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Article

A Practical Method for Assessing Lip Compression Strengthening in Healthy Adults

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Abstract: There is no practical and accessible assessment method to evaluate lip muscle compression strength. The purpose of this study was to examine the relationship between the standard method (i.e., Iowa Oral Performance Instrument) and a practical method in healthy adults. In order to achieve our research purpose, ninety-eight healthy adults (18–40 years) completed lip compression strength measurements (standard method) and lip grasping performance tests using a standard recyclable plastic water bottle (practical method). In the overall sample, the mean and standard deviation for standard method and practical method was 26.7 (7.0) kPa and 255 (119) g, respectively. For the overall sample (n = 98), there was a positive relationship between the two strength tasks [r = 0.56 (0.41, 0.68)]. When separated by sex, positive correlations were observed for men and women with no differences between the observed correlations [difference of 0.06 (−0.2646, 0.3917)]. This result indicates that those individuals who are strong in the standard task will often be strong in the practical task. Future research is needed to determine how well changes in each test track with each other in response to a lip strength training program.

Keywords: lip closure function; orbicularis oris muscle; water bottle; lip grasping

1. Introduction

It is known that the orofacial muscles play a crucial role with positioning and shaping of the tongue, as well as the activation of the oropharynx during tasks such as mastication, swallowing, and speech [1–3]. The tongue, lips, and cheeks are closely related, offering synergistic roles to these functions if an appropriate pressure and force must be applied. Several studies [4–7] have investigated the characteristics of orofacial muscle strength (i.e., tongue elevation, cheek compression, and lip compression) using a standard device such as the Iowa Oral Performance Instrument (IOPI). Interestingly, these cross-sectional studies showed different patterns of age-related changes in orofacial strength, which includes a gradual decline in orofacial strength from young to old adults [5,6] or a maintenance of strength during the aging process until old age [4,7]. There were also large inter-individual variations (range between 10 and 70 kPa) in strength levels, within each age group [4,5].

Although it is unclear whether changes in facial muscle strength are involved in the loss of facial muscle and skin integrity with the generation of wrinkles and sagging [8], one study reported that wrinkles could be reduced by an exercise that involves holding an instrument in the mouth [9]. Furthermore, a recent case study reported lip and tongue exercise therapy as part of the orthodontic treatment for class three malocclusion [10]. Therefore, measuring lip compression strength may provide

useful information to understand the current condition of lip strength. Considering that evaluation of orofacial strength is difficult without the use of specialized equipment, it is important to develop a simpler and more accessible practical assessment method. Our laboratory has recently devised a simple clinical method (referred to as the practical method) that allows for a more feasible assessment of lip compression strength. However, it is unclear whether this method reflects comparable lip compression strength that would be measured with the standardized lip compression apparatus (referred to as the standard method). Thus, the purpose of this study was to examine the relationship between the standard method and the practical method. If the two tests are related, then that might indicate that the practical method can be used as an alternative to more specialized equipment for assessing lip compression strength in healthy adults.

2. Methods

2.1. Participants and Study Design

A total of 98 healthy adults between the ages of 18 and 40 [46 men and 52 women; mean age, 23.9 (4.8) years; standing height, 169.6 (9.6) cm; body mass, 69.3 (15.0) kg; body mass index, 23.8 (3.5) kg/m^2] were recruited through printed advertisement and by word of mouth from the surrounding area of the university campus. The study was approved by the University of Mississippi Institutional Review Board (#19-107, 2019). Written informed consent was obtained from all participants according to procedures for human-subjects research. Participants reported no history of facial or head trauma, facial palsy, or any other neurological disorder. As this was their first experience for assessing lip grasping performance and measuring lip compression strength, a familiarization session was provided prior to the actual testing visit. The testing visit was completed within 6 days of their familiarization session. Participants were instructed to refrain from any vigorous physical activity and alcohol consumption 24 h prior to testing and familiarization sessions. Body mass and standing height were measured before testing to the nearest 0.1 kg and 0.1 cm, respectively, using an electronic weight scale and a portable stadiometer (both Seca 220; Hamburg, Germany).

2.2. Lip Grasping Performance Test (Practical Method)

The lip grasping performance test incorporated the use of a standard recyclable plastic water bottle (500 mL). Each participant was given his or her own individual water bottle for each session. The test was performed in a standing position, and a water bottle was placed on a table at a suitable height (90 cm). Participants were asked to pinch the top of the plastic bottle, around the cap, using only their lips and without using their teeth. In addition, participants were instructed to lift the bottle about one inch above the table without sucking inward, and hold for a duration of two seconds before returning it to the table (Figure 1a). Before testing began, a small hole (about 1 mm in diameter) was punctured in the center of the bottle cap to eliminate the effect of the participants' ability to suck on the bottle. In addition, another hole (about 1 cm in diameter) was cut into the top of plastic bottle to easily and progressively add water to increase the weight following successful lifts (Figure 1b). Testing began with an empty bottle and then the examiner gradually increased the weight of the bottle by incrementally adding water, between 50 g (early stage) and 20 g (later stage), following each successful lift. Adding coins were used if the bottle mass reached over 500 g. The rest interval between attempts was 30 s. The cap of the bottle was wiped off before each attempt. If the inside of the lips was wet with saliva, the participants dried this with a paper towel prior to the attempt. The mass of the bottle was measured using a digital scale (EK9180WM, Wal-Mart Stores Inc, Bentonville, AR, USA) (Figure 1c). If the participant was unable to maintain their grasp on the bottle, this was deemed as their first failed attempt. After a rest interval (30 s), the participant made a second attempt to lift the bottle at the same weight. If the lift was successful, then the examiner continued to gradually increase the amount of water in the bottle until the participant was unable to maintain their grasp on the bottle. However, if the participant was unable to lift the bottle on their second attempt, the weight of the water bottle

was decreased 10 g and the participant would have another attempt to lift the bottle. Two consecutive failing attempts resulted in terminating the test. At this point, the examiner weighed the bottle with the final amount of water.

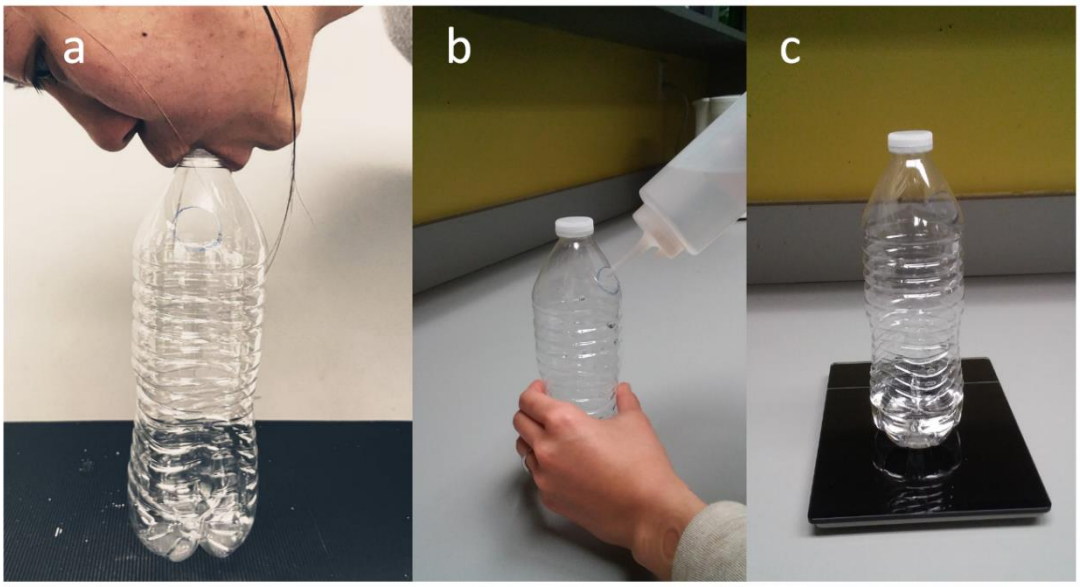

Figure 1. Measurements of lip grasping performance as the practical method; (**a**) pinch the top of a plastic water bottle, around the cap, using only his/her lips and without using their teeth, and lift the bottle about one inch above the table, and hold for a duration of two seconds before returning it to the table; (**b**) cut a one centimeter hole into the top of plastic bottle to easily and progressively add water to increase the weight; and (**c**) measuring the mass of the water bottle using a digital scale.

2.3. Lip Compression Strength Test (Standard Method)

Lip strength was measured using the IOPI bulb that was carefully placed between two wooden blades as described previously [4]. According to previous work [4], the blade structure permits an evenly distributed pressure that transmits over the entire surface of the tongue bulb, providing accurate pressure measurements. The blades were positioned between the midline of the lips. The participants were instructed to comfortably close their teeth on top of each other and to slightly protrude the lips to clasp onto the two wooden blades. This prevented participants from applying pressure to the wooden blades with a bulb using their jaw muscles. Participants were instructed to squeeze their lips together as hard as possible (2 to 3 s). Each specific measurement technique was taken three times with a 30-second rest interval between individual measures. The highest value recorded was used for data analysis.

2.4. Statistical Analysis

A Pearson's correlation was used to determine the relationship between the standard method and the practical method [r value (95% confidence interval)]. The correlation between variables was also calculated separately for men and women. This analysis was completed using JASP version 0.11(Netherlands) from the JASP Team (2019). The "cocor" function (version 1.1-3) in RStudio (version 1.2.1335) was used to statistically compare the r values between men and women. Statistical significance was set at $p \leq 0.05$.

3. Results

In the overall sample, the mean and standard deviation for lip compression strength (standard method) and lip grasping performance (practical method) was 26.7 (7.0) kPa and 255 (119) g, respectively. The range was between 10 and 52 kPa for the standard method and between 30 and 560 g for the

practical method. For the overall sample (n = 98), there was a positive relationship between the two strength tasks [r = 0.56 (0.41, 0.68); $p = 1.613 \times 10^{-9}$]. When separated by sex, there was a positive relationship between the two strength tasks for men [r = 0.41 (0.13, 0.62); p = 0.0043] and women [r = 0.47 (0.23, 0.66); p = 0.0004] (Figure 2). The difference between correlations was 0.06 (−0.2646, 0.3917) with a p-value of 0.7207 (Fisher's z = 0.3576). This result indicates that those individuals who are strong at the standard task will often be strong at the practical task. More advanced analysis could not be completed due to differing units for the two methods.

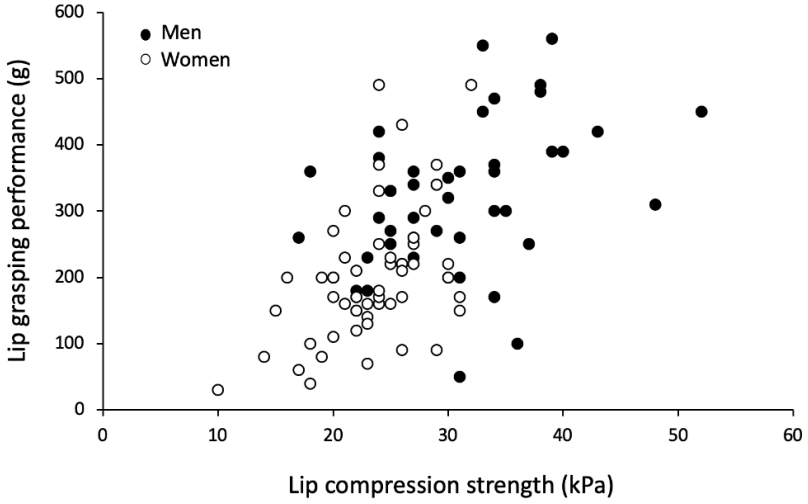

Figure 2. Relationship between lip compression strength (standard method) and lip grasping performance (practical method) in women and men.

4. Discussion

The primary findings from this study were twofold: (1) large inter-individual variations were observed in the two variables measured and (2) the simple method using a water bottle was positively correlated to the standard method by IOPI.

In addition to this study, previous research has reported large variations in lip muscle strength. For example, Clark and Solomon [4] measured lip compression strength in 68 young (25 men and 43 women), 41 middle-aged (28 men and 13 women) and 38 older adults (26 men and 12 women), and found the wide ranges of variation in lip strength in all age groups (range between 12 and 73 kPa in young adults, between 13 and 74 kPa in middle-age adults and between 15 and 62 kPa in older adults). Other studies also reported a similar phenomenon [5,11,12]. In healthy individuals, it is unclear whether the difference in lip compression strength affects various functions such as mastication, swallowing, and speech. Interestingly, however, patients with dysphagia exhibited lower tongue protrusion and lip closure strength compared to normal individuals [13]. Most patients with dysphagia cannot close their lips completely, leading to food spillage [13]. In studies of stroke patients and old individuals living in an elderly care facility, improvements of masticatory ability and eating behaviors were found following lip muscle strength training [14,15].

Our findings indicated that there was only a moderate relationship between the two methods (practical method vs. standard method) of lip closure strength. This might be related, in part, to what each device is specifically measuring. For example, the IOPI device measures lip compression and the water bottle measures lip grasping performance. The difference in lip position between the two tasks may affect the expression of lip closure strength. That is, the cap of the water bottle has a round shape (2.7 cm in diameter), and the mouth that holds the cap tends to be performed with a puckered lip. By contrast, the measurement of lip compression strength using IOPI presses the two wooden blades centered on the tongue bulb so that they are sandwiched from above and below (1.8 cm in distance between the two blades). Considering the similar contraction time during the lip performance test in

both standard and practical methods (2 to 3 s vs. 2 s), the differences in muscular strength between closed lips in parallel and puckered lips may be a reason for the moderate relationship between the two methods. There are also differences in how lip compression was evaluated between the two methods. In the standard method (i.e., IOPI), the peak value of pressure during a contraction was displayed for evaluating lip compression strength, whereas the practical method (i.e., water bottle) entails holding the weight of a water bottle for a certain time (2 s) with the lips. The difference in evaluation methods needs to be considered when interpreting the statistical relationship.

As mentioned above, it is unclear whether training-induced increases in lip closure muscle strength are associated with improvement of age-related wrinkles and sagging [8], although one study reported those possibilities [9]. We believe that the evaluation of lip muscle function with the water bottle used in this study can also be used as a means of training for lip closure muscle strength. The advantage of this practical method is that the device (a standard recyclable plastic water bottle) is inexpensive which may help make the testing/training of lip closure strength more assessable compared to devices used in previous reports [4,16,17]. At this time, it is unknown what exercise intensity is most effective for improving lip muscular strength. Previous studies have provided lip training at varying intensities. For example, one study used 70% of the maximal strength as determined by IOPI for patients recovering from a stroke [18] while other studies used a lip closure device with the goal of maintaining lip closure for three minutes in older adults [15]. For our practical method, the training effect, i.e., the weight of the water bottle lifted during training can be checked daily, although this is a relatively rough measurement. One possible protocol is to hold the water bottle until failure or near failure utilizing a relative high weight (repeated several times). However, it is unclear whether similar effects would be observed with each method following lip muscle strength training in children and adults with and without disease such as stroke [15,18,19].

A number of limitations of this study should be mentioned. First, each method has different units which makes a direct comparison difficult. One consideration for future research is to compare the training effects (% change) of each device. In other words, when strength changes in one, does it change in the other and to what magnitude? Future research is warranted to find answers to these questions. Furthermore, it is known that the lip closure strength is greater in the upper lip compared to the lower lip in patients with lip incompetence [20]. In order to measure the force of the upper lip and the lower lip separately, it is necessary to attach a sensor to each when using the method of this study.

In conclusion, we confirmed that there was a positive relationship between the two methods of lip strength. Our result suggests that those individuals who are strong in the standard task will often be strong in the practical task. At present, there is no consensus [4,21] on standard values for healthy adults utilizing the practical method.

Author Contributions: T.A., Z.W.B., R.W.S., V.W., R.B.V., and J.P.L. conceived and designed the study. T.A., Z.W.B., R.W.S., V.W., R.B.V., Y.Y., and R.N.C. performed the data collection. T.A. and J.P.L. analyzed the data. T.A. wrote the manuscript. Z.W.B., R.W.S., V.W., R.B.V., Y.Y., R.N.C., and J.P.L. reviewed and critically revised the manuscript. All authors have read and agreed to the published version of the manuscript.

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