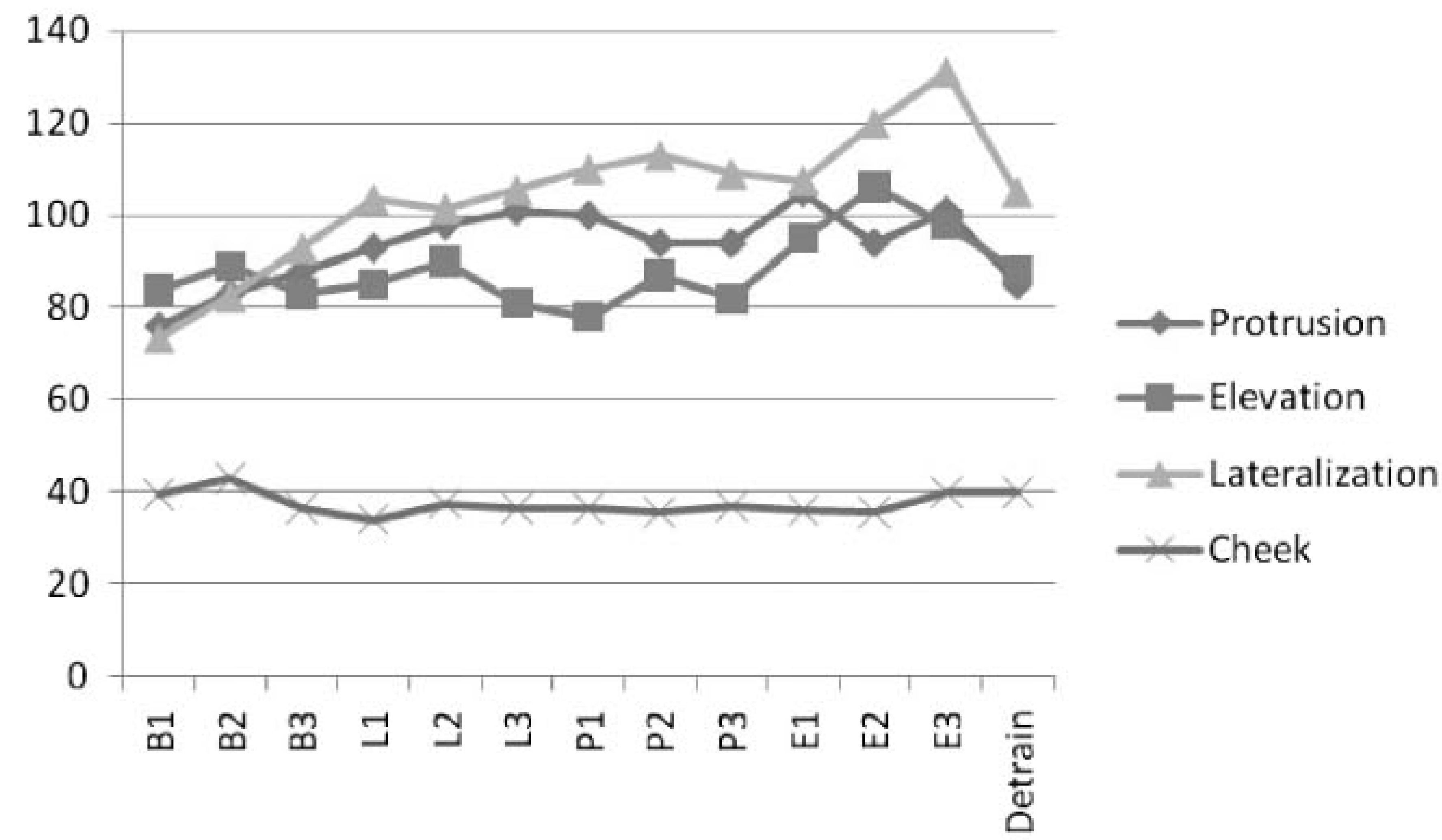
In the present study, participants demonstrated significant decreases in lingual strength in the weeks following the discontinuation of training. Although strength measures remained numerically higher than pre-training measures, this difference did not reach statistical significance. These findings suggest that the lingual musculature is susceptible to detraining effects and that these effects may be greater than those observed for other muscle groups contributing to speech and swallowing (Baker et al., 2005). It is unknown (a) whether the detraining effects observed in the present study of healthy adults are typical of patients with lingual weakness who undergo strength training or (b) how detraining impacts any functional gains resulting from training (e.g., Robbins et al., 2007). The current findings suggest that both researchers and clinicians should be mindful of potential detraining effects when designing intervention protocols.

## Performance of Individual Participants

The design of the experiment allowed us to approach the analysis of data from individual participants in the sequential exercise group from the perspective of single-subject multiple baseline design. Figure 10 depicts the performance pattern of a participant who completed the exercises in sequence. The strength measures obtained during each of the 9 weeks of training illustrate how performance changed as specific exercises were introduced or removed. For this participant, lingual elevation strength appears to remain unchanged until elevation exercise is introduced, at which point an increase in strength is noted. Similar evidence of training specificity is not apparent for lingual protrusion or lateralization strength. It is of interest to note that this participant, a 54-year-old female, demonstrated among the highest strength measures obtained from the participants following training.

The performance of a participant who completed all three exercises concurrently is depicted in Figure 11. What is unusual about this participant's performance is that lingual elevation strength remained greater than lingual lateralization strength throughout the course of training. For nearly every participant, even when lingual elevation elicited greater pressures at baseline, lingual

**Figure 10.** Performance of Participant 14. This participant was assigned to the sequential training condition with lateralization exercised for 3 weeks (L1, L2, and L3) followed by 3 weeks each of protrusion and lateralization.



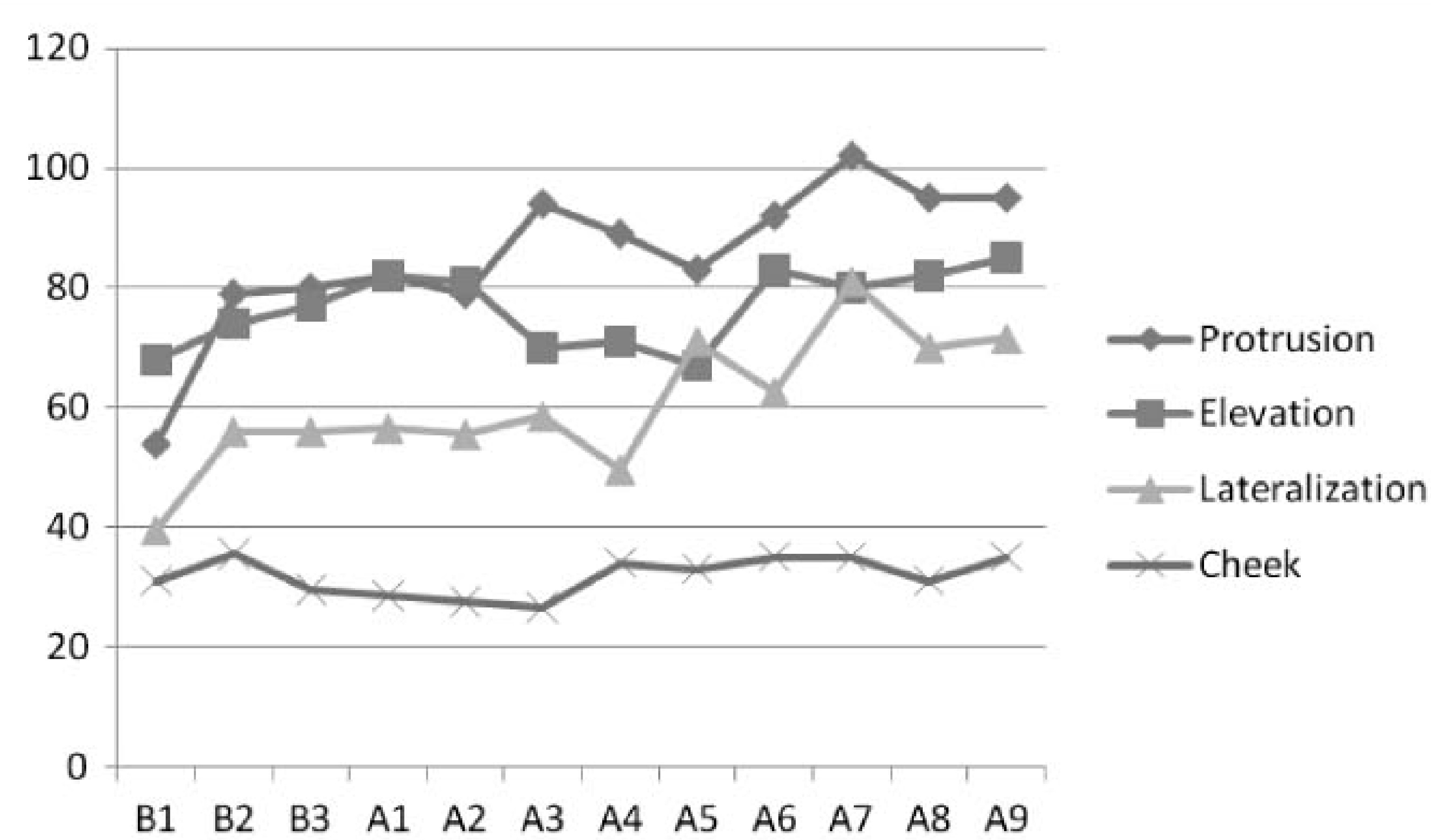

protrusion and lateralization pressures exceeded those of elevation at the end of training.

With respect to detraining, none of the participants maintained the levels of performance noted at the end of the 9th week of training. Because the length of the detraining period varied across participants, a correlational analysis was conducted to determine if length of detraining predicted the degree of detraining. A correlation of .263 was obtained, suggesting that the detraining interval did not substantially contribute to variations in detraining effects.

## Limitations of the Experiment

Although care was taken to limit bias as much as possible, at least two potential sources of bias were identified. First, although examiners were blinded to the training condition of each participant, they were aware of the number of weeks of training that had been completed at each measuring point. Bias may have been introduced in the form of the examiners expecting higher strength scores later in the training program. Examiners were also aware that cheek exercises were not

**Figure 11.** Performance of Participant 39. This participant was assigned to the concurrent training condition, performing elevation, protrusion, and lateralization exercises for the entire 9-week training period.



conducted and may thus have expected these strength measures to remain unchanged. Because each examiner evaluated several participants each week and because each week's measurements were documented on individual recording sheets, these sources of bias were limited although not eliminated. Utilizing an objective measure of lingual strength with high inter- and intrajudge reliability (Clark et al., 2003) further reduced the potential for examiner bias to influence the findings.

Similarly, because participants were not blinded to the purpose of the experiment or to their assigned training condition, it is possible that the results were distorted by the participants intentionally exerting lower pressures at specific measuring points. Such effects were minimized by withholding information about which measurements were relevant to the experiment and by blinding participants to their own measurements until the experiment was completed. Nonetheless, participant bias effects cannot be ruled out.

An issue related to bias is participant motivation. Although all participants were compensated at the same rate and provided with the same instructions and encouragement, it was apparent to the examiners that some participants were extremely enthusiastic about the experiment and even seemed to approach the training with a competitive attitude. Although these subjective impressions were not quantified in the present study, it is possible that motivation both to complete exercise at the requested intensity level and to perform maximally during the assessment sessions could contribute to individual variation in performance and influence the overall findings.

Participant compliance was monitored solely through self-report. Although training fidelity would have been more readily ensured had the participants completed the exercises under supervision (e.g., Clark et al., 2004), it is typical of clinical and research protocols for strength training to be conducted as part of a home program (Baker et al., 2005; Lazarus et al., 2003; Robbins et al., 2005, 2007). Research examining differential effects of supervised versus unsupervised exercise would be a valuable contribution to the lingual strength training literature.

A crucial component of any experimental design is experimental control. The control measure utilized in the current experiment was cheek compression strength. This behavior was measured each week, but participants were not actively trained on it. Because cheek strength did not change over multiple assessment periods, it was concluded that the observed changes in lingual strength did not reflect solely a practice effect arising from multiple assessments. Unfortunately, because it has yet to be established whether cheek compression strength can be increased by intentional training, any lack of change cannot be clearly interpreted. An alternative control that might have been instituted is a no-training condition in which a group of participants underwent weekly assessment of all measures but did not perform any exercise. Clark et al. (2004) found that lingual elevation strength did not significantly increase in 5 participants who were assessed once per week for 8 weeks, but similar control data are not available for lingual protrusion or lateralization strength.

## Implications for Speech and Swallowing Treatment

The present study was motivated by a desire to better understand the physiologic effects of lingual strength training, an intervention commonly employed to improve speech and swallowing function of individuals with and without demonstrated weakness (Lof & Watson, 2008). Theoretical and empirical support for this practice varies, depending on whether the treatment target is speech or swallowing function.

With respect to speech, it is commonly acknowledged that the forces produced during articulatory gestures are quite small relative to those produced during maximum voluntary contractions (see Kuehn & Moon, 2000, for review). Although Luschei (1991) argued that significant lingual strength is required to move the tongue with the velocities typical of speech movements, empirical study has failed to demonstrate a clear relationship between lingual strength and speech performance (see Clark, 2003, for review), even in the case of dysarthria (Solomon, Clark, Makashay, & Newman, 2008). Moreover, systematic reviews of the literature have failed to reveal treatment literature demonstrating improved speech function as a result of strength training (Arvedson et al., 2007).

In contrast, converging evidence suggests that lingual strength may be a more appropriate treatment target for individuals with dysphagia. Not only is the relationship between lingual strength and swallowing function more clearly described (Clark et al., 2003; Youmans & Stierwalt, 2006), but at least one efficacy study has revealed both physiologic and functional improvements in deglutition following lingual strength training (Robbins et al., 2007).

The present study addressed very specific research questions related to the changes in strength demonstrated by healthy participants in response to specific training protocols. The findings do not speak to whether the performance of healthy adults is typical of those with orofacial weakness. Moreover, the findings in no way suggest that the exercises studied impacted the speech and swallowing function of the participants. Thus, although the findings may inform the design of future clinical trials, the present study is most appropriately considered an exploratory study of intervention principles, not a treatment study (Arvedson et al., 2008).

## Conclusions

As speech-language pathologists are urged to consider the theoretical foundations of strength training (e.g., Burkhead et al., 2007; Clark, 2003), it is critical that the training principles arising from exercise and rehabilitation sciences are tested on the unique physiology of the speech and swallowing musculature. Many training principles, particularly those developed from motor learning models (Schmidt & Lee, 1998; Schmidt & Wrisberg, 2000), are proving applicable to speech and swallowing rehabilitation (e.g., Adams & Page, 2000; Knock, Ballard, Robin, & Schmidt, 2000; Maas, Barlow, Robin, & Shapiro, 2002). The current findings demonstrating unique exceptions to accepted training principles provide strong rationale for careful study of these principles in healthy adults and children as well as in those with speech and swallowing impairments.

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## References

**Adams, S. G., & Page, A. D.** (2000). Effects of selected practice and feedback variables on speech motor learning. *Journal of Medical Speech-Language Pathology, 8,* 215–220.

**Andersen, L. L., Andersen, J. L., Magnusson, S. P., & Aagaard, P.** (2005). Neuromuscular adaptations to detraining following resistance training in previously untrained subjects. *European Journal of Applied Physiology, 93*(5–6), 511–518.

**Arvedson, J., Clark, H. M., Lazarus, K., Lof, G., McCauley, R., Strand, E., et al.** (2007, November). *The effectiveness of oral-motor exercises: An evidence-based systematic review.* Seminar presented at the Annual Convention of the American Speech-Language-Hearing Association, Boston, MA.

**Baker, S., Davenport, P., & Sapienza, C.** (2005). Examination of strength training and detraining effects in expiratory muscles. *Journal of Speech, Language, and Hearing Research, 48,* 1325–1333.

**Barlow, S. M., & Farley, G. R.** (1989). Neurophysiology of speech. In D. P. Kuehn, M. L. Lemme, & J. M. Baumgartner (Eds.), *Neural bases of speech, hearing, and language* (pp. 146–200). Boston: College-Hill.

**Blazevich, A. J.** (2006). Effects of physical training and detraining, immobilisation, growth and aging on human fascicle geometry. *Sports Medicine, 36,* 1003–1017.

**Burkhead, L. M., Sapienza, C. M., & Rosenbek, J. C.** (2007). Strength-training exercise in dysphagia rehabilitation: Principles, procedures, and directions for future research. *Dysphagia, 22,* 251–265.

**Cerny, F., Sapienza, C., Lof, G., & Robbins, J.** (2007, November). *Muscle training principles and resulting changes to speech and swallowing*. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, Boston, MA.

**Clark, H. M.** (2003). Neuromuscular treatments for speech and swallowing: A tutorial. *American Journal of Speech-Language Pathology, 12,* 400–415.

**Clark, H. M., Barber, W. D., & Irwin, W.** (2004, March). *Specificity of training in the lingual musculature*. Paper presented at the Biennial Conference on Motor Speech, Albuquerque, NM.

**Clark, H. M., Henson, P. A., Barber, W. D., Stierwalt, J. A. G., & Sherrill, M.** (2003). Relationships among subjective and objective measures of tongue strength and oral phase swallowing impairments. *American Journal of Speech-Language Pathology, 12,* 40–50.

**Clark, H. M., Solomon, N. P., Newcomb, S., O'Brien, K., & Calleja, A.** (2007, November). *Stability of orofacial strength measures*. Paper presented at the Annual Convention of the American Speech-Language-Hearing Association, Boston, MA.

**Clark, H. M., Solomon, N. P., O'Brien, K., Calleja, A., & Newcomb, S.** (2008, March). *Lingual and buccal strength: Innovations in clinical assessment*. Poster presented at the Biennial Conference on Motor Speech, Monterey, CA.

**Elliott, K. J., Sale, C., & Cable, N. T.** (2002). Effects of resistance training and detraining on muscle strength and blood lipid profiles in postmenopausal women. *British Journal of Sports Medicine, 36,* 340–344.

**Gangale, D. C.** (2001). *The source for oral-facial exercises*. East Moline, IL: Linguisystems.

**Jones, N. L., McCartney, M., & McComas, A. J.** (1986). *Human muscle power.* Champagne, IL: Human Kinetics.

**Knock, T. R., Ballard, K. J., Robin, D. A., & Schmidt, R. A.** (2000). Influence of order of stimulus presentation on speech motor learning: A principled approach to treatment for apraxia of speech. *Aphasiology, 14,* 653–658.

**Kuehn, D. P., & Moon, J. B.** (2000). Induced fatigue effects on velopharyngeal closure force. *Journal of Speech, Language, and Hearing Research, 43,* 486–500.

**Kutz, M. R.** (2002). Strength training for sports performance. *Fitness Management,* 34–37.

**Lazarus, C., Logemann, J. A., Huang, C. F., & Rademaker, A. W.** (2003). Effects of two types of tongue strengthening exercises in young normals. *Folia Phoniatrica et Logopaedica, 55,* 199–205.

**Lof, G., & Watson, M.** (2008). A nation-wide survey of nonspeech oral motor exercise use: Implications for evidence-based practice. *Language, Speech, and Hearing Services in Schools, 39,* 392–407.

**Luschei, E. S.** (1991). Development of objective standards of nonspeech oral strength and performance. In C. A. Moore,

K. M. Yorkston, & D. R. Beukelman (Eds.), *Dysarthria and apraxia of speech* (pp. 3–13). Baltimore: Paul H. Brookes.

**Maas, E., Barlow, J. A., Robin, D. A., & Shapiro, L. P.** (2002). Treatment of sound errors in aphasia and apraxia of speech: Effects of phonological complexity. *Aphasiology, 16,* 609–622.

**Reddy, N. P., Costarella, B. R., Grotz, R. C., & Canilang, E. P.** (1990). Biomechanical measurements to characterize the oral phase for dysphagia. *IEEE Transactions on Biomedical Engineering, 37,* 392–397.

**Robbins, J., Gangnon, R. E., Theis, S. M., Kays, S. A., Hewitt, A. L., & Hind, J. A.** (2005). The effects of lingual exercise on swallowing in older adults. *Journal of the American Geriatric Society, 53,* 1483–1489.

**Robbins, J., Kays, S. A., Gangnon, R. E., Hind, J. A., Hewitt, A. L., Gentry, L. R., et al.** (2007). The effects of lingual exercise in stroke patients with dysphagia. *Archives of Physical Medicine and Rehabilitation, 88,* 150–158.

**Robin, D. A., Somodi, L. B., & Luschei, E. S.** (1991). Measurement of tongue strength and endurance in normal and articulation disordered subjects. In C. Moore, K. Yorkston, & D. Beukelman (Eds.), *Dysarthria and apraxia of speech: Perspectives on management* (pp. 173–184). Baltimore: Paul H. Brooks.

**Robinovitch, S. N., Herschler, C., & Romilly, D. P.** (1991). A tongue force measurement system for the assessment of oral-phase swallowing disorders. *Archives of Physical Medicine and Rehabilitation, 72,* 38–42.

**Schmidt, R. A., & Lee, T. D.** (1998). *Motor control and learning: A behavioral emphasis* (3rd ed.). Champaign, IL: Human Kinetics.

**Schmidt, R. A., & Wrisberg, C. A.** (2000). *Motor learning and performance: A problem-based learning approach* (2nd ed.). Champaign, IL: Human Kinetics.

**Solomon, N. P., Clark, H. M., Makashay, M. J., & Newman, L. A.** (2008, March). *Orofacial strength and speech in normal and disordered adults*. Poster presented at the Biennial Conference on Motor Speech, Monterey, CA.

**Solomon, N. P., & Munson, B.** (2004). The effect of jaw position on measures of tongue strength and endurance. *Journal of Speech, Hearing, and Language Research, 47,* 584–594.

**Youmans, S. R., & Stierwalt, J. A.** (2006). Measures of tongue function related to normal swallowing. *Dysphagia, 21,* 102–111.

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