A COMPARATIVE STUDY ON TONGUE MUSCLE PERFORMANCE IN WEIGHTLIFTERS AND RUNNERS

A Dissertation by

Heidi Ann VanRavenhorst-Bell

Master of Education, Wichita State University, 2005
Bachelor of Education, Wichita State University, 1997

Submitted to the Department of Communication Sciences and Disorders
and the faculty of the Graduate School of
Wichita State University
in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy

May 2015
A COMPARATIVE STUDY ON TONGUE MUSCLE PERFORMANCE IN WEIGHTLIFTERS AND RUNNERS

The following faculty members have examined the final copy of this dissertation for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Doctor of Philosophy.

Kathy Coufal, Committee Chair

Antje Mefferd, Committee Co-Chair

Rosalind Scudder, Committee Member

Trisha Self, Committee Member

Jeremy Patterson, Committee Member

Accepted for the College of Health Professions

Sandra Bibb, Dean

Accepted for the Graduate School

Abu Masud, Interim Dean
DEDICATION

To my son that he may be inspired to make his dreams become reality
Inspired faith...Believe.
ACKNOWLEDGMENTS

I am truly indebted to many people who have been there for me during this evolving process of writing a dissertation. The multitudes of obstacles and challenges that I have encountered throughout this journey have gradually been transformed into opportunities of learning. The support and encouragement of those close to me provided me with the motivation and determination to overcome each challenge and achieve this milestone. I would like to thank everyone who has walked beside me and supported me through this journey.

First and foremost, I owe my sincere and deepest gratitude to my committee chair Dr. Kathy Coufal and co-chair Dr. Antje Mefferd. Each has spent countless hours reviewing and editing my writings, even on weekends and late nights, to help me complete this study successfully. Individually, I am grateful to Dr. Kathy Coufal for her calming hand and continuously guided words. I often reflect on the very first writing assignment she required of me three and half years ago that expressed why I wanted a PhD. To this day that one page assignment has helped keep me centered as I earned my degree. She believed in me from the beginning and I felt her support and encouragement throughout my studies and dissertation work.

I owe a special thank you to Dr. Antje Mefferd, for the incalculable hours we spent in discussions related to my dissertation project, in addition to the countless hours reviewing and editing my writing. She helped guide me through the process as I gained a deeper appreciation of writing a dissertation. It was a privilege and an honor to work with her.

I also wish to thank the other members of my dissertation committee. I owe a special thank you to Dr. Rosalind Scudder, who throughout my time spent as a Communication Sciences and Disorders student was always there to offer reassuring support and encouragement. Her fluidity to step into various roles on my committee was always purposed toward helping me
to continue moving forward. Ro is the “rescue room”! Thank you to Dr. Trisha Self, who without hesitation was there to step in and fill a need. Her selfless act will always be appreciated. I am grateful to Dr. Jeremy Patterson, who recognized a gift within me before I was able to believe in it myself. He was the one who encouraged me to earn my PhD and directed me to the Communication Sciences and Disorders Department. He has always provided me with the support and mentorship to enable me to achieve greater success in my career.

To all of the faculty and staff in the Department of Communication Sciences and Disorders, I would like to say thank you for their support and assistance in completing my studies. There was many an occasion when a simple smile helped turn my frown upside-down. I have fond memories of one moment or another when each expressed sincere interest in my progress and personal well-being, and without hesitation offered an “olive branch” when I needed it most.

To the four Graduate Assistants (yes, four), David A. R. Gaddam, Ashwini B. Kanade, Petey W. Mumford, and Aaron C. Tribby, I was blessed to have assisting in the Human Performance Laboratory during data collection, Thank You!! The commitment and dedication each of them willingly offered was truly appreciated and deserves to be recognized. Their enthusiasm and eagerness to understand the research at hand made the entire experience that much more enjoyable. Appreciation is also extended to the Department of Human Performance Studies for allowing me access to the Human Performance Laboratory and equipment throughout the data collection process.

To my fellow doctoral students, Jennifer Francois, Sean Hess, Ashwini B. Kanade, Kai-Mei Chen, Karissa Marble, Jared Reyes, Jag Rajagopalan, Nicole Schmidt, and Rosemary Wright, to whom I am proud to call life-long friends. We have shared moments of
laughter, tears, and joyous celebrations along the way. The encouragement and supportive words each of them has offered along this adventurous journey has truly been appreciated. The memories we have created will forever be cherished.

Last, but not least, I would like to thank my family and friends who have been a constant support system for me. Thank you to my husband Derek Bell and son Drayden Bell; you have sacrificed so much in order for me to fully dedicate my all to this project. I am truly grateful for your understanding and support as I spent many long days and nights completing my studies. To my parents, Gerald and Deborah VanRavenhorst, for all the love, support, and encouragement they have provided me. Their nurturing throughout the years has helped me to develop the inner character I needed to earn my degree.
ABSTRACT

Various factors of physical exercise (e.g., mode, intensity) are known to affect directly and indirectly targeted muscles in the skeletal system, however, few research efforts have been directed towards delineating how exercise factors indirectly impact muscles of the tongue. Research regarding the indirect effects of exercise on tongue strength and endurance has importance because tongue strength and endurance are important for daily functional tasks such as swallowing, speaking, and maintaining upper airway patency. Furthermore, tongue muscle performance declines with age. The purpose of this study was to determine if tongue muscle performance (i.e., strength, endurance) differs between individuals who regularly engage in a resistance mode of exercise (weightlifting) and endurance mode of exercise (running). Additionally, the study sought to determine if anterior and posterior tongue muscle performance were differentially affected in individuals that were weightlifters and endurance runners.

A total of 45 healthy young adults, 19-29 years of age, were divided into two groups based on the exercise mode they regularly engage in: 1) weightlifting, and 2) running. The Iowa Oral Performance Instrument was used to measure tongue strength and tongue endurance. Measurements were obtained in the anterior and posterior regions of the tongue.

Results showed that tongue endurance was significantly greater in runners than weightlifters with a more pronounced difference in the anterior region of the tongue. It was also observed that, tongue strength was greater in weightlifters than runners, particularly in the anterior region of the tongue. These findings are in line with earlier studies on indirect exercise effects on skeletal muscles. In conclusion, this study suggests that exercise may indirectly influence tongue strength and endurance; however, future research is necessary to better understand the indirect effect of each factor of exercise on tongue muscle performance.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.</td>
<td></td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>2</td>
</tr>
<tr>
<td>Significance</td>
<td>3</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>4</td>
</tr>
<tr>
<td>II.</td>
<td></td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>5</td>
</tr>
<tr>
<td>Anatomy and Physiology of the Tongue</td>
<td>5</td>
</tr>
<tr>
<td>Tongue Muscle Strength and Endurance</td>
<td>7</td>
</tr>
<tr>
<td>Exercise and its Effect on Strength and Endurance</td>
<td>10</td>
</tr>
<tr>
<td>Exercise Modes</td>
<td>10</td>
</tr>
<tr>
<td>Resistance Training</td>
<td>11</td>
</tr>
<tr>
<td>Isometric</td>
<td>12</td>
</tr>
<tr>
<td>Isotonic</td>
<td>13</td>
</tr>
<tr>
<td>Endurance Training</td>
<td>14</td>
</tr>
<tr>
<td>Indirect Effect of Physical Exercise</td>
<td>15</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>22</td>
</tr>
<tr>
<td>Significance</td>
<td>22</td>
</tr>
<tr>
<td>Summary</td>
<td>23</td>
</tr>
<tr>
<td>Research Aims and Hypothesis</td>
<td>25</td>
</tr>
<tr>
<td>Research Aim #1</td>
<td>25</td>
</tr>
<tr>
<td>Hypothesized Outcome #1</td>
<td>25</td>
</tr>
<tr>
<td>Research Aim #2</td>
<td>25</td>
</tr>
<tr>
<td>Hypothesized Outcome #2</td>
<td>25</td>
</tr>
<tr>
<td>III.</td>
<td></td>
</tr>
<tr>
<td>METHODOLOGY</td>
<td>26</td>
</tr>
<tr>
<td>Participants</td>
<td>26</td>
</tr>
<tr>
<td>Inclusion Criterion</td>
<td>26</td>
</tr>
<tr>
<td>Research Design and Protocol</td>
<td>28</td>
</tr>
<tr>
<td>Physical Measures</td>
<td>28</td>
</tr>
<tr>
<td>Assessment of Skeletal Muscle Strength</td>
<td>28</td>
</tr>
<tr>
<td>Measures to Normalize Assessments</td>
<td>29</td>
</tr>
<tr>
<td>Assessment of Cardiovascular/Muscle Endurance</td>
<td>30</td>
</tr>
<tr>
<td>Tongue Measures</td>
<td>32</td>
</tr>
<tr>
<td>Assessment of Tongue Muscle Strength and Endurance</td>
<td>32</td>
</tr>
<tr>
<td>Maximal Tongue Strength</td>
<td>33</td>
</tr>
<tr>
<td>Maximal Tongue Endurance</td>
<td>33</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>34</td>
</tr>
</tbody>
</table>
**TABLE OF CONTENTS (continued)**

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV. RESULTS</td>
<td>35</td>
</tr>
<tr>
<td>Tongue Strength Measures</td>
<td></td>
</tr>
<tr>
<td>Tongue Endurance Measures</td>
<td></td>
</tr>
<tr>
<td>V. DISCUSSION</td>
<td>40</td>
</tr>
<tr>
<td>Tongue Strength Measures</td>
<td></td>
</tr>
<tr>
<td>General Findings</td>
<td>41</td>
</tr>
<tr>
<td>Current Findings on Tongue Strength in the Context of Previously Found Indirect Effects of Exercise Mode on Skeletal Muscle Strength</td>
<td>41</td>
</tr>
<tr>
<td>Tongue Endurance Measures</td>
<td></td>
</tr>
<tr>
<td>General Findings</td>
<td>43</td>
</tr>
<tr>
<td>Current Findings on Tongue Endurance in the Context of Previously Found Indirect Effects of Exercise Mode on Skeletal Muscle Endurance</td>
<td>43</td>
</tr>
<tr>
<td>Potential Mechanisms Underlying Tongue Muscle Performance Differences Between Weightlifters and Runners</td>
<td>47</td>
</tr>
<tr>
<td>Implications of Findings</td>
<td>49</td>
</tr>
<tr>
<td>Summary and Conclusion</td>
<td>50</td>
</tr>
<tr>
<td>Limitations of the Study</td>
<td>52</td>
</tr>
<tr>
<td>Future Directions</td>
<td>54</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>56</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>70</td>
</tr>
<tr>
<td>A. VanRavenhorst-Bell, H.A., Mefferd, A. S., Coufal, K., Scudder, R., &amp; Patterson, J. (2015). Tongue Strength and Endurance: Comparison in Active and Non-Active Younger and Older Adults. (In Progress)</td>
<td>71</td>
</tr>
<tr>
<td>B. Informed Consent Form</td>
<td>109</td>
</tr>
<tr>
<td>C. Oral Health History Questionnaire</td>
<td>113</td>
</tr>
<tr>
<td>D. PAR-Q &amp; You Questionnaire</td>
<td>114</td>
</tr>
<tr>
<td>E. Physical Activity Questionnaire</td>
<td>116</td>
</tr>
<tr>
<td>F. Wichita State University Institutional Review Board Approval Letter</td>
<td>127</td>
</tr>
<tr>
<td>G. YMCA Protocol</td>
<td>128</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Recorded Measures of Tongue Strength and Endurance for the Resistance Trained Hammer Thrower and the Endurance Trained Distance Runner with Comparative Published Reference Measures</td>
<td>20</td>
</tr>
<tr>
<td>3.1</td>
<td>Descriptive Group Means, Standard Deviations, and Sum of Weightlifters, Runners and Overall</td>
<td>27</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Extrinsic Muscles of the Tongue</td>
<td>5</td>
</tr>
<tr>
<td>2.2</td>
<td>Intrinsic Muscles of the Tongue</td>
<td>6</td>
</tr>
<tr>
<td>2.3</td>
<td>Regions of the Tongue</td>
<td>6</td>
</tr>
<tr>
<td>2.4</td>
<td>Distribution of Fiber Types Within Separate Tongue Regions</td>
<td>7</td>
</tr>
<tr>
<td>3.1</td>
<td>Means and Standard Errors of Handgrip Strength of Weightlifters and Runners</td>
<td>29</td>
</tr>
<tr>
<td>3.2</td>
<td>Means and Standard Errors of Cardiovascular Endurance of Weightlifters and Runners</td>
<td>32</td>
</tr>
<tr>
<td>3.3</td>
<td>Anterior and Posterior Tongue Placement of the IOPI Bulb</td>
<td>33</td>
</tr>
<tr>
<td>4.1</td>
<td>Means and Standard Errors of Tongue Strength in Weightlifters and Runners</td>
<td>35</td>
</tr>
<tr>
<td>4.2</td>
<td>Means and Standard Errors of Anterior and Posterior Tongue Strength</td>
<td>36</td>
</tr>
<tr>
<td>4.3</td>
<td>Means and Standard Errors of Anterior and Posterior Tongue Strength in Weightlifters and Runners</td>
<td>37</td>
</tr>
<tr>
<td>4.4</td>
<td>Means and Standard Errors of Tongue Endurance in Weightlifters and Runners</td>
<td>38</td>
</tr>
<tr>
<td>4.5</td>
<td>Means and Standard Errors of Anterior and Posterior Tongue Endurance</td>
<td>38</td>
</tr>
<tr>
<td>4.6</td>
<td>Means and Standard Errors of Anterior and Posterior Tongue Endurance in Weightlifters and Runners</td>
<td>39</td>
</tr>
</tbody>
</table>
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bpm</td>
<td>Beats per minute</td>
</tr>
<tr>
<td>e.g.</td>
<td>For example</td>
</tr>
<tr>
<td>F</td>
<td>F value</td>
</tr>
<tr>
<td>i.e.</td>
<td>Such as</td>
</tr>
<tr>
<td>$H_0$</td>
<td>Null hypothesis</td>
</tr>
<tr>
<td>IOPI</td>
<td>Iowa Oral Performance Instrument</td>
</tr>
<tr>
<td>IRB</td>
<td>Institutional Review Board</td>
</tr>
<tr>
<td>kPa</td>
<td>Kilopascal</td>
</tr>
<tr>
<td>kp-m-min⁻¹</td>
<td>Kilopond per meter per minute</td>
</tr>
<tr>
<td>ml-kg-min⁻¹</td>
<td>Milliliters per kilogram per minute</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
</tr>
<tr>
<td>$\eta^2_p$</td>
<td>Partial eta squared</td>
</tr>
<tr>
<td>$p$</td>
<td>Probability value</td>
</tr>
<tr>
<td>PAQ</td>
<td>Physical Activity Questionnaire</td>
</tr>
<tr>
<td>PAR-Q</td>
<td>Physical Activity Readiness Questionnaire</td>
</tr>
<tr>
<td>$P_{\text{max}}$</td>
<td>Maximal tongue strength pressure</td>
</tr>
<tr>
<td>RPE</td>
<td>Rate of perceived exertion</td>
</tr>
<tr>
<td>rpm</td>
<td>Rotations per minute</td>
</tr>
<tr>
<td>VO₂</td>
<td>Volume of oxygen consumed</td>
</tr>
<tr>
<td>YMCA</td>
<td>Young Men’s Christian Association</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

Exercise is a form of physical activity that is known to affect muscular strength and endurance in the skeletal system (e.g., limb and trunk muscles) (Ferreira et al., 2012; Haskell, Blair, & Hill, 2009; Haskell et al., 2007; Spirduso, Francis, & MacRae, 2005; Stewart, 2005). In addition, the mode of exercise (i.e., weightlifting, running) performed during an exercise session is shown to have a differential effect on skeletal muscle fiber types and whether the directly targeted muscles improve in strength or endurance (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Kraemer, Adams, et al., 2002; Kraemer & Ratamess, 2004; Wilson, Marin, et al., 2012). Previous studies have shown that resistance training has a greater effect on Type II fast-twitch muscle fibers that contribute to muscular strength, speed, and power; while endurance training has a greater effect on Type I slow-twitch muscle fibers that are shown to utilize oxygen more efficiently and reduce the muscles’ rate of fatigue (Holloszy, 1984; Kraemer, Ratamess, & French, 2002; Reilly, Morris, & Whyte, 2009; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al., 2012). Further, exercise has been shown to benefit muscles that are not directly targeted during exercise (Hamlyn, Behm, & Young, 2007; Munn, Herbert, & Gandevia, 2004; Tew, Nawaz, Zwierska, & Saxton, 2009; Tordi, Belli, Mougin, Rouillon, & Gimenez, 2001). For example, although performing squats is a form of resistance training that directly targets the leg muscles’ strength, squatting is also known to indirectly benefit the muscles of the abdomen (Fisher, Steele, Bruce-Low, & Smith, 2011; Hamlyn et al., 2007).

Recognizing the direct and indirect benefits of exercise within the skeletal muscles, recent interest is reported as to the potential benefits of physical exercise on tongue muscles. Further exploring such an interest is important because the muscles of the tongue must produce
adequate levels of strength and endurance to perform daily tasks such as swallowing, talking, and maintaining upper airway patency (McHorney, Martin-Harris, Robbins, & Rosenbek, 2006; Neel, Palmer, Sprouls, & Morrison, 2006; Nicosia, 2000; Robbins et al., 2005; Stierwalt & Youmans, 2007; Yoshida et al., 2006). Kletzien, Russell, Levenson, and Connor (2013) were one of the first to explore the effects of physical exercise (i.e., treadmill running) on indirectly targeted tongue strength and endurance. They studied these indirect effects in rats and found that both tongue strength and endurance improved following running exercise. A study by VanRavenhorst-Bell, Mefferd, Patterson, and Scudder (2013) (See Appendix A) further investigated the notion that physical exercise may affect indirectly targeted tongue muscle performance in humans. They reported that in younger and older individuals who exercise regularly, tongue strength and tongue endurance were significantly greater than in those who do not exercise regularly. Although much is still unknown about these observed findings, they do support the notion that regular physical exercise may positively affect indirectly targeted tongue muscle strength and endurance in humans.

**Statement of the Problem**

Researchers are just beginning to investigate the benefits of physical exercise on tongue strength and endurance. In fact, the study on rats by Kletzien et al., (2013) and the pilot study on humans by VanRavenhorst-Bell et al., (2013) are among the few currently available. The paucity of evidence, therefore, has left a very elementary understanding of the indirect effect physical exercise may have on tongue muscle strength and endurance. To further establish a better understanding, research must deduce whether the various factors of exercise (i.e., mode of exercise) known to directly and indirectly elicit skeletal muscle fiber adaptations that affect muscle strength and endurance differently (Fisher et al., 2011; Karavirta et al., 2011; Kraemer,
Adams, et al., 2002; Kraemer & Ratamess, 2004; Wilson, Marin, et al., 2012) have a similar effect on tongue musculature. The indirect effect of exercise mode on tongue muscle performance is particularly interesting because the tongue is comprised of various muscle fiber types that greatly differ in arrangement from the anterior region of the tongue to the posterior tongue region. For example, the anterior region of the tongue is comprised predominantly of Type II fast-twitch muscle fibers. These Type II fast-twitch muscle fibers perform movements purposed toward strength, power, and speed. In contrast, the posterior region of the tongue is comprised primarily of Type I slow-twitch muscle fibers that allow the tongue to perform necessary movements with minimal fatigue (Clark, 2012; J. R. Green & Wang, 2003; Stal, Marklund, Thornell, De Paul, & Eriksson, 2003; Trawitzki, Borges, Giglio, & Silva, 2011; Zaidi, Meadows, Jacobowitz, & Davidson, 2012). Therefore, it is important to determine whether each mode of exercise has a differential effect on indirectly targeted anterior and posterior tongue muscle strength and endurance similar to that of the indirectly targeted skeletal muscle strength and endurance.

**Significance.** A better understanding about effects of physical exercise mode on tongue strength and endurance is important to understand how tongue muscle performance can be potentially modified by specific forms of exercise. A decline in tongue muscle strength and endurance may negatively affect tongue function, such as in swallowing, speaking, and maintenance of airway patency (Blumen et al., 2004; Humbert & Robbins, 2008; Neel et al., 2006; Ney, Weiss, Kind, & Robbins, 2009; Solomon, Robin, & Luschei, 2000). Furthermore, aging-related decline in tongue muscle performance is typical but may initially be subtle and undetected. As the decline continues or in the presence of other health issues, its negative impact on swallowing or maintaining airway patency can become more pronounced and result in
disordered swallowing (dysphagia) or disordered breathing (sleep apnea) (Blumen et al., 2004; Clark & Solomon, 2012; Humbert & Robbins, 2008; Ney et al., 2009; Nicosia, 2000). In addition, dysphagia and sleep apnea are associated with serious secondary health concerns such as high blood pressure, stroke, aspiration, and pneumonia (Duran, Esnaola, Rubio, & Iztueta, 2001; Langmore, 1998; Marik & Kaplan, 2003). Advancing knowledge about how exercise mode differentially affects tongue muscle performance will pave the way for future research studies investigating how aging-related effects on tongue muscle performance can be retarded, and serious illness due to tongue function loss can be minimized or prevented because of more specified lifestyle recommendations that can be made with regards to specific modes of physical exercise.

**Purpose of the Study**

The purpose of this study was to determine if there is a difference in tongue muscle performance (i.e., strength, endurance) between individuals who regularly engage in resistance training exercise (e.g., weightlifting) and individuals who regularly engage in endurance training exercise (e.g., running). In addition, the study sought to determine if there was a differential performance of anterior and posterior tongue musculature in weightlifters and runners.
CHAPTER II
LITERATURE REVIEW

Anatomy and Physiology of the Tongue

The tongue is a complex structure consisting of four extrinsic muscles and four intrinsic muscles. The extrinsic muscles originate on structures outside the tongue with insertion points in the tongue. The extrinsic muscles enable the tongue to protrude, retract, elevate and depress (Adb-El-Malek, 1939; Takemoto, 2001; Zaidi et al., 2012). Figure 2.1 provides an overview of the extrinsic muscles (i.e., genioglossus, hyoglossus, styloglossus, palatoglossus).

![Figure 2.1. Extrinsic Muscles of the Tongue (Cambridge Questions, 2013).](image-url)

In contrast to extrinsic muscles, intrinsic muscles originate and insert within the muscles of the tongue. The intrinsic muscles allow the tongue to manipulate its shape by rolling, curling, twisting, extending, and shortening (Adb-El-Malek, 1939; Takemoto, 2001; Zaidi et al., 2012). Figure 2.2 provides an overview of the intrinsic muscles (i.e., transversus, verticalis, longitudinalis superior, longitudinalis inferior).
The tongue is further distinguished into two regions, anterior and posterior (Adb-El-Malek, 1939; Stal et al., 2003). Figure 2.3 displays the anterior and posterior regions of the tongue.

The anterior region describes the anterior two-thirds of the tongue, which primarily includes the tip and the tongue body. The muscle fiber arrangement within this region consists primarily of Type II fast-twitch muscle fibers. These fibers are well-suited to produce fast and powerful movements; for example, to accommodate functions such as bolus manipulation and
propulsion during swallowing (J. R. Green & Wang, 2003; Stal et al., 2003; Trawitzki et al., 2011; Zaidi et al., 2012).

The posterior region describes the posterior one-third of the tongue. It is composed primarily of Type I and Type IM/IC slow-twitch fibers, which are relatively fatigue resistant. These fibers are well suited for functions such as maintaining an open upper airway during respiration and closing off the upper airway during mastication to prevent premature advancement of the bolus (J. R. Green & Wang, 2003; Stal et al., 2003; Trawitzki et al., 2011; Zaidi et al., 2012). To emphasize the anatomical difference between the anterior tongue and posterior tongue, Figure 2.4 displays the differential distribution of tongue fiber types in these two regions.

![Figure 2.4. Distribution of Fiber Types Within Separate Tongue Regions (Zaidi et al., 2012).](image)

**Tongue Muscle Strength and Endurance**

When extrinsic and intrinsic tongue muscles contract, they produce muscle force. Tongue strength is a measure that relates to the amount of force the tongue muscle fibers produce (Clark, 2012; Robbins, Levine, Wood, Roecker, & Luschei, 1995; Stierwalt & Youmans, 2007). It is this muscle strength that enables the execution of powerful and rapid tongue movements, for example, to manipulate and propel a bolus during swallowing (Cheng, Butler, Gandevia, & Bilston, 2011; Youmans & Stierwalt, 2006). Maximal tongue strength is defined as the maximal
force the muscles of the tongue are capable of producing (Adams, Mathisen, Baines, Lazarus, & Callister, 2013b; Clark & Solomon, 2012; Crow & Ship, 1996; Robbins et al., 1995; Stierwalt & Youmans, 2007). Tongue strength within the anterior region has been shown to be slightly higher than that of the posterior region, yet tongue strength values for both regions are collectively reported (Adams, Mathisen, Baines, Lazarus, & Callister, 2013a; Adams et al., 2013b; Clark & Solomon, 2012; Kays, Hind, Gangnon, & Robbins, 2010). Maximal tongue strength values for both the anterior and posterior regions are shown to vary between 40 kPa – 80 kPa in healthy adults (18-59 years of age) with 60 kPa representing the average maximal tongue strength (Adams et al., 2013b; Clark & Solomon, 2012; Crow & Ship, 1996; Robbins et al., 1995; Stierwalt & Youmans, 2007). These values, however, are shown to decline gradually, an average of 10-15 kPa, with increasing age in healthy adults 60 years of age and older (Adams et al., 2013b; Clark & Solomon, 2012; Crow & Ship, 1996). Furthermore, a tongue strength value declining below 35 kPa is viewed as a concern to be able to produce adequate tongue function (Adams et al., 2013b; Hewitt et al., 2008; Nicosia, 2000).

As for sex differences, findings have been mixed. Although many studies have found no sex effect on tongue strength (Nicosia, 2000; Stierwalt & Youmans, 2007), other studies have shown a difference in anterior tongue strength measures between men and women. Specifically, males have been shown to produce a slight, yet significantly higher average maximal tongue strength compared to females (Adams et al., 2013b; Crow & Ship, 1996; Youmans & Stierwalt, 2006).

Tongue endurance is defined as the length of time one can maintain a submaximal contraction (Clark, 2012; Crow & Ship, 1996; Stierwalt & Youmans, 2007). From the initial moment the muscle contracts, the process of fatigue begins and may compromise lingual
function if tongue muscle endurance is not adequate (Bigland-Ritchie, Dawson, Johansson, & Lippold, 1986; Bigland-Ritchie, Furbush, & Woods, 1986; McSharry et al., 2012). Although only a few studies have addressed tongue endurance and there is not a widely accepted consensus, many experts would agree that healthy individuals, male and female, regardless of age should be able to maintain approximately 50% of their maximum tongue strength for at least 25-35 seconds when measured either at the anterior or posterior regions (Adams et al., 2013b; Crow & Ship, 1996; Stierwalt & Youmans, 2007). A few studies have shown that the anterior region is able to maintain a slightly longer tongue endurance measure than the posterior region (Adams et al., 2013a, 2013b; Kays et al., 2010). Regardless of regional tongue endurance differences, a performance of 10 seconds or less on such a tongue endurance test is viewed as a concern for maintenance of adequate tongue function (Adams et al., 2013b; Crow & Ship, 1996; Stierwalt & Youmans, 2007).

Due to the anatomical heterogeneity of the muscle fibers and functions from the anterior to posterior sections of the tongue, it is recommended that tongue strength and endurance be measured in at least two different regions of the tongue (e.g., anterior, posterior) (Adams et al., 2013a; Miller, Watkin, & Chen, 2002; Robbins et al., 2007). The Iowa Oral Performance Instrument (IOPI) is the standard tool used to assess tongue strength and tongue endurance (Adams et al., 2013b; Chang, Chen, Ko, & Lin, 2008; Crow & Ship, 1996; Steele, Bailey, Molfenter, & Yeates, 2009; Youmans & Stierwalt, 2006; Youmans, Youmans, & Stierwalt, 2009). The recommended placements of the IOPI include anterior (10 mm posterior to the tongue tip) and posterior (10 mm anterior to the most posterior circumvallate papilla) (Robbins et al., 2007; Robbins et al., 1995) positions.
Exercise and its Effect on Strength and Endurance

Exercise is a form of physical work that affects many systems in the human body. This project concentrated on muscle strength and muscle endurance (Caspersen, 1985; Garland et al., 2011). During exercise the amount of effort required to perform a desired movement is greater than the level of muscular effort during everyday activities. Each exercise session is intentionally scheduled and focused toward achieving a specific goal (Caspersen, 1985; Garland et al., 2011).

To meet specifics of the exercise goal (i.e., increase muscle strength, increase muscle endurance), factors known to modulate the effects of exercise on muscles must be considered. These exercise factors are mode, intensity, frequency, duration. Each factor contributes to the desired goal in a specific way (Kraemer, Adams, et al., 2002). In skeletal muscles, each factor elicits muscle fiber adaptations that affect muscle strength and muscle endurance differently (Karavirta, Hakkinen, Sillanpaa, et al., 2011). The following section will discuss mode of exercise, and will focus specifically on the mode-dependent exercise effects of resistance training (weightlifting) and endurance training (running) on muscle strength and endurance.

Exercise Modes

Exercise mode refers to the type of activity an individual performs during an exercise session (Karavirta, Hakkinen, Sillanpaa, et al., 2011). There is a diverse selection of exercise modes (e.g., running, bicycling, weightlifting) and each mode aims to enhance the muscle performance (e.g., strength, endurance) of a particular system by targeting specific muscle groups (J. S. Green & Crouse, 1995; Lemmer et al., 2000; Murias, Kowalchuk, & Paterson, 2010; Westcott et al., 2001; Wilson, Marin, et al., 2012). For example, weightlifting, a resistance training mode of exercise, aims to improve muscular strength (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Lemmer et al., 2000; Westcott et al., 2001). In contrast, distance running, an endurance
training mode of exercise, aims to improve muscle endurance (J. S. Green & Crouse, 1995; Karavirta, Hakkinen, Sillanpaa, et al., 2011; Murias et al., 2010). Muscle strength and muscle endurance have been shown to differentially improve over time depending on the mode of exercise performed (Ferreira et al., 2012; Karavirta, Hakkinen, Sillanpaa, et al., 2011; Karavirta, Hakkinen, Kauhanen, et al., 2011; Sillanpaa et al., 2009).

**Resistance training.** Resistance training is a mode of physical exercise that engages one or more muscle groups to contract against an external force followed by a brief period of rest. The amount of force the muscle(s) produces to oppose the external force is greater than the amount of force the same muscle(s) must produce while performing everyday routine tasks (Caspersen, 1985; Kraemer, Ratamess, et al., 2002). This increased workload has been shown to increase the size and number of the exercised muscle fibers (Bickel, Cross, & Bamman, 2011; Campos et al., 2002; Claflin et al., 2011; Koopman & van Loon, 2009; Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Verdijk et al., 2009), in particular, fast-twitch type II muscle fibers (Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al., 2012). Such adaptations in muscle fibers are known to promote muscle strength, power, and speed and combat muscle mass loss (Bickel et al., 2011; Campos et al., 2002; Claflin et al., 2011; Koopman & van Loon, 2009; Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Verdijk et al., 2009).

The extent of such benefits on muscle strength, however, is also dependent on the contractile action of the muscle. In other words, the positional change (i.e., lengthening, shortening) of the muscle(s) fibers with each muscle contraction impacts the effect of resistance training on muscle strength (Kraemer & Ratamess, 2004). Isometric and isotonic are two forms
of resistance training that produce different muscle contractile actions. In the following sections the differences between isometric and isotonic resistance training will be further reviewed.

**Isometric.** Isometric resistance training exercise is defined as a static muscle contraction in that the length of the muscle does not change as the muscle resists an external force, nor does the range of motion of the muscle produce any movement at the joint (Fleck & Kraemer, 2004). This form of resistive training is commonly used for rehabilitative purposes because it has a rather low risk of injury (Fleck & Kraemer, 2004; Wyss & Patel, 2013). Currently, isometric resistance training is a common rehabilitative approach to improve tongue strength. It includes various static tongue muscle contraction techniques such as, pushing a pressure air-filled bulb, and pressing against a tongue depressor blade. (Clark, O’Brien, Calleja, & Corrie, 2009; Connor et al., 2009; Lazarus, Logemann, Huang, & Rademaker, 2003; Robbins, 2011; Robbins et al., 2005; Robbins et al., 2007; Yeates, Molfenter, & Steele, 2008).

However, during isometric work the muscle contraction is not performed through a full range of motion. The gain in muscle strength is limited to the static position the muscle is holding while contracting against the external force (Fleck & Kraemer, 2004, Wyss & Patel, 2013). Thus the angle the body is being held in (i.e., 90-degree arm flexion) is where strength will be improved. It is also widely accepted that isometric training produces slower gains in skeletal muscle strength improvement compared to other types of resistance training (American College of Sports Medicine, 2010; Ehrman, 2010; Fleck & Kraemer, 2004; Wyss & Patel, 2013). Therefore, this type of resistance training is not preferred for maintaining and improving muscle strength for functional full range of motion tasks involving the trunk and limb muscles (American College of Sports Medicine, 2010; Ehrman, 2010; Fleck & Kraemer, 2004) or tongue muscles (Clark, 2012; Lazarus et al., 2003).
**Isotonic.** Isotonic resistance training exercise involves the shortening (concentric) and lengthening (eccentric) of a muscle(s) while it contracts against an external force. The external force remains constant as the muscle(s) contracts throughout the entire range of motion. Due to a constant resistive load being applied to the muscle during both the concentric and eccentric contractions the exercise challenges the muscle, which results in hypertrophy of muscle fibers and hyperplasia (increased cell production) (Bickel et al., 2011; Campos et al., 2002; Claflin et al., 2011; Koopman & van Loon, 2009; Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Verdijk et al., 2009). In particular, fast-twitch type II skeletal muscle fibers have been shown to benefit from isotonic resistance training (Hornby et al., 2011; Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Reilly et al., 2009; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al., 2012). This is important, as fast-twitch type II muscle fibers contribute to muscle strength, speed, and power (Stal et al., 2003; Wilson, Loenneke, et al., 2012; Zaidi et al., 2012). Further, the movements performed during isotonic exercise often mimic those movements associated with everyday activities that involve these muscles or group of muscles. These effects of isotonic exercise all relate to skeletal muscles. Isotonic exercise, however, may be a favorable exercise approach over isometric exercise when aiming to improve strength, speed, and power of the tongue (Clark, 2012), because of the heterogeneity of fiber composition throughout the tongue (Stal et al., 2003).

Various studies conducted on rats have used direct isotonic resistance training on the tongue muscles and showed an increase in hypoglossal motor units and cross-sectional tongue muscle fibers, as well as increased tongue strength. Each of these studies used an isotonic resistance training program that *directly* targeted the tongue muscles by requiring a rodent to push a pressure loaded spout to receive water (Behan, 2012; Connor et al., 2009; Kletzien,
Russell, LeVerson, & Connor, 2013). This method of isotonic resistance training required the tongue muscles to contract within a functional range of motion against an increased load. The increased load was greater than that of an everyday activity load, such as drinking. The increase in tongue strength and endurance following the targeted isotonic resistance also showed a benefit on tongue performance (Clark, 2012; Connor et al., 2009; Lazarus et al., 2003). Unfortunately, there is no known research evidence for direct isotonic resistance training effects on tongue strength and tongue endurance in humans.

**Endurance training.** Endurance training modes of exercise such as running, bicycling, and swimming target muscular endurance and the cardiorespiratory system (J. S. Green & Crouse, 1995; Karavirta, Hakkinen, Sillanpaa, et al., 2011; Murias et al., 2010). Endurance training involves repetitive contractions of a muscle or group of muscles over an extended duration of time. Each contraction is executed at a level of effort that is below that of maximal capacity (i.e., submaximal contraction) (Holloszy, 1984; Jones & Carter, 2000). The prolonged submaximal muscle contractions result in more efficient utilization of oxygen by muscle cells, which delay the onset of muscle fatigue. In turn, an individual can perform muscle contractions for a longer duration of time and at a greater intensity (Holloszy, 1984; Jones & Carter, 2000).

For the muscle to become more efficient and fatigue resistant, muscle fibers within the muscle have to adapt to the training requirements. One of these adaptations involves the slow-twitch type I muscle fibers. Slow-twitch type I fibers are naturally more efficient in using oxygen as an energy source (Fitts, Booth, Winder, & Holloszy, 1975; Holloszy, 1984). With endurance training, these fibers are shown to increase in number and become even more efficient in using oxygen (Demirel, Powers, Naito, Hughes, & Coombes, 1999; Fitts et al., 1975; Holloszy, 1984). Numerous studies have shown that the muscles responsible for locomotion have a greater
number of slow-twitch type I fibers and produce a greater volume of oxygen consumed (VO₂) in endurance trained individuals (i.e., distance runners) than resistance trained and untrained individuals (Demirel et al., 1999; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al., 2012). There are, however, no known reports of the effect(s) of endurance training on tongue fibers and tongue muscle performance in humans (Clark, 2012).

**Indirect Effect of Physical Exercise**

During physical exercise, not only are the muscles *directly* targeted during that exercise engaged; other muscles in the body are also *indirectly* affected by the physical exercise. In skeletal muscles, isotonic exercise activates skeletal muscle fibers in the *directly* targeted muscle(s) and the muscle fibers in *non-targeted* muscle(s). The activated muscle fibers promote muscle hypertrophy and contribute to an increase in muscle strength, speed, and power of the *targeted* and *non-targeted* muscles (Fisher et al., 2011; Garber et al., 2011; Hamlyn et al., 2007; Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Munn et al., 2004). For example, Munn (2004) reviewed multiple isotonic resistance training studies and found that *direct* isotonic training on one limb increased muscle strength in both, the exercised limb and in the contralateral *non-exercised* limb. Other studies have further shown that performing isotonic exercises by performing squats, which *target* leg muscles, also activates *non-targeted* abdominal muscles. As a result, the *targeted* leg muscles and the *non-targeted* abdominal muscles increase muscle strength (Fisher et al., 2011; Hamlyn et al., 2007). Endurance exercise, on the other hand, elicits muscle fiber adaptations driven by the need for more efficient use of oxygen in the *directly* targeted muscle(s) as well as the muscle fibers in *non-targeted* muscle(s) (Demirel et al., 1999; Fitts et al., 1975; Holloszy, 1984; Tordi et al., 2001; Wilson, Loenneke, et al., 2012). The adaptive muscle fibers contribute to an increase in muscle endurance in *targeted* and *non-targeted* muscle(s).

For the tongue, it is known that tongue muscles are indirectly activated during physical exercise. For example, physical activity, such as running, not only increases skeletal muscle activity in the arms and legs; it also results in increased tongue muscle activation to dilate the upper airway for more efficient gas exchange (Shi, Seto-Poon, & Wheatley, 1998; Williams, Janssen, Fuller, & Fregosi, 2000). Based on these findings, the indirect training effect on tongue muscles was investigated by comparing direct isotonic resistance training and indirect endurance training effects in tongues of younger, middle-aged and older rats (Kletzien et al., 2013).

The direct exercise consisted of isotonic resistance training of the tongue, which required the rats to apply a specific force against a spout, which was then rewarded with a drink of water. The indirect physical exercise involved running on a treadmill (endurance exercise). Following an eight-week exercise period the group of rats enrolled in the direct tongue resistance training produced greater maximal twitch tension (tongue strength) than the group of rats that completed the treadmill running, whereas the rate of fatigue (tongue endurance) between the groups was age dependent. The young indirect endurance trained rats fatigued at a slower rate than the young direct resistance trained rats, while the older direct resistance trained rats fatigued at a slower rate than the older indirect endurance trained rats. Nevertheless, the rats from the direct tongue resistance training and indirect endurance training groups demonstrated improved maximal twitch tension (tongue strength) and reduced muscle fatigue (improved muscle endurance) compared to the rats in the control group (no exercise) (Kletzien et al., 2013).
The authors speculated that the observed increase in tongue muscle strength and endurance of rats completing the treadmill protocol might have been due to the increased respiration rate while running. A greater respiratory rate during physical activity may have placed greater demands on tongue fibers to support upper airway patency (Shi et al., 1998; Wheatley, Amis, & Engel, 1991; Williams et al., 2000).

These findings by Kletzien and colleagues (2013) offer insight into the effects of direct and indirect exercise on tongue muscle performance in rats; however, these findings may not directly translate to humans. Although humans and rats are found to have several anatomical and physiological characteristic similarities (Bailey, Huang, & Fregosi, 2006; Bailey, Janssen, & Fregosi, 2005; Doran & Baggett, 1972), VanRavenhorst-Bell and colleagues (2013) identified several differences. For example, a human’s upper airway is an L-shaped structure and its positioning remains constant to the individual’s posture. In contrast, a rat’s upper airway is described as rectilinear and is considered to be in an “upright” position when the rat is residing in its natural supine posture (standing on all four feet) (Barbizet, 1958; Hast, 1989; Lu & Kubin, 2009; Matsuo & Palmer, 2010). Second, the movement of the hyoid bone differs. During inspiratory respiration the tongue muscles of a rat typically remain atonic due to the hyoid bone being anchored to the trachea and providing upper airway stabilization, whereas in humans the hyoid bone is not anchored and is free moving requiring the muscles of the tongue to activate during inspiratory respiration to maintain upper airway patency (Barbizet, 1958; Hast, 1989; Lu & Kubin, 2009; Matsuo & Palmer, 2010; Mezzanotte, Tangel, & White, 1992; Series, Cormier, Desmeules, & La Forge, 1989). Another difference, the delivery of a respiratory cycle under voluntary response (i.e., intentional breath, smelling a flower) is only reproducible in humans, while rats are solely reliant on an automatic respiratory reaction. This difference in automatic
and voluntary behavior between humans and rats alters the mechanisms responsible for motoneurons stimulation (Younes, Park, & Horner, 2007) which may differentiate breathing patterns between species during exercise. Finally, the sensory afferent input and response to negative pressure during respiration is much lower in rats than that of humans (Bailey & Fregosi, 2004; Bailey et al., 2005; Lee, Fuller, Lu, Lin, & Hwang, 2007; Mateika, Millrood, Kim, Rodriguez, & Samara, 1999; Ryan, McNicholas, O'Regan, & Nolan, 2001). Such differences between these two species may result in different tongue muscle activation responses during increased respiration during exercise.

Further, the methods administered by Kletzien et al., (2013) differed from methods that are typical of tongue muscle performance measures in humans. For example, tongue muscle performance measures of the genioglossus muscle were measured during an involuntary muscle response to outside stimuli while the rat was placed under anesthesia, whereas a human would remain in a wakened-state and tongue muscle performance measures would be based on a voluntary muscle contraction. In addition, VanRavenhorst-Bell et al., (2013) stated that the actual measures reported for tongue strength and endurance on the rats (e.g., maximal twitch tension for tongue strength, fatigue index percentage for tongue endurance) did not emulate measures typically reported for human tongue strength and endurance (pressure of tongue strength and duration of tongue endurance), nor did they differentiate measures particular to any one region of the tongue. Given that studies have shown that the anterior and posterior regions of the tongue differ in muscle fiber composition (J. S. Green & Crouse, 1995; Stal et al., 2003; Trawitzki et al., 2011; Zaidi et al., 2012), the findings reported by Kletzien et al., (2013) may not accurately represent the effects of direct and indirect exercise on tongue muscle fibers by region.
To further our knowledge on the notion that physical exercise may affect indirectly targeted tongue muscles in humans, VanRavenhorst-Bell and colleagues (2013) investigated differences in tongue strength and tongue endurance (anterior and posterior) between individuals who exercised regularly and those who did not exercise regularly. The study observed differences in both male and female young adults age 18 to 29 years, and older adults age 61 years and older. The overall findings of the study showed that individuals who exercised regularly (active) produced anterior and posterior tongue strength and endurance measures that were significantly greater than those who did not exercise regularly (non-active). Further, although this observation was seen in younger and older adults, it was greater between older active and non-active adults than in younger adults. The study also reported that in older adults who exercised regularly, tongue strength and endurance were comparable to those of younger adults.

The findings from the studies by Kletzien et al., (2013) and VanRavenhorst-Bell et al., (2013) each provide support for the notion that physical exercise may benefit indirectly targeted tongue strength and endurance in humans. Apart from the main group findings, VanRavenhorst-Bell et al., (2013) made an interesting observation on tongue strength and tongue endurance measures within the active younger adult group. Specifically, two participants in the younger active group recorded tongue measures that greatly differed from one another, as well as from participants within the active younger adult group. One participant was a reported hammer-thrower who regularly engaged in isotonic resistance training exercise, and the second participant was a reported endurance trained runner who regularly engaged in long distance running. The resistance trained hammer-thrower had greater tongue strength than any other participant in the group, and likewise, the endurance trained marathon runner displayed greater
tongue endurance than all other participants in the group. Table 2.1 displays the tongue strength and tongue endurance measures of these two individuals along with published reference data as a within-group reference.

Table 2.1

Recorded Measures of Tongue Strength and Endurance for the Resistance Trained Hammer Thrower and the Endurance Trained Distance Runner with Comparative Published Reference Measures.

<table>
<thead>
<tr>
<th></th>
<th>Tongue Strength (kPa)</th>
<th>Tongue Endurance (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
</tr>
<tr>
<td>Hammer Thrower*</td>
<td>85</td>
<td>88</td>
</tr>
<tr>
<td>Distance Runner*</td>
<td>56</td>
<td>61</td>
</tr>
<tr>
<td>Published Reference Measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean*</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Range*</td>
<td>40-80</td>
<td>40-80</td>
</tr>
</tbody>
</table>

Note: kPa = Kilopascals.
\* (VanRavenhorst-Bell, Mefferd, Patterson, & Scudder, 2013).

The tongue muscle performances of these two participants were shown to greatly differ from the typical tongue muscle performance measures shown to occur in healthy adults, yet it is unknown why these two participant’s measures were so different. There are a number of possible factors known to influence skeletal muscle adaptations, such as genetics, nutrition, and blood and oxygen supply (Bouchard, Rankinen, & Timmons, 2011; Castro, Pedrosa, & Nobrega, 2011; Hawley, Burke, Phillips, & Spriet, 2011; Manimmanakorn, Hamlin, Ross, Taylor, & Manimmanakorn, 2013; Manimmanakorn, Manimmanakorn, et al., 2013; Shi et al., 1998), which may explain these tongue muscle performance differences. Another possible factor, however, may be the specific mode of exercise each of these two participants engaged in during exercise.
As previously stated, different modes of training (i.e., weightlifting, running) are shown to elicit muscle fiber adaptations that affect skeletal muscle strength and skeletal muscle endurance differently (Karavirta, Hakkinen, Sillanpaa, et al., 2011). In addition, different modes of exercise that are shown to affect targeted skeletal muscles are also shown to affect indirectly targeted skeletal muscles (Fisher et al., 2011; Kraemer & Ratamess, 2004; Kraemer, Ratamess, et al., 2002; Munn et al., 2004; Tew et al., 2009; Tordi et al., 2001).

Furthermore, various modes of exercise yield particular breathing patterns (Castro et al., 2011; Cerny & Ucer, 2004; Elliott & Grace, 2010; Kalsas & Thorsen, 2009). For example, weightlifting (isotonic resistance training) is associated with an intense and forceful breathing pattern referred to as the Valsalva maneuver. The Valsalva maneuver is segmented with forceful phases of inhalation that produce increased negative pressure from the diaphragm followed by a brief pause before exerting great force and exhaling against an open glottis (Ikeda et al., 2009; Kawabata, Shima, Hamada, Nakamura, & Nishizono, 2010; Talasz, Kofler, & Lechleitner, 2011). In contrast, endurance runners engage in a controlled and rhythmic pattern of breathing that efficiently utilizes oxygen known as coupling. (Bernasconi & Kohl, 1993; Castro et al., 2011; Daley, Bramble, & Carrier, 2013; Elliott & Grace, 2010). Coupling allows the muscles to contract at a submaximal level of effort over an extended period of time with minimal fatigue (Holloszy, 1984; Jones & Carter, 2000). These individualized breathing patterns may indirectly influence the tongue muscle activation response needed to maintain an open upper airway when different modes of exercise are engaged.

Given the literature on indirect effect of exercise mode on indirectly targeted skeletal muscles and recognizing that these two participants, who regularly engaged in a specific mode of exercise produced vastly different tongue muscle performance measures, provided grounds to
investigate the effect of exercise mode on *indirectly* targeted tongue muscles as a logical next step.

**Purpose of the Study**

The purpose of this study was to determine if there is a difference in tongue muscle performance (i.e., strength, endurance) between individuals who regularly engage in resistance training exercise (e.g., weightlifting) and individuals who regularly engage in endurance training exercise (e.g., running). In addition, the study sought to determine if there was a differential performance of anterior and posterior tongue musculature in weightlifters and runners.

**Significance.** With age, the tongue muscles undergo anatomical and histological changes that are known to affect tongue function. For example, similar to age-related decline in skeletal muscle mass, tongue muscle mass is also known to decline. This process is commonly known as sarcopenia (Cruz-Jentoft et al., 2010; Evans, 1995; Fielding et al., 2011; Logemann et al., 2000; Muscaritoli et al., 2010; Robbins, Hamilton, Lof, & Kempster, 1992). In addition to the loss of muscle mass, the size and number of the muscle fibers decrease (Nicosia, 2000; Robbins et al., 1995; Steele et al., 2009; Tamine et al., 2010; Youmans & Stierwalt, 2006).

In the skeletal system, physical exercise is known to retard this aging process. A better understanding about how physical exercise may *indirectly* affect tongue muscle performance in healthy younger adults may in the future assist to identify ways to retard tongue strength and tongue endurance decline due to aging or other health related issues. Such insights are important because age-related decline of tongue strength and endurance negatively impacts tongue functions, particularly in the presence of a neurological disease (Adams et al., 2013b; Clark & Solomon, 2012; Crow & Ship, 1996; Nicosia, 2000; Robbins et al., 1995; Trawitzki et al., 2011; Youmans & Stierwalt, 2006; Youmans et al., 2009). Further, dysphagia, a disordered swallowing
function, and sleep apnea, an obstructed upper airway disorder, can occur in older adults if tongue strength and endurance decline significantly as part of the overall aging process (Connor et al., 2009; McSharry et al., 2012; Mezzanotte et al., 1992; Nicosia, 2000; O'Connor, Langran, O'Sullivan, Nolan, & O'Malley, 2004; Ono, 2012; Remmers, deGroot, Sauerland, & Anch, 1978; Robbins et al., 2005; Yeates et al., 2008; Youmans & Stierwalt, 2006). Thus, it is important to maintain adequate tongue strength and endurance in later stages of life to ensure quality of life and well-being.

Summary

Research has shown that exercise has a beneficial indirect effect on skeletal muscle strength and endurance (Fisher et al., 2011; Hamlyn et al., 2007; Munn et al., 2004; Tew et al., 2009). Research has further shown that different modes of exercise elicit individualized muscle adaptations that benefit directly and indirectly targeted skeletal muscle strength and endurance (Kraemer, Adams, et al., 2002). In addition, research has shown that exercise (i.e., running) has an indirect effect on tongue muscle strength and endurance of rats (Kletzien et al., 2013). However, to our knowledge research has yet to determine whether physical exercise or mode of exercise has an indirect effect on tongue strength and endurance of humans similar to that of skeletal musculature. A recent study by VanRavenhorst-Bell et al., (2013), has provided some support for the notion that exercise may have an indirect effect on tongue strength and endurance. The authors reported that tongue strength and endurance differed between individuals who exercised and those who did not exercise. The active group in their study, however, represented various modes of exercise, thereby eliminating the ability to identify whether tongue muscle performance differed between each mode of exercise.

Capitalizing on these insights, the current study focused on whether tongue muscle
strength and endurance differed by modes of exercise (weightlifting, running) as has been
evident in skeletal muscles. Further, the current study explored whether tongue muscle strength
and endurance differed with each mode of exercise by tongue region (anterior, posterior) due to
the individualized muscle fiber arrangement of each tongue region. Although there are many
explanations for why tongue muscle strength and endurance may display differing measures in
active individuals (e.g., genetics, nutrition, blood and oxygen supply) (Bouchard et al., 2011;
Castro et al., 2011; Hawley et al., 2011; Manimmanakorn, Hamlin, et al., 2013;
Manimmanakorn, Manimmanakorn, et al., 2013; Shi et al., 1998), the rationale for this study was
grounded on the fact that targeted and indirectly targeted skeletal muscle strength and
endurance, as well as muscle fiber adaptations, differ when comparing resistance training and
endurance training (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Kraemer & Ratamess, 2004;
Kraemer, Ratamess, et al., 2002; Wilson, Marin, et al., 2012).

Findings of this study, therefore, provide valuable insights regarding differences in
tongue strength and endurance when comparing different modes of exercise (weightlifting,
running), therefore establishing a better understanding of the notion that physical exercise may
have an indirect effect on tongue function. An adequate level of tongue strength and endurance is
necessary for the proper execution of tongue functions, such as bolus preparation and swallowing
(Robbins, Coyle, Rosenbek, Roecker, & Wood, 1999; Steele et al., 2009; Steele & Van Lieshout,
2009; Stierwalt & Youmans, 2007; Youmans & Stierwalt, 2006; Youmans et al., 2009), as well
as maintaining upper airway patency during respiration (Bailey, Rice, & Fuglevand, 2007;
Blumen et al., 2004; Cheng, Butler, Gandevia, & Bilston, 2008; Fregosi, 2011; Saboisky et al.,
2006; Takahashi, Ono, Ishiwata, & Kuroda, 2002). Further, these insights may have implications
for future research on the typical aging processes and tongue function.
Research Aims and Hypotheses

Research aim #1. This study aimed to determine if tongue strength differed between weightlifters and runners and if group difference varied with tongue regions (anterior, posterior).

Hypothesized outcome #1. Based on previous studies it was expected that weightlifters would produce greater tongue strength than runners. Further, based on the anatomical differences in tongue muscle fibers, it was expected that the between-group difference in tongue strength would be significantly greater in the anterior tongue than the posterior tongue. The null hypothesis $H_0$ states: Tongue strength would not differ between weightlifters and runners and group difference will not differ between the anterior and posterior region.

Research aim #2. This study aimed to determine if tongue endurance differed between weightlifters and runners and if group difference varied with tongue regions (anterior, posterior).

Hypothesized outcome #2. Based on previous studies it was expected that runners would produce greater tongue endurance than weightlifters. Further, based on the anatomical differences in tongue muscle fibers, it was expected that the between-group difference in tongue endurance would be significantly greater in the posterior tongue than the anterior tongue. The null hypothesis $H_0$ states: Tongue endurance would not differ between weightlifters and runners and group difference will not differ between the anterior and posterior region.
CHAPTER III

METHODOLOGY

Participants

A total of 45 healthy, male and female adults, 19-29 years of age volunteered for the study. Participants were divided into two groups based on their self-reported exercise mode: 1) resistance training, and 2) endurance training. Recruitment efforts focused on individuals engaged in weightlifting (resistance training mode) and long-distance running (endurance training mode). Fliers and technology-based communication links as well as word-of-mouth were used to connect with weightlifters or runners in Wichita, Kansas and the surrounding area. All volunteers read and signed an *Informed Consent Form* (See Appendix B) approved by the Wichita State University Institutional Review Board (IRB) prior to completing any questionnaires or participating in data collection.

Inclusion criterion. Volunteers answered three intake questionnaires to determine participation and group placement. To participate in this study, volunteers reported no history of a neurological disease as well as diseases or injuries that would negatively impact lingual function (*see Oral Health History Questionnaire*, Appendix C). Further, volunteers qualified if they were in adequate physical health to complete all experimental tasks [determined by the *Physical Activity Readiness Questionnaire (PAR-Q, CSEP, 2002, Appendix D)*] and did not take any medication identified on the *PAR-Q* as prohibitive for completion of the experimental tasks. Finally, volunteers qualified if they reported regular resistance training (weightlifting) or endurance training (distance-running) four or more days per week over the past year. Individuals reporting a cross training exercise schedule (e.g., equal days of resistance training and endurance training, 3-day/4-day split of resistance training to endurance training) and individuals who
reported training for less than one year did not qualify [determined by the Physical Activity Questionnaire (PAQ, MeDesign, 2013, Appendix E)].

All 45 volunteers successfully completed the intake questionnaires and participated in the study. One male weightlifter, however, was unable to perform the necessary tasks for tongue measures and was removed from the study. Table 3.1 provides a description of the remaining 44 participants in the two groups.

Table 3.1

*Descriptive Group Means, Standard Deviations, and Sum of Weightlifters, Runners and Overall*

<table>
<thead>
<tr>
<th>Group</th>
<th>Gender</th>
<th>Age + SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weightlifters</td>
<td>Male</td>
<td>24.09 ± 3.02</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>22.70 ± 3.23</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23.43 ± 3.12</td>
<td>21</td>
</tr>
<tr>
<td>Runners</td>
<td>Male</td>
<td>23.92 ± 3.12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>23.45 ± 3.01</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23.70 ± 3.01</td>
<td>23</td>
</tr>
<tr>
<td>Overall</td>
<td>Male</td>
<td>24.00 ± 3.00</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>23.10 ± 3.06</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>23.57 ± 3.03</td>
<td>44</td>
</tr>
</tbody>
</table>
Research Design and Protocol

Data collection was conducted in the Human Performance Laboratory, Heskett Center Room 210 at Wichita State University. Procedures followed all required human safety and ethical measures with approval from the Wichita State University IRB (See Appendix F).

Physical measures. To provide an objective evaluation of each participant’s physical status and identify differences in the body physiology between members of the two experimental groups, measures of skeletal muscle strength and cardiovascular/muscle endurance were obtained from each participant. The following measures are frequently used for such purposes: handgrip strength and estimated VO2 (Ehrman, 2010; Ehrman, Gordon, Visich, & Keteyian, 2009).

Assessment of skeletal muscle strength. Maximal handgrip strength measures have been commonly used to establish upper-body muscle functional force (Bassey & Harries, 1993; Jakobsen, Rask, & Kondrup, 2010; Taekema, Gussekloo, Maier, Westendorp, & de Craen, 2010). In this study, handgrip strength was used to objectively distinguish skeletal muscle strength differences between the two groups. A hydraulic hand dynamometer (Jamar, Sammons Preston Inc., Bolingbrook, IL) measured the participant’s maximal handgrip strength. While standing, the participant held the dynamometer in the non-dominant hand and applied maximal force by squeezing the dynamometer for two to three seconds and releasing. A total of three trials were performed with a 30-second rest between trials to avoid fatigue. The highest achieved value was recorded as maximal handgrip strength (ACSM, 2010; Ehrman et al., 2009; Ehrman, 2010).

To identify if there were differences in handgrip strength between members of the two experimental groups and determine whether participants were placed into the appropriate group
an Independent t-test was conducted. The Independent t-test yielded no statistically significant
difference in handgrip strength between weightlifters and runners, \( t(42) = 1.90, p = .07 \).
Although statistical significance was not reached, handgrip strength of the weightlifters \( (M = 104.90 \pm SE = 5.96) \) tended to be greater than handgrip strength of runners \( (M = 90.35 \pm SE = 4.92) \) and suggested the expected performance patterns for the two experimental groups (see
Figure 3.1.).

![Figure 3.1. Means and Standard Errors of Handgrip Strength in Weightlifters and Runners](image)

**Measures to normalize assessments.** To normalize measures of cardiovascular/muscle
endurance function *age, height, and weight* were taken at the beginning of data collection. *Height*
was measured using a stand-o-meter scale while the participant stood bare-footed in an upright
posture, shoulders pulled back and head in a neutral, front-facing position with the maximum
stature being recorded. *Body weight* was measured using a stand-alone personal floor scale. The
participant’s shoes, extra clothing (i.e., jacket, hat) and accessories (i.e., jewelry) were removed
prior to recording weight.
**Assessment of cardiovascular/muscle endurance.** The participant’s estimated VO₂ level was assessed one time in this study to objectively distinguish skeletal muscle endurance differences between the two groups. The estimated VO₂ level was measured using the Ergomedic 828E cycle ergometer (Monark, Vansbro, Sweden) with the Young Men’s Christian Association (YMCA) 85% submaximal cycle ergometer protocol (*YMCA Protocol*, Appendix G). This is a standardized multi-stage test lasting 9 to 12 minutes. The participant began with a 2-3 minute warm-up. This warm-up allowed the participant to become familiar with the 60 rotations per minute (rpm) pedaling cadence that he/she was required to maintain throughout the test. Once the test began, the participant maintained the 60-rpm pedaling cadence and the work output was set according to a standardized workload chart, ranging from 150 to 900 kilopond per meter per minute (kp*m*min⁻¹). The advancement of workload and stage was based upon standardized YMCA protocol. Completion of at least 2 stages along with obtaining a heart rate between 110 beats per minute (bpm) and 85% of age-predicted maximum heart rate, and a steady state heart rate within 6 bpm marked the end of the test. Following the test, the participant cooled down for three minutes while remaining on the bicycle ergometer. The participant then transitioned to a stationary chair for an additional three minutes of recovery (ACSM, 2010; Ehrman et al., 2009; Ehrman, 2010). The participant’s heart rate, blood pressure, and rate of perceived exertion were monitored according to established protocol. The Borg *Rating of Perceived Exertion (RPE)*, which was used, identified each participant’s perceived physical effort as it accurately reflected a specific number rating (e.g., The lowest numeric value “6” represents no exertion at all, The highest numeric value “20” represents maximal exertion) on the Borg scale. The participant’s RPE was recorded to monitor the participant’s perceived physical status throughout the submaximal VO₂ test (Borg, 1982).
A baseline blood pressure was measured prior to the submaximal VO₂ test using an appropriately sized blood pressure cuff and stethoscope. The participant was seated and allowed to rest for five minutes before the blood pressure measure. Subsequent blood pressure measures were also taken throughout the submaximal VO₂ test per protocol and were compared to the baseline blood pressure to monitor the participant’s well-being throughout the test. Per protocol, the test was prematurely stopped if the participant’s blood pressure indicated any signs of unusual physical distress. Two additional blood pressure measures were obtained three and six minutes after the test to monitor recovery (Ehrman, 2010; Ehrman et al., 2009).

Heart rate was monitored with the use of the Polar HR a1 heart rate monitor (Polar Electro, Lake Success, NY). The sensor strap was placed directly on the skin at the participant’s lower chest. Prior to the submaximal VO₂ test, the participant rested for five minutes in a seated position. The heart rate was recorded after the resting period to establish the baseline for the submaximal VO₂ test. Additional heart rate measures were obtained throughout the test per protocol to determine test stage and workload advancement to identify the point at which the participant had reached 85% maximal heart rate. The participant’s heart rate was also measured three and six minutes after the submaximal VO₂ test to monitor recovery (Ehrman, 2010; Ehrman et al., 2009).

To identify if there were differences in cardiovascular endurance between members of the two experimental groups and determine whether participants were placed into the appropriate group an Independent \( t \)-test was conducted. The Independent \( t \)-test yielded a significant difference in cardiovascular endurance between weightlifters and runners, \( t(42) = -4.80, p < .001 \), with weightlifters producing a significantly lower VO₂ (\( M = 45.47 \pm SE = 5.96 \)) than
runners ($M = 61.13 \pm SE = 4.92$). This significant difference in cardiovascular endurance confirms that the participants were placed into the appropriate group (See Figure 3.2).

![Figure 3.2. Means and Standard Errors of Cardiovascular Endurance of Weightlifters and Runners](image)

**Tongue measures.** To determine if there was a difference in tongue strength and tongue endurance between weightlifters and runners and if the group differences varied with tongue region, tongue strength and tongue endurance measures in the anterior and posterior regions of the tongue were obtained from each participant. The following objective measures are frequently used for such purposes.

**Assessment of tongue muscle strength and endurance.** The IOPI (IOPI Medical, Redmond, WA) measured maximal tongue pressure and tongue endurance with the use of a small disposable air-filled plastic bulb connected to a hand-held device which calculated applied pressure as the tongue pushed the bulb against the roof of the mouth. Measurements were taken from the anterior (10 mm posterior to the tongue tip), and posterior (10 mm anterior to the most posterior circumvallate papilla) regions of the tongue (Robbins et al., 2007). To control for order effect on bulb placement, each group was split in half with the first half starting with anterior
measures and the second half starting with posterior measures. Figure 3.3 displays a typical experimental setup for the use of the IOPI for tongue strength and endurance measures.

Figure 3.3. Anterior and Posterior Tongue Placement of the IOPI Bulb (Robbins et al., 2007).

**Maximal tongue strength.** With the participant remaining in a seated position the air-filled bulb was inserted into the participant’s mouth in the pre-determined site. To confirm proper placement within the designated tongue region a sterile tongue depressor, pre-marked at 10mm, confirmed proper placement. Once proper placement was completed and the tongue depressor removed from the participant’s mouth, the participant was asked to apply maximal static pressure against the roof of the mouth for one to two seconds. The best of three measurement trials was recorded as the maximal tongue strength. Between each of the three trials, a 30 second rest was provided (Adams et al., 2013a; Crow & Ship, 1996; Robbins et al., 2007; Robbins et al., 1995; Robin, Goel, Somodi, & Luschei, 1992, Solomon, 2004). The stated protocol was administered for both the anterior and posterior tongue regions respectively.

**Maximal tongue endurance.** Using the tongue depressor to confirm proper placement, the air-filled bulb was returned into the participant’s mouth and he/she was instructed to maintain
50% maximal tongue strength pressure against the roof of the mouth for as long as he/she was able a total of one time. The maintained duration of time was recorded as tongue endurance (Adams et al., 2013a; Crow & Ship, 1996; Robbins et al., 2007, Solomon, 2004). The stated protocol was administered for both the anterior and posterior tongue regions respectively.

**Statistical Analysis**

The following statistical analyses addressed the proposed research questions:

1. A 2x2 (Tongue Strength [anterior, posterior] x Training Mode Group [weightlifters, runners]) mixed measures analysis of variance (ANOVA) was conducted to determine between-subjects main effect of training mode (weightlifting, running) and within-subjects main effect of tongue region as well as the interaction of group and tongue region on tongue strength. The interaction and main effects were tested with a critical alpha level of $p \leq .05$. If the interaction was significant then post-hoc comparison $t$-tests were administered at a $p \leq .05$.

2. A 2x2 (Tongue Endurance [anterior, posterior] x Training Mode Group [weightlifters, runners]) mixed measures analysis of variance (ANOVA) was conducted to determine between-subjects main effect of training mode (weightlifting, running) and within-subjects main effect of tongue region as well as the interaction of group and tongue region on tongue endurance. The interaction and main effects were tested with a critical alpha level of $p \leq .05$. If the interaction was significant then post-hoc comparison $t$-tests were administered at a $p \leq .05$. 

34
CHAPTER IV
RESULTS

Tongue Strength Measures

A 2x2 (Tongue Strength [anterior, posterior] x Training Mode Group [weightlifters, runners]) mixed measures ANOVA was used to determine if there was a difference in tongue strength between weightlifters and runners, as well as if there was a difference in tongue strength measured at the anterior and posterior regions of the tongue. Further, this analysis determined if the group difference depended on tongue region.

The between-subjects analysis revealed no significant main effect of group on tongue strength as depicted in Figure 4.1, $F(1,42) = 2.52, p = .12, \eta^2_p = .06, \text{Observed Power}_a = .34$; weightlifters ($M = 64.62 \pm SE = 2.51$), runners ($M = 59.11 \pm SE = 2.40$).

Figure 4.1. Means and Standard Errors of Tongue Strength in Weightlifters and Runners

The within-subjects measure revealed a significant main effect of tongue region on tongue strength, $F(1,42) = 8.81, p = .01, \eta^2_p = .17, \text{Observed Power}_a = .83$. As depicted in Figure
tongue strength was significantly greater in the anterior region of the tongue ($M = 63.85 \pm SE = 1.56$) than the posterior region ($M = 59.88 \pm SE = 2.12$).

There was no significant group by region interaction, $F(1, 42) = 1.89, p = .18, \eta^2_p = .04$. Observed Power, $\alpha = .27$. However, as Figure 4.3 shows, the significant effect of tongue region depends on the group; in weightlifters anterior ($M = 67.52 \pm SE = 2.26$) was greater than the posterior tongue strength ($M = 61.71 \pm SE = 3.06$), whereas in runners the anterior ($M = 60.17 \pm SE = 2.16$) and posterior ($M = 58.04 \pm SE = 2.93$) tongue strength were similar.
Tongue Endurance Measures

A 2x2 (Tongue Endurance [anterior, posterior] x Training Mode Group [weightlifters, runners]) mixed measures ANOVA was used to determine if there was a difference in tongue endurance between weightlifters and runners, as well as if there was a difference in tongue endurance measured at the anterior and posterior regions of the tongue. Further, this analysis determined if the group difference depended on tongue region.

The between-subjects analysis revealed a significant main effect of group on tongue endurance, $F(1, 42) = 8.88, p = .01, \eta^2_p = .18$, Observed Power$_a = .83$. As Figure 4.4 shows, tongue endurance of runners ($M = 20.37 \pm SE = 2.41$) was significantly greater than tongue endurance of weightlifters ($M = 9.98 \pm SE = 2.52$).
The within-subjects measures used Wilks’ Lambda because equal variances could not be assumed. The within-subjects measure revealed no significant main effect of tongue region on tongue endurance as depicted in Figure 4.5, $F(1,42) = 3.78, p = .06, \eta^2_p = .02$, Power Observed$_a = .47$; anterior tongue endurance ($M = 16.67 \pm SE = 1.95$), and posterior tongue endurance ($M = 13.68 \pm SE = 1.86$).

*Figure 4.4. Means and Standard Errors of Tongue Endurance in Weightlifters and Runners*

*Figure 4.5. Means and Standard Errors of Anterior and Posterior Tongue Endurance*
There was no significant group by region interaction, $F(1, 42) = 2.18$, $p = .15$, $\eta^2_p = .05$, Observed Power, $\alpha = .30$. Although statistical significance was not reached, Figure 4.6 shows that the significant main effect of group was more pronounced in the anterior tongue regions (runners’ ($M = 23.00 \pm SE = 2.70$), weightlifters’ ($M = 10.33 \pm SE = 2.82$)) than in the posterior tongue regions (runners’ ($M = 17.74 \pm SE = 2.57$), weightlifters’ ($M = 9.62 \pm SE = 2.69$)).

Figure 4.6. Means and Standard Errors of Anterior and Posterior Tongue Endurance in Weightlifters and Runners
CHAPTER V
DISCUSSION

Researchers are just beginning to investigate the *indirect* effects of physical exercise on tongue muscle performance. In fact, the study by Kletzien and colleagues (2013) investigated the *indirect* effects of running on tongue muscle performance of rats, and the study by VanRavenhorst-Bell et al., (2013) that compared tongue muscle performance differences between physically active and physically non-active young and older adults are among the few studies to provide such insight. The general purpose of this study was to further our understanding about the *indirect* effects of exercise mode on tongue muscle performance. This study, however, did not use a pre/post exercise paradigm to address this question. Rather, this study compared individuals who reportedly engaged regularly in resistance training (weightlifting) or endurance training (running). Based on available literature reporting *directly* and *indirectly* targeted skeletal muscular strength and endurance improved differentially depending on the mode of exercise performed, it was expected that tongue muscle performance measures would differ between weightlifters and runners. Specifically, it was expected that weightlifters’ tongue strength would be greater than runners, while runners’ tongue endurance was expected to be greater than weightlifters’. In addition, this study sought to determine if potential between-group differences in tongue muscle performance varied with tongue regions. Based on previous studies reporting that each skeletal muscle fiber type adapts differently to different modes of exercise, we expected tongue muscle performance measures to differ by region for weightlifters and runners similar to that of skeletal muscle performance. It was expected that weightlifters’ and runners’ tongue strength differences would be greatest in the
anterior region of the tongue. In contrast, we expected weightlifters’ and runners’ tongue endurance differences to be greatest in the posterior region of the tongue.

Since this study did not directly investigate the indirect effects of each mode of exercise on tongue muscle performance it is important to acknowledge that the findings of the current study can only speculate that weightlifting and running may have an indirect effect on tongue strength and tongue endurance. There are a number of possible factors such as genetics, nutrition, and blood and oxygen circulation that are known to influence skeletal muscle adaptations (Bouchard et al., 2011; Castro et al., 2011; Hawley et al., 2011; Manimmanakorn, Hamlin, et al., 2013; Manimmanakorn, Manimmanakorn, et al., 2013) and may have a similar effect on tongue muscle adaptation.

**Tongue Strength Measures**

**General findings.** The results of the current study did not support our stated hypothesis that weightlifters would produce significantly greater tongue strength measures than runners. The difference between the two groups, however, did suggest that weightlifters tended to produce greater tongue strength measures than runners. Further, the tongue region by group interaction was not supported. Although the interaction was not found to be significant the difference in tongue strength between weightlifters and runners tended to be greater in the anterior tongue region than in the posterior tongue region.

**Current findings on tongue strength in the context of previously found indirect effects of exercise mode on skeletal muscle strength.** The lack of difference in tongue strength between weightlifters and runners, as well as the non-significant tongue region by group interaction was surprising. Our findings did not concur with previous literature on skeletal musculature that reported muscle strength of directly and indirectly targeted muscles to be
greater in resistance trained (weightlifter) individuals than endurance trained (runner)
individuals, particularly in muscles predominantly comprised of Type II fast-twitch muscle fibers
(Fisher et al., 2011; Hamlyn et al., 2007; Karavirta, Hakkinen, Sillanpaa, et al., 2011; Kraemer,
Ratamess, et al., 2002; Munn et al., 2004; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al.,
2012). Instead, our findings showed that both groups, weightlifters and runners, produced
healthy tongue strength measures (anterior, posterior) that fell within the acceptable normative
range of 40 kPa to 80 kPa (Adam et al., 2013b; Clark & Solomon, 2012; Crow & Ship, 1996;
Robbins et al., 1995; Stierwalt & Youmans, 2007).

Our findings emulate previous studies reporting that tongue strength is greater in the
anterior region of the tongue than the posterior region of the tongue (Adams et al., 2013a, 2013b;
Clark & Solomon, 2012; Kays et al., 2010). Further, the regional tongue strength difference
reported in our findings suggests that tongue muscle fiber types perform in a similar manner to
that of skeletal muscle fiber types (e.g., Type II fast-twitch skeletal muscle fibers produce muscle
strength, speed and power, Type I slow-twitch skeletal muscle fibers produce submaximal
fatigue resistant muscle contractions) (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Wilson,
Loenneke, et al., 2012; Wilson, Marin, et al., 2012). The anterior tongue region is comprised
predominantly of Type II fast-twitch muscle fibers in comparison to the posterior region of the
tongue being comprised predominantly of Type I slow-twitch muscle fibers (Green & Wang,
2003; Stal et al., 2003; Trawitzki et al., 2011; Zaidi et al., 2012), thereby supporting the
significantly greater tongue strength in the anterior region of the tongue.

Our findings confirm that weightlifters and runners each produced healthy tongue
strength measures that are within the normative values of previously reported studies. Further,
our findings concur with previous findings reporting that tongue strength differs between regions with the anterior region being significantly stronger than the posterior region.

**Tongue Endurance Measures**

**General findings.** The results of the current study supported our stated hypothesis that runners’ tongue endurance measures would be significantly greater than weightlifters’ tongue endurance measures. However, the expected performance patterns of the two tongue regions on tongue endurance were not supported. Furthermore, the performance patterns were uncharacteristic of the fiber types within the anterior region. The anterior tongue region, which has relatively more Type II fast-twitch fibers purposed for strength than Type I slow-twitch fibers purposed for endurances tended to produce a greater tongue endurance measure than the posterior tongue region, which consists of relatively more Type I slow-twitch fibers. Additionally, findings did not support the tongue region by exercise group interaction.

**Current findings on tongue endurance in the context of previously found indirect effects of exercise mode on skeletal muscle endurance.** Findings of runners having significantly greater tongue endurance measures than weightlifters suggests that tongue musculature may respond to the *indirect* effects of exercise mode similar to that of skeletal musculature. Running has been shown to improve muscle endurance of *indirectly* targeted skeletal muscles (Jones & Carter, 2000; Karavirta, Hakkinen, Sillanpaa, et al., 2011; Karavirta, Hakkinen, Kauhanen, et al., 2011; Kraemer, Adams, et al., 2002; Tew et al., 2009), as well as enable skeletal muscles to contract at a submaximal intensity for a longer duration of time compared to resistance training (weightlifting) (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al., 2012).
Findings of this study further revealed an area of concern for the weightlifters when compared to healthy tongue endurance values. Previous studies have reported that maintaining a submaximal tongue muscle contraction for 25-35 seconds is considered to be a healthy tongue endurance measure, while a tongue endurance measure performed for 10 seconds or less is viewed as less than optimal to maintain adequate tongue function (Adams et al., 2013b; Crow & Ship, 1996; Stierwalt & Youmans, 2007). In the current study weightlifters tongue endurance measures were at borderline levels for effectively performing everyday tongue functions, yet none of the weightlifters reported any difficulty with functional tongue tasks (i.e., swallowing, fatigue during chewing, maintaining airway patency). One consideration for these lower tongue endurance measures may be due to the greater level of tongue pressure each weightlifter was required to maintain while performing the tongue endurance assessment task. Previous research has shown that maintaining a maximal tongue strength pressure level of 50% while performing the tongue endurance assessment task provides the most acceptable duration of a submaximal tongue muscle contraction (Solomon, 2004). Since maximal tongue strength pressure, although not significantly different, was greater in the weightlifting group ($M = 64.62 \pm SE = 2.51$) than running group ($M = 59.11 \pm SE = 2.40$); the weightlifters were required to maintain on average a greater tongue strength pressure than runners. The relatively greater tongue pressures weightlifters were required to maintain may explain the relatively poor tongue endurance performance in that group compared to runners.

Furthermore, it is important to acknowledge that resistance training has been shown to provide beneficial indirect effects on skeletal muscle endurance. Resistance training differentially improves skeletal muscle endurance depending on the other factors of exercise (i.e., intensity, duration, frequency, volume) (Karavirta, Hakkinen, Sillanpaa, et al., 2011;
For example, a moderate to low intensity (light weight) resistance training program with high repetitions promotes skeletal muscle endurance, whereas a high intensity (heavy weight) with low repetition program promotes skeletal muscle strength (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Kraemer, Ratamess, et al., 2002). The participants in the current study reported that they performed high intensity with low repetition workouts. This level of resistance training is not purposed toward improving muscle endurance. Therefore, the conclusion drawn from the current study may not apply to all modes of weightlifting when different exercise factors, such as level of intensity, are executed.

Additional support provided by Kletzien et al., (2013) mirror our findings that endurance training is associated with a healthier normative value on tongue muscle endurance than that of resistance training. They investigated the effects of targeted resistance training and indirectly targeted endurance training on tongue endurance of rats. Although there are notable differences in the anatomical structure and physiological response of the subjects (Barbiset, 1958; Hast, 1989; Lu & Kubin, 2009; Matsuo & Palmer, 2010; Mezzanotte et al., 1992; Series et al., 1989) between the Kletzien et al., (2013) study and the current study; Kletzien’s findings are similar to the current study. The young adult rats in the Kletzien et al., (2013) study reported significantly greater fatigue index percentages (tongue endurance) in the indirectly trained treadmill running group than the targeted resistance trained group.

The current studies tongue region x exercise group interaction, although not significant, tended to suggest that the significantly greater tongue endurance measures maintained by runners compared to weightlifters tended to be true for the anterior and posterior regions of the tongue. Although our findings were not significant they emulate previous studies on skeletal muscle endurance reporting that endurance exercises (i.e., running) have a greater beneficial indirect
effect on muscle endurance than resistance training exercises (i.e., weightlifting) (Tew et al., 2009; Wilson, Loenneke, et al., 2012).

Although non-significant, the observation that anterior tongue endurance tended to be greater than tongue endurance in the posterior region in runners emulates previous studies reporting anterior tongue endurance to be greater than posterior tongue endurance (Adams et al., 2013a, 2013b; Kays et al., 2010). Interestingly, when comparing our findings to previous studies on skeletal muscles (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Wilson, Loenneke et al., 2012; Wilson, Marin, et al., 2012), these findings are uncharacteristic of the expected performance pattern based on muscle fiber composition within the two tongue regions. The anterior region of the tongue consists primarily of Type II fast-twitch muscle fibers. These fibers are responsible for producing strong and powerful movements (Green & Wang, 2003; Stal et al., 2003; Trawitzki et al., 2011; Zaidi et al., 2012). In contrast, the posterior region of the tongue is comprised primarily of Type I and Type IM/IC slow-twitch fibers. These fibers are purposed more toward maintaining a submaximal contraction and delaying muscle fatigue (Green & Wang, 2003; Stal et al., 2003; Trawitzki et al., 2011; Zaidi et al., 2012). Based on the composition of the fiber arrangements within each tongue region it would be expected that the posterior region of the tongue would produce a greater tongue endurance measure than the anterior region of the tongue. Further acknowledging the uncharacteristic muscle performance of runners’ tongue endurance based on muscle fiber type. Endurance training has been shown to produce an increase in muscle endurance of skeletal muscles predominantly comprised of Type I and IM/IC muscle fibers (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Wilson, Loenneke, et al., 2012; Wilson, Marin, et al., 2012). It is unknown why runners tended to have greater tongue endurance in the anterior tongue region comprised predominantly of Type II fast-twitch muscle
fibers than the posterior tongue region comprised primarily of Type I and IM/IC muscle fibers. In addition, it is unknown why the tongue muscle fibers do not follow the expected performance pattern of muscle fiber types as shown in skeletal muscles. To further investigate this uncharacteristic response (e.g., skeletal muscle endurance based on fiber type) future research is necessary. For example, evaluating the tongue muscle fiber activation pattern within each tongue region during various daily activities (i.e., eating, talking, rest, house work, yard work) and different modes of exercise at set levels of intensity may provide further insight.

Furthermore, it is important to point out that the IOPI instrumentation and plastic air-filled bulbs required for the use of the IOPI may have limitations. In particular, movement of the plastic air-filled bulb from the desired set location (region) on the tongue is typical (Hewitt et al., 2008). The smallest of movement and repositioning of the bulb, which cannot be prevented by the experimenter, may have displaced the bulb inside of the oral cavity and may have provided tongue muscle endurance measures from a site other than from the desired set location in the mouth (anterior, posterior). This may explain the discrepant findings for endurance between the present study and previous reports in the literature on skeletal muscle performance.

Our findings showed that runners were capable of producing acceptable tongue endurance measures, whereas weightlifters produced tongue endurance measures that were low and of concern for performing daily functional tasks (i.e., swallowing, maintaining upper airway patency). Additionally, our findings revealed an uncharacteristic response with anterior tongue endurance being greater than posterior tongue endurance. This finding will require future research before drawing a conclusion.

Potential Mechanisms Underlying Tongue Muscle Performance Differences Between Weightlifters and Runners
The two modes of exercise in the current study each engaged in a distinctly different breathing pattern. For example, the brief, yet intense and forceful Valsalva maneuver breathing pattern associated with weightlifting increases negative pressure in the intra-abdominal region (Ikeda et al., 2009; Kawabata et al., 2010; Talasz et al., 2011). To overcome the powerful negative pressure being produced by the diaphragm as a heavy resistance lift is performed the tongue muscles may be required to adapt and increase strength. As the current study depicts, the weightlifters’ tongue strength (anterior, posterior) measures were healthy and strong. This implies that the breathing pattern weightlifters engage may have an indirect effect on tongue strength due to the increased demand placed on the activated tongue muscle to maintain an open upper airway with each lift. However, the duration of time the tongue muscles are required to activate during each lift may be so short that muscles may not be able to become efficient in utilizing oxygen or delaying the onset of muscle fatigue. As a result, tongue endurance may remain unchanged or begin to decline. The findings of the current study showed that anterior and posterior tongue endurance of weightlifters was bordering with measures associated with health concerns implying that the breathing pattern weightlifters employ may not have a beneficial indirect effect on tongue endurance.

In contrast, runners utilize an efficient pattern of breathing that is controlled and rhythmic known as coupling. This form of breathing is efficient in utilizing oxygen (Bernasconi & Kohl, 1993; Castro et al., 2011; Daley, Bramble, & Carrier, 2013; Elliott & Grace, 2010) and allows the muscles to contract at a submaximal level of effort and over an extended period of time with minimal fatigue (Holloszy, 1984; Jones & Carter, 2000). With running, the respiration rate increases (Castro et al., 2011); therefore to maintain an open upper airway while running the tongue muscles must activate (Bernasconi & Kohl, 1993; Castro et al., 2011; Daley et al., 2013;
Elliott & Grace, 2010; Shi et al., 1998; Williams et al., 2000). Because of this natural response, the tongue muscle fibers associated with respiratory function may adapt to the increased demand of the submaximal contraction over an extended period of time to guarantee airway patency. The results of the current study suggest such a response. For example the runners displayed healthy tongue strength (anterior, posterior) measures, but these measures were not as great as weightlifters. These findings imply that the breathing pattern runners engage (i.e., submaximal tongue muscle contraction) may have a subtle indirect effect on tongue strength. In addition, just as tongue muscles are shown to activate to maintain an open upper airway at rest (Bernasconi & Kohl, 1993; Castro et al., 2011; Daley et al., 2013; Elliott & Grace, 2010; Shi et al., 1998; Williams et al., 2000) they may have to adapt and activate more frequently and for an extended duration of time during a run. In return the tongue muscle fibers may become more efficient in the utilization of oxygen and experience gains in tongue endurance. Based on the results of the current study, the runners displayed healthy anterior and posterior tongue endurance measures. These measures are interpreted to imply that the breathing pattern runners engage may have an indirect effect on tongue endurance due to the extended duration of time the tongue may have to remain activated to maintain an open upper airway.

**Implications of findings.** Previous studies have shown that tongue muscle performance (strength, endurance) is shown to decline with age and negatively impact tongue function, particularly in the presence of a neurological insult (Adams et al., 2013b, Clark & Solomon, 2012; Crow & Ship, 1996, Nicosia, 2000; Robbins et al., 1995; Steele et al., 2009, Youmans et al., 2009). For example, a disordered swallowing function known as dysphagia is commonly associated with a significant age-related decline in tongue strength (Connor et al., 2009; Nicosia, 2000; Robbins et al., 2005; Yeates et al., 2008; Youmans & Stierwalt, 2006). Further, a
significant age-related decline in both tongue strength and endurance is typical of an obstructed upper airway disorder known as sleep apnea (McSharry et al., 2012; Mezzanotte et al., 1992; O’Connor et al., 2004; Ono, 2012; Remmers et al., 1978). The current study paves the way for future research investigating how aging-related decline on tongue muscle performance can be retarded and serious illness due to tongue function loss may be prevented with the inclusion of specific modes of exercise. The current findings suggested differences on tongue strength and tongue endurance between weightlifters and runners. Further, the current findings suggested that weightlifting may not be a beneficial indirect mode of exercise for tongue endurance.

Capitalizing on the current findings, in addition to the study by VanRavenhorst-Bell et al., (2013) that suggested that physical activity may be associated with retarding the aging-related decline in tongue muscle performance (strength, endurance) because physically non-active older adults had tongue muscle performance measures that were lower than all other young and older adult groups in their study; the potential indirect benefit of either one of these exercise modes may be detected if you investigated this issue in older adults.

**Summary and Conclusion**

Recently, research has begun to provide support for the notion that exercise may have an indirect effect on tongue muscle performance similar to that of skeletal muscles. Such findings are important because adequate tongue strength and endurance are necessary to perform daily tasks such as swallowing, talking, and maintaining upper airway patency. The paucity of evidence, however, has left a very elementary understanding of the indirect effect physical exercise may have on tongue muscle strength and endurance. To provide further insight the current study investigated whether tongue muscle performance (i.e., strength, endurance) differed between individuals who engage regularly in different modes of exercise. Therefore,
muscle performance between weightlifters (resistance training) and runners (endurance training) was compared. In addition, the current study sought to determine whether differences between groups were specific to tongue regions.

Findings revealed that, although not significant, weightlifters tended to produce greater measures of tongue strength compared to runners, particularly in the anterior region of the tongue where muscle fibers are primarily purposed for strength. In contrast, runners produced significantly greater tongue endurance than weightlifters in both the anterior and posterior regions of the tongue. However, anterior tongue endurance tended to be greater than the posterior tongue endurance.

Although there are other factors that could possibly account for these finding (i.e., genetics, nutrition, and adequate blood and oxygen supply) (Bouchard et al., 2011; Castro et al., 2011; Hawley et al., 2011; Manimmanakorn, Hamlin, et al., 2013; Manimmanakorn, Manimmanakorn, et al., 2013; Shi et al., 1998), the results suggest that tongue muscle performance may be impacted by the mode of exercise one regularly engages in. Further, it is possible that these mode-dependent indirect effects of exercise on tongue muscle performance may be a result of how the tongue muscles activate in response to respiration during different modes of exercise.

The current study suggested that tongue muscle performance may be affected by the mode of exercise one regularly engages in. Further the findings suggest that the differences in tongue muscle performance in weightlifters and runners may be specific to a particular region of the tongue. Tongue strength tended to be greater in weightlifters than runners, particularly in the anterior region of the tongue. Tongue endurance (anterior, posterior) was significantly greater in runners than weightlifters with the greatest difference being in the anterior region of the tongue.
Our findings provided valuable insights on the *indirect* effect of mode of physical exercise on tongue muscle performance. Future studies are warranted to further delineate factors of physical exercise that impact tongue muscle performance.

**Limitations of the Study**

As with any study, there are limitations to this investigation. A major limitation is that this study did not allow insights in pre-exercise and post-exercise changes to directly determine *indirect* effect on tongue muscle performance in humans. More to the point, previous studies and the current study, have not investigated a treatment effect of exercise or exercise mode on tongue muscle strength and endurance. Until research provides evidence that exercise and mode of exercise have an *indirect* effect on tongue muscle performance, our findings must acknowledge that other factors (i.e., genetics, nutrition, and adequate blood and oxygen supply) (Bouchard et al., 2011; Castro et al., 2011; Hawley et al., 2011; Manimmanakorn, Hamlin, et al., 2013; Manimmanakorn, Manimmanakorn, et al., 2013; Shi et al., 1998) may have been responsible or in combination with exercise for any differences reported between weightlifters’ and runners’ tongue strength and endurance measures. In addition, it is important to consider that these findings do not translate directly to a large portion of the general population. The general population includes individuals who may not engage in physical exercise while other samples of the general population may not be familiar with the level of intensity or mode of physical activity reported by the participants in the current study. For example, the general population may not be familiar with performing maximal isotonic weightlifting, such as the style of weightlifting performed by the weightlifting subjects in the current study. The general population may be more comfortable with circuit-weight machines, Thera-Band exercises, and isometric resistance training. In similar context, many individuals are unable to run or may prefer to walk instead of
run, unlike the runners in the current study who report accumulated mileage several days per week. In addition, other individuals may prefer to engage in an entirely different mode of exercise such as bicycling or swimming. A different mode of exercise may have an indirect effect on tongue strength and endurance that greatly differs from weightlifting and running. The current findings, therefore, may not accurately reflect the effects of various modes of exercise an individual may perform.

Furthermore, other factors of exercise (intensity, duration, frequency, volume) may also influence the indirect effect of an exercise mode(s) on tongue strength and endurance. Studies on skeletal muscles have shown that each of these exercise factors plays an influential role with differential effects on skeletal muscle strength and endurance (Karavirta, Hakkinen, Sillanpaa, et al., 2011; Kraemer, Ratamess, et al., 2002). The current study, however, only verified that each participant trained for four or more days per week for at least the past year within his or her specified mode of exercise (weightlifting, running). In addition, the study verified that none of the participants engaged in cross training. No further details regarding their exercise routines (e.g., intensity, duration, frequency, volume) were identified. Such information may have identified a sub-group(s) within the two groups investigated, thereby altering the current findings.

One last limitation to make note of in this study would be the sample size. An a priori power analysis was conducted prior to administering the study; however, the recommended sample size of 85 participants was larger than the final number of participants included. Some of the results of the current study reported an absence of adequate power to show significance, along with small effect sizes. This indicated that the smaller sample size may have been too small to appropriately answer some of the main effects and interactions.
Future Directions

Future studies investigating changes in an individual’s tongue muscle performance with direct pre- and post-training measures are necessary. It may then be possible to identify whether any improvements shown to occur in tongue muscle performance are a result of exercise. With a third measure, several weeks post training, it would also be possible to determine a de-training effect. In other words, it can be delineated if individuals who have completed an exercise will also experience a decline in performance when the exercise has ceased. Establishing such findings would provide a platform for all future research investigating direct and indirect effects of exercise on tongue muscle performance.

Future studies should also address other factors of exercise (intensity, frequency, duration, volume) as well as other modes of exercise and how they may influence the indirect effect of physical activity on tongue strength and endurance. Findings of such studies would establish exercise protocol recommendations for tongue strength and tongue endurance.

Another area of interest identified in this study, as well as other previous studies, is that it was found that tongue endurance in the anterior region of the tongue (Type II fast twitch fibers) maintains a submaximal contraction for a longer duration of time than the posterior region of the tongue (Type I and IM/IC slow twitch fibers). In addition, running (endurance training) had a greater differential effect on tongue endurance in the anterior tongue region than the posterior tongue region. Future studies designed to investigate this uncharacteristic response in muscle fiber types of the tongue is needed for the purpose of identifying specialized recommendations that may apply to an exercise protocol designed for tongue endurance.

Future studies should also aim to delineate the mechanism underlying group differences in tongue muscle performance (e.g., differences between weightlifters and runners). These
differences may relate to tongue muscle activation due to the distinguishing breathing pattern. The *indirect* effect may be solely respiratory related or may be a combination of other physiological responses that the body undergoes during exercise. Finally, future longitudinal research studies on adults who regularly engage in exercise and those who do not are necessary to directly investigate how aging-related effects on tongue muscle performance may be retarded with the inclusion of physical exercise. Such findings may further provide insights on how to prevent serious illness due to tongue function loss.
REFERENCES


Abstract

*Purpose:* It is well known that physical activity affects non-targeted skeletal muscles, however, little is currently known about the indirect effect of physical activity on tongue muscles. The purpose of this study was to determine if tongue muscle performance differs between highly active and non-active individuals and if such an effect varies with age.

*Method:* Fourth-eight healthy adults (24 young adults, 18-29 years; 24 older adults, 61-76 years) participated in this study. Participants in each group were further divided equally into highly active and non-active adults based on *The General Practice Physical Activity Questionnaire* (GPAAQ). Activity level (high/low) was further verified objectively based on handgrip strength and cardiovascular endurance measures. Tongue strength (TS) and tongue endurance (TE) measures were obtained using the Iowa Oral Performance Instrument (IOPI).

*Results:* A significant main effect of activity level on TS and TE was found. Although the main effect of age on TS and TE and the age x activity level interactions were not significant, the effect of activity level on TS and TE was much more pronounced in older adults than younger adults.

*Conclusion:* Findings suggest that physical activity may affect TS and TE, particularly in older adults. Future research is warranted to better understand the underlying mechanisms contributing to these group differences. Clinical implications of these findings are discussed.

*Keywords:* Tongue Strength, Tongue Endurance, Physical Activity, Indirect Effects of Exercise
INTRODUCTION

The tongue is involved in important daily functions such as swallowing, talking, and upper airway patency during respiration (McHorney, Martin-Harris, Robbins, & Rosenbek, 2006; Neel, Palmer, Sprouls, & Morrison, 2006; Nicosia, 2000; Robbins et al., 2005; Stierwalt & Youmans, 2007; Yoshida et al., 2006). Although the relations between tongue muscle performance (i.e., tongue strength and endurance) and speech are complex, poor tongue muscle performance is thought to be a risk factor for dysphagia and sleep apnea (Blumen et al., 2004; Clark & Solomon, 2012; Humbert & Robbins, 2008; Ney, Weiss, Kind, & Robbins, 2009; Nicosia, 2000). However, apart from normal aging and diseases (e.g., cerebrovascular disease, neuromuscular degeneration due to Parkinson’s disease, amyotrophic lateral sclerosis), little is known about factors impacting tongue muscle performance. Such information is important to advance assessment and treatment strategies for persons with impaired tongue function.

Aging-Related Changes in Muscle Performance and the Impact of Physical Activity

One of the most robust findings in the literature on muscle performance is the decline with advanced age. This aging-related decline has been shown for skeletal muscles (e.g., handgrip strength) (Doherty, 2001; Rantanen et al., 1999; Spirduso, Francis, & MacRae, 2005) and tongue muscles (e.g., tongue strength, tongue endurance) (Clark & Solomon, 2012; Crow & Ship, 1996; Logemann et al., 2000; Robbins, Hamilton, Lof, & Kempster, 1992). Sarcopenia, the aging-related loss of muscle mass, is thought to be the major factor contributing to muscle performance decline in older adults (Booth, Laye, & Roberts, 2011; Cruz-Jentoft et al., 2010; Doherty, 2003; Fielding et al., 2011; Spirduso et al., 2005). However, vast individual differences exist in the rate at which muscle performance declines with age.
APPENDIX A (continued)

Various factors are known to contribute to individual variations in muscle performance (e.g., genetics, nutrition, daily activity level, adequate blood and oxygen supply) (Bouchard, Rankinen, & Timmons, 2011; Hawley, Burke, Phillips, & Spriet, 2011; Manimmanakorn, Hamlin, Ross, Taylor, & Manimmanakorn, 2013; Manimmanakorn, Manimmanakorn, et al., 2013; Spirduso et al., 2005). The identification of life style related factors has been of particular interest because such knowledge can be used to recommend behaviors that promote muscle performance, retard aging-related decline, and ultimately reduce health risks. For example, a long-standing finding in research on skeletal muscles is that older adults who regularly engage in physical activity have greater muscle strength and endurance than those who live a sedentary lifestyle (Cadore, Pinto, Bottaro, & Izquierdo, 2014; Freiberger, Sieber, & Pfeifer, 2011; Hawkins, Wiswell, & Marcell, 2003; Macaluso & De Vito, 2004).

An individual’s physical activity level describes the amount of movement skeletal muscles produce and the level of energy used to perform a functional daily task (Caspersen, 1985; Garland et al., 2011). An individual’s physical activity level can be determined by use of well-established questionnaires such as The General Physical Activity Questionnaire (GPPAQ) (Department of Health, 2009). Objective measures such as maximal handgrip strength and cardiovascular endurance (submaximal volume of oxygen consumed (VO2) are assessments commonly administered and highly associated with an individual’s level of physical fitness (American College of Sports Medicine, 2010; Caspersen, 1985; Ehrman, 2010; Ehrman, Gordon, Visich, & Keteyian, 2009; Garland et al., 2011).

As a general rule, a higher physical activity level is associated with greater muscular strength and endurance, which in turn is associated with a higher level of functional capacity (the
APPENDIX A (continued)

performance level of daily tasks) (Cooper et al., 2011; Cooper et al., 2010; Garber et al., 2011; Paalanne, Korpelainen, Taimela, Remes, et al., 2009; Spirduso et al., 2005; Tanaka & Seals, 2003). A greater functional capacity further results in a greater reserve capacity. The reserve capacity indexes the difference between the minimal performance level necessary to perform functional daily tasks and an individual’s functional capacity level (Booth et al., 2011; Cooper et al., 2011; Cooper et al., 2010; Goldspink, 2005; Rantanen et al., 1999; Spirduso et al., 2005).

In older adults, functional capacity and reserve capacity are of great relevance for overall well-being and longevity (Spirduso et al., 2005). As muscle strength and endurance naturally decline with age, functional capacity also naturally declines unless such an aging process is slowed by engaging these muscles sufficiently in physical activity to prevent such a functional decline (Booth et al., 2011; Goldspink, 2005; Paalanne, Korpelainen, Taimela, Auvinen, et al., 2009; Spirduso et al., 2005; Tanaka & Seals, 2003; Tikkanen et al., 2012). For example, handgrip strength was found to be greater in individuals who are highly physically active than in individuals who are sedentary (Bassey & Harries, 1993; Dodds, Kuh, Aihie Sayer, & Cooper, 2013; Jakobsen, Rask, & Kondrup, 2010; Rantanen et al., 1999; Reuter, Massy-Westropp, & Evans, 2011). Based on this and similar findings, physical activity is encouraged regardless of age to ensure a high level of functional capacity, which can be maintained well into the later stages of life.

Direct and Indirect Effects of Physical Activity on Muscles Performance

Physical activity provides beneficial effects on directly targeted skeletal muscles as well as non-targeted skeletal muscles. The skeletal muscles primarily used to perform the intended physical activity (directly targeted muscles) experience muscle fiber adaptations (e.g., muscle
APPENDIX A (continued)

fiber hypertrophy, increased number of muscle fibers, utilization of available oxygen) that directly benefit muscle strength and endurance (Karavirta et al., 2011; Kraemer & Ratamess, 2004; Kraemer, Ratamess, & French, 2002; Wilson et al., 2012). Similarly, skeletal muscles that support the physical activity in a secondary sense (non-targeted muscle) also undergo muscle fiber adaptations and also improve in their muscle performance, but to a lesser extent than directly targeted muscles (Fisher, Steele, Bruce-Low, & Smith, 2011; Hamlyn, Behm, & Young, 2007; Munn, Herbert, & Gandevia, 2004; Tew, Nawaz, Zwierska, & Saxton, 2009).

The indirect effects of physical activity on skeletal muscles (Fisher et al., 2011; Hamlyn et al., 2007; Munn et al., 2004; Tew et al., 2009) may also be observable in the muscles of the tongue. Support for this notion is provided by findings of a recent study on rats showing improved tongue strength and endurance after an 8-week exercise program consisting of treadmill running (Kletzien, Russell, LeVerson, & Connor, 2013). The authors speculated that the observed increase in tongue muscle strength and endurance of rats completing the treadmill protocol might have been due to the increased respiration rate while running. An increased respiratory rate during physical activity may have placed greater demands on tongue muscle fibers to support upper airway patency (Shi, Seto-Poon, & Wheatley, 1998; Wheatley, Amis, & Engel, 1991; Williams, Janssen, Fuller, & Fregosi, 2000). However, studies that examine the impact of physical activity on tongue muscle performance in humans are currently lacking. Further, the reported beneficial effects of physical activity on tongue muscle fibers in rats may not hold true for humans. Previous research has shown that the anatomy of the human’s upper airway is different than that of rats (Barbizet, 1958; Lu & Kubin, 2009; Matsuo & Palmer, 2010; Mezzanotte, Tangel, & White, 1992; Series, Cormier, Desmeules, & La Forge, 1989). Therefore,
if respiration is the mechanisms underlying changes in tongue muscle performance in rats, the anatomical differences between these two species may suggest tongue muscle(s) activation during respiration may also differ.

**Purpose Statement**

The purpose of this study was to determine if tongue strength and endurance differed between individuals with a high physical activity level and those with a low physical activity level. Further, the study sought to determine if the potential effect of the physical activity level on tongue muscle performance is more pronounced in older adults than in younger adults. Based on the available literature on indirect effects of physical activity on skeletal muscles, it was hypothesized that individuals with a high physical activity level would have significantly greater anterior and posterior tongue strength and endurance than individuals with a low physical activity level regardless of age. Further, it was hypothesized that differences in tongue muscle performance between highly active and sedentary individuals would be more pronounced in older adults than in younger adults.

**METHODS**

**Participants**

Forty-eight participants (18-76 years of age) were divided into four groups each with 12 participants (6 male, 6 female) based on physical activity level and age. Table 1 provides an overview of the participants in each group. Physical activity level of each participant was based on the GPPAQ Questionnaire (Department of Health, 2009). Participants in the high activity level group achieved the highest score whereas participants in the “non-active” group received the lowest score.
APPENDIX A (continued)

Table 1 Descriptives of age grouped active and non-active participants

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of Subjects</th>
<th>Mean Age (years) (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>Male</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>20.75 ± 3.31</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20.17 ± 2.48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21.33 ± 4.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>21.17 ± 3.27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20.33 ± 3.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22.00 ± 3.22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20.96 ± 3.22</td>
<td></td>
</tr>
<tr>
<td>Non-Active</td>
<td>Male</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>66.58 ± 3.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.33 ± 4.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.83 ± 2.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.33 ± 4.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.33 ± 4.97</td>
<td></td>
</tr>
<tr>
<td></td>
<td>63.33 ± 1.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.96 ± 3.72</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active</td>
<td>Male</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>66.58 ± 3.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.33 ± 4.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.83 ± 2.64</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.33 ± 4.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td>67.33 ± 4.97</td>
<td></td>
</tr>
<tr>
<td></td>
<td>63.33 ± 1.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.96 ± 3.72</td>
<td></td>
</tr>
</tbody>
</table>

Further inclusion criteria included the Physical Activity Readiness Questionnaire (PAR-Q) (Canadian Society for Exercise Physiology, 2002) to ensure adequate physical health to complete the objective cardiovascular endurance assessment. In addition, the PAR-Q was used to control for medication(s) that may alter the cardiovascular endurance assessment (e.g., blood pressure medication, diuretic). All participants had no history of any neurological disorders, head or neck surgery, or oral cancer per self-report. The Wichita State University Institutional Review Board approved the study and informed consent was obtained from all participants prior to data collection.

Study Design

To objectively verify level of physical activity, handgrip strength and cardiovascular endurance was tested in all participants. Maximal handgrip strength was measured according to protocol using the non-dominant hand. The cardiovascular endurance assessment included the submaximal VO2 measure and was completed to determine how efficiently the muscles of the
body utilized oxygen while performing a standardized cardiovascular endurance test. The *Young Men’s Christian Association* (YCMA) protocol was implemented for that purpose using the bicycle ergometer. An examiner experienced in administering this protocol provided all instructions and obtained this measure.

Then, anterior and posterior tongue strength and endurance measures were taken using the *Iowa Oral Performance Instrument* (IOPI). Tongue strength measures consisted of six attempts to produce maximal isometric pressure each for anterior and posterior tongue region. Tongue endurance measures consisted of one attempt to sustain 50% maximal isometric pressure each for anterior and posterior tongue region (Adams, Mathisen, Baines, Lazarus, & Callister, 2013; Robbins et al., 2007; Robbins, Levine, Wood, Roecker, & Luschei, 1995). To control for order effect, measures of tongue strength and endurance were counterbalanced within each group, with half the group performing anterior measures first and the others performing posterior measures first.

**Instrumentation.**

*BASELINE Handgrip Dynamometer*

The BASELINE hydraulic handheld dynamometer (Fabrication Enterprises Inc., Irvington, NY) was used to obtain each participant’s maximal handgrip strength up to 200 pounds or 90 kilograms of pressure. The adjustable BASELINE handle allowed for a properly fitting and comfortable grip to enable the participant to produce reliable isometric handgrip strength.

*Monark Cycle Ergometer*

The Monark Ergomedic 828E cycle ergometer (Monark, Vansbro, Sweden) was used in
APPENDIX A (continued)

conjunction with the YMCA Cycle Ergometer protocol to obtain each participant’s cardiovascular endurance measure. The Monark 828E offers a manually controlled pendulum system to adjust workload ranging from 4 to 1400 Watts. The control panel on the cycle ergometer provided a continuous digital display of rotations per minute (RPM) and duration of time elapsed (minutes and seconds) once pedaling began. The digital control panel on the Monark 828E also synchronized automatically with the PolarWearLink Coded heart rate sensor system (Polar Electro, Lake Success, NY) to provide continuous monitoring of the participant’s heart rate. The Monark Ergomedic 828E was calibrated prior to each test session to ensure accurate and reliable measures as recommended by the manufacturer.

**IOPI**

The IOPI 2.1 (IOPI Medical, Carnation, WA) was used to obtain all tongue strength and endurance measures. The IOPI is a small hand-held pressure transducer device with a disposable air-filled plastic bulb that is connected to the pressure transducer via a plastic connecting tube. The IOPI system calculated and displayed the applied maximal tongue pressure in kilopascals (kPa) as the tongue pushed the bulb against the roof of the mouth to assess tongue strength measures. During the tongue endurance measures a light emitting diodes (LED) display provided visual feedback to indicate the desired pressure level was being applied while a timer indicated the duration of the desired hold in seconds. To ensure accurate and reliable measures, the IOPI was calibrated monthly, as recommended by the manufacturer.

**Procedures.**

**Handgrip Strength**

All handgrip strength measures were administered while standing in a shoulder width
APPENDIX A (continued)

stance. To control for career and daily task biases involving handgrip strength (e.g., squeezing a rivet gun trigger on a manufacturing line), the non-dominant hand was used (Ehrman, 2010; Ehrman et al., 2009). With the elbow joint of the non-dominant arm placed in a 15-degree angle, the participant was asked to apply maximal isometric force by squeezing the BASELINE hydraulic handheld dynamometer for two to three seconds and release. Each participant received verbal encouragement with each trial as follows, “squeeze, squeeze, squeeze, good”. A total of three trials were performed with a 30-second rest between trials to control for fatigue. The pressure gauge on the BASELINE dynamometer was reset to zero “0” following each trial. The highest achieved value was recorded as maximal handgrip strength (American College of Sports Medicine, 2010; Ehrman, 2010; Ehrman et al., 2009).

Cardiovascular Endurance

The YMCA cycle ergometer protocol is a standardized multi-stage test lasting 9 to 12 minutes. According to protocol, all participants completed a 2-3 minute warm-up. Following warm-up all participants were asked to maintain a 60-rpm pedaling cadence throughout the test. The workload was advanced at the end of each 3-minute stage for each participant in relation to his/her heart rate based upon standardized YMCA protocol. Further, the participant stated his/her rating of perceived exertion at the end of each stage using the Borg Rating of Perceived Exertion (RPE) scale. The RPE is a number rating scale ranging from 6 (no exertion at all) up to 20 (maximal exertion) that has been shown to accurately reflect the level of effort a participant feels he/she is exerting (Borg, 1982a, 1982b). The test was successful when the participant was able to complete at least 2 stages along with obtaining a heart rate between 110 beats per minute (bpm) and 85% of age-predicted maximum heart rate, and a steady state heart rate within 6 bpm marks.
between the last 2 minutes of each stage. Following the test, all participants completed a 3-minute cool-down and then transitioned to a chair for a 3-minute recovery (American College of Sports Medicine, 2010; Ehrman, 2010; Ehrman et al., 2009).

**Tongue Muscle Performance**

All tongue measures were administered with participants seated in an upright position. The IOPI was used to obtain all measures of anterior and posterior tongue muscle performance. Tongue muscle performance measures were obtained from the anterior and posterior tongue due to the anatomic heterogeneity of the muscles fibers (Green & Wang, 2003; Stal, Marklund, Thornell, De Paul, & Eriksson, 2003; Trawitzki, Borges, Giglio, & Silva, 2011; Zaidi, Meadows, Jacobowitz, & Davidson, 2012) and individualized functions within the two regions of the tongue (Adams et al., 2013; Miller, Watkin, & Chen, 2002; Robbins et al., 2007). However, no hypothesis was made on different findings between the two regions. Experimental setup for the use of the IOPI for anterior and posterior tongue strength and endurance measures followed typical bulb placement recommendations (e.g., anterior placement is 10 mm posterior to the tongue tip, posterior placement is 10 mm anterior to the most posterior circumvallate papilla) (Kays, Hind, Gangnon, & Robbins, 2010; Robbins et al., 2007). Proper bulb placement was verified using a sterile tongue depressor with a pre-marked 10mm line.

**Tongue strength**

Tongue strength measures consisted of 6 trials for each anterior and posterior region. Each participant’s data collection session began by performing three trials each, anterior and posterior, tongue strength measures followed by performing all physical measures. Upon completion of the physical measures an additional three trials for each tongue region were
APPENDIX A (continued)

collected. To control for potential order effect of bulb placement, the trials were equally divided with half the participants performing anterior measures first and the other half of the participants beginning with posterior measures. After bulb placement all participants were instructed to press as hard as possible with the tongue against the roof of the mouth for 2-3 seconds. The examiner provided verbal encouragement during each trial, “push, push, push, good”. A 30 second rest was provided between each trial. The best of six trials was used for further statistical analysis (Iowa Oral Performance Instrument Medical (IOPI), 2012; Robbins et al., 2007).

**Tongue endurance**

Tongue endurance measures for the anterior and posterior regions of the tongue were each measured one-time following the completion of the initial tongue strength measures for each region and a 30 second rest period. The bulbus was returned into the participant’s mouth at the specified anterior or posterior site and the participant was instructed to maintain 50% of maximal tongue strength pressure for as long as he/she was able. The participant was encouraged to visually monitor the LED display on the IOPI instrument to assist producing the desired tongue pressure against the bulb. The maintained duration of time was recorded as tongue endurance (Iowa Oral Performance Instrument Medical (IOPI), 2012; Robbins et al., 2007).

**Data Analysis.**

To verify that physical activity level was significantly different between the highly active and the non-active groups a 2x2 between-group Analysis of Variance (ANOVA) was completed for each physical measure (handgrip strength, cardiovascular endurance). To objectively test the research hypothesis anterior and posterior tongue strength and endurance measures of active and non-active young and older adults were submitted to four separate 2x2 between-group
APPENDIX A (continued)

ANOVAs. Post-hoc comparisons (t-tests) were completed if significant age x activity level interactions were found. The critical alpha level was set at $p < .05$ for all statistical tests.

RESULT

Table 2 provides group means and standard deviations of all measures obtained in this study.

Table 2. Means and Standard Deviations for Dependent Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Age Group</th>
<th>Activity Level</th>
<th>Non-Active</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>Handgrip Strength (lbs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>95.17 ± 26.45</td>
<td>83.17 ± 23.20</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>89.42 ± 29.56</td>
<td>69.83 ± 23.62</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>92.29 ± 27.59</td>
<td>76.50 ± 23.89</td>
<td></td>
</tr>
<tr>
<td>Cardiovascular Endurance (ml-kg-min$^{-1}$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>58.08 ± 14.87</td>
<td>32.80 ± 8.83</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>36.14 ± 10.19</td>
<td>22.30 ± 3.75</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>47.11 ± 16.76</td>
<td>27.55 ± 8.54</td>
<td></td>
</tr>
<tr>
<td>Anterior Tongue Strength (kPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>62.92 ± 10.03</td>
<td>57.33 ± 16.28</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>61.25 ± 14.86</td>
<td>44.17 ± 11.26</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>62.08 ± 12.43</td>
<td>50.75 ± 15.25</td>
<td></td>
</tr>
<tr>
<td>Posterior Tongue Strength (kPa)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>59.83 ± 12.61</td>
<td>50.83 ± 15.59</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>57.08 ± 12.58</td>
<td>40.25 ± 12.81</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>58.46 ± 12.40</td>
<td>45.54 ± 14.87</td>
<td></td>
</tr>
<tr>
<td>Anterior Tongue Endurance (seconds)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>23.33 ± 12.17</td>
<td>16.50 ± 9.97</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>24.00 ± 16.42</td>
<td>13.83 ± 11.01</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23.67 ± 14.14</td>
<td>15.17 ± 10.36</td>
<td></td>
</tr>
<tr>
<td>Posterior Tongue Endurance (seconds)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>18.50 ± 12.93</td>
<td>12.50 ± 7.86</td>
<td></td>
</tr>
<tr>
<td>Older</td>
<td>19.67 ± 11.60</td>
<td>9.17 ± 7.12</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19.08 ± 12.03</td>
<td>10.83 ± 7.52</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX A (continued)

Group Verification

Handgrip Strength. The 2x2 between-group ANOVA yielded a statistically significant main effect for activity level, \[ F(1,48) = 4.48; p = .04; \eta^2_p = .09 \]. Handgrip strength of active individuals \((M = 92.29 \pm SD = 27.59)\) was significantly greater than handgrip strength of non-active individuals \((M = 76.50 \pm SD = 23.89)\). The main effect for age was not statistically significant \([F(1,48) = 1.64; p = .21; \eta^2_p = .04]\); however, young adults’ \((M = 89.17 \pm SD = 25.09)\) handgrip strength tended to be greater than older adults’ handgrip strength \((M = 79.63 \pm SD = 28.01)\). Although there was no significant interaction between activity level and age on handgrip strength, \([F(1,48) = .26; p = .61; \eta^2_p = .01]\) it can be seen in Figure 1 that the trend of an aging effect depended on the activity level. That is, only older adults of the non-active group \((M = 69.83 \pm SD = 23.62)\) tended to have much lower handgrip strength than young adults in the active \((M = 95.17 \pm SD = 26.45)\) and non-active groups \((M = 83.17 \pm SD = 23.20)\).

Figure 1. Group Means and Standard Deviations of Handgrip Strength
Cardiovascular Endurance. A significant main effect of activity level on cardiovascular endurance was found, \[ F (1,48) = 44.06; p = .00; \eta^2_p = .50 \]. Specifically, active individuals had significantly better cardiovascular endurance (\( M = 47.11 \pm SD = 16.76 \)) than non-active individuals (\( M = 27.55 \pm SD = 8.53 \)). Further, the main effect of age on cardiovascular endurance was statistically significant \[ F (1,48) = 30.23; p = .00; \eta^2_p = .41 \]. The young adults’ cardiovascular endurance (\( M = 45.44 \pm SD = 17.60 \)) was significantly greater than the older adults’ cardiovascular endurance (\( M = 29.22 \pm SD = 10.32 \)). Although there was no significant interaction between activity level and age on cardiovascular endurance, \[ F (1,48) = 3.76; p = .06; \eta^2_p = .08 \], Figure 2 shows that the aging effect on cardiovascular endurance tended to depend on the activity level. Specifically, only non-active older adults (\( M = 22.30 \pm SD = 3.75 \)) tended to have lower cardiovascular endurance than young non-active (\( M = 32.80 \pm SD = 8.83 \)) and young active adults (\( M = 58.08 \pm SD = 14.87 \)).

![Figure 2. Means and Standard Deviations of Cardiovascular Endurance in Active and Non-Active Groups by Age](image-url)
**APPENDIX A (continued)**

**Tongue Measures**

**Tongue Strength**

A significant main effect of activity level on anterior tongue strength \( F(1,48) = 8.64; p = .01; \eta^2 \rho = .16 \) as well as on the posterior tongue strength \( F(1,48) = 11.05; p = .00; \eta^2 \rho = .20 \) was found. Specifically, anterior tongue strength of active individuals \( M = 62.08 \pm SD = 12.43 \) was significantly greater than anterior tongue strength of non-active individuals \( M = 50.75 \pm SD = 15.25 \). Similarly, posterior tongue strength of active individuals \( M = 58.46 \pm SD = 12.40 \) was significantly greater than posterior tongue strength of non-active individuals \( M = 45.54 \pm SD = 14.97 \) as depicted in Figure 3.

![Figure 3. Means and Standard Deviations of Anterior and Posterior Tongue Strength in Active and Non-Active Groups](image)

There were no statistically significant main effects of age on anterior tongue strength \( F(1,48) = 3.70; p = .06; \eta^2 \rho = .08 \) and on posterior tongue strength \( F(1,48) = 2.94; p = .09; \eta^2 \rho = .06 \); however, as can be seen in Figure 4 the young adults’ anterior tongue strength \( M = \)
60.13 \pm SD = 13.52) tended to be greater than the older adults’ anterior tongue strength \((M = 52.71 \pm SD = 15.57)\). Similarly, the young adults’ posterior tongue strength \((M = 55.33 \pm SD = 14.61)\) tended to be greater than the older adults’ posterior tongue strength \((M = 48.67 \pm SD = 15.10)\).

![Figure 4. Means and Standard Deviations of Anterior and Posterior Tongue Strength in Young and Older Adults](image)

In addition, there were no statistically significant interactions between activity level and age for anterior tongue strength \([F (1,48) = 2.23; p = .14; \eta^2 \rho = .05]\) and posterior tongue strength \([F (1,48) = 1.02; p = .32; \eta^2 \rho = .02]\). The trend of an aging effect on tongue strength tends to depend on the activity level, as can be seen in Figure 5 and Figure 6 (respectively).

That is anterior tongue strength of the active older adults \((M = 61.25 \pm SD = 14.86)\) tended to be similar to anterior tongue strength of young active adults \((M = 62.92 \pm SD = 10.03)\) and young non-active adults \((M = 57.33 \pm SD = 26.28)\), respectively. Similarly, posterior tongue strength of the active older adults \((M = 57.08 \pm SD = 12.58)\) tended to be similar to the posterior tongue strength of the active older adults.
strength of young active adults \( (M = 59.83 \pm SD = 12.61) \) and young non-active adults \( (M = 50.83 \pm SD = 15.59) \).

Figure 5. Means and Standard Deviations of Anterior Tongue Strength in Active and Non-Active Young and Older Adults

Figure 6. Means and Standard Deviations of Posterior Tongue Strength in Active and Non-Active Young and Older Adults
Tongue Endurance

Significant main effect of activity level on anterior tongue endurance \( F(1,48) = 5.44; p = .02; \eta^2 = .11 \) as well as on posterior tongue endurance \( F(1,48) = 7.89; p = .01; \eta^2 = .15 \) were found. Active individuals had on average significantly greater anterior tongue endurance \( (M = 23.67 \pm SD = 14.14) \) than non-active individuals \( (M = 15.17 \pm SD = 10.36) \). Similarly, active individuals had significantly greater posterior tongue endurance \( (M = 19.08 \pm SD = 12.03) \) than non-active individuals \( (M = 10.83 \pm SD = 7.52) \) as depicted in Figure 7.

![Figure 7](image_url)

Figure 7. Means and Standard Deviations of Anterior and Posterior Tongue Endurance in Active and Non-Active Groups

No significant main effect of age on anterior tongue endurance \( F(1,48) = .08; p = .79; \eta^2 = .00 \) as well as on posterior tongue endurance \( F(1,48) = .14; p = .71; \eta^2 = .00 \) were found as can be seen in Figure 8.
Although no statistically significant activity level x age interactions were found for anterior tongue endurance \( F(1,48) = .21; p = .65; \eta^2 \rho = .01 \) and posterior tongue endurance \( F(1,48) = .59; p = .45; \eta^2 \rho = .01 \) it can be seen in Figure 9 and Figure 10 (respectively) that non-active older adults tended to have lower anterior tongue endurance \( (M = 13.83 \pm SD = 11.01) \) and posterior tongue endurance \( (M = 9.17 \pm SD = 7.11) \) than non-active young adults \( (M = 16.50 \pm SD = 7.97, M = 12.50 \pm SD = 7.86, \) respectively).
Figure 9. Means and Standard Deviations of Anterior Tongue Endurance in Active and Non-Active Young and Older Adults

Figure 10. Means and Standard Deviations of Posterior Tongue Endurance in Active and Non-Active Young and Older Adults
DISCUSSION

The purpose of this study was to determine (1) if anterior and posterior tongue muscle performance differed between physically active and physically non-active individuals and (2) how aging impacted the potential effects of physical activity level on tongue muscle performance. Based on the review of the literature it was expected that, regardless of age, highly active individuals would demonstrate greater anterior and posterior tongue strength and endurance than non-active individuals. Further, it was expected that aging-related differences in anterior and posterior tongue strength and endurance would only be observable in non-active older adults.

In general, results of this study confirmed these stated hypotheses. That is, a significant effects of physical activity level on anterior and posterior tongue strength as well as on anterior and posterior tongue endurance were found. The effect of physical activity level on tongue muscle performance tended to be more pronounced in older adults than in young adults. Effects of age on tongue strength and endurance measures as well as age x activity group interactions were not significant. However, trends were observed suggesting that only non-active older adults demonstrated poorer tongue muscle performances compared to young adults suggesting that the aging-related muscle performance decline tended to depend on an individual’s physical activity level. The following sections will discuss these findings in more detail.

Objective Assessment of Physical Activity Level

Between-group comparisons of handgrip strength and cardiovascular endurance were completed to objectively verify that the group membership, which was determined based on the results of questionnaires, yielded two groups who showed distinct differences in their skeletal
muscle performance. That is, based on the literature physically active individuals, regardless of age, should demonstrate significantly greater handgrip strength and cardiovascular endurance than physically non-active individuals.

*Handgrip Strength.* Handgrip strength was significantly greater in physically active individuals than physically non-active individuals. This finding concurred with previous studies reporting that physically active adults produced greater handgrip strength than physically non-active adults (Dodds et al., 2013).

No significant difference in handgrip strength was found between young and older adults; however, age-group x activity level interactions tended to emulate previous reports that skeletal muscles strength is greater in young and older adults who are physically active compared to non-active adults (Cadore et al., 2014; Freiberger et al., 2011; Karavirta et al., 2011; Rantanen et al., 1999).

*Cardiovascular Endurance.* The groups in our study confirmed the overall expected performance patterns of cardiovascular endurance between the two physical activity levels. As in many previous studies the submaximal VO₂ measure obtained for each participant showed that cardiovascular endurance was significantly greater in participants of the physical active group compared to the cardiovascular endurance of participants in the non-active group (Cadore et al., 2014; Garber et al., 2011; Hawkins et al., 2003; Tanaka & Seals, 2003). The significant main effect for age also replicated previous findings that cardiovascular endurance was significantly lower in older adults than in young adults (Booth et al., 2011; Goldspink, 2005; Spirduso et al., 2005; Tanaka & Seals, 2003). Although no significant age x activity level interaction was found, the interaction term was approaching significance ($p = .06$). This finding is similar to previous
ones, which reported that, the aging effect is marked in non-active older adults while the decline in active older adults is greatly attenuated (Cadore et al., 2014; Hawkins et al., 2003; Spirduso et al., 2005).

The Effect of Physical Activity Level on Tongue Muscle Performance

The results of the study supported the stated hypothesis for the effects of physical activity levels on tongue strength and endurance. Specifically, physically active individuals demonstrated significantly greater anterior and posterior tongue strength and endurance than physically non-active individuals. Findings of the present study are congruent with previous studies that investigated the effects of physical activity on skeletal muscle performance (Dodds et al., 2013; Karavirta et al., 2011; Paalanne, Korpelainen, Taimela, Auvinen, et al., 2009; Spirduso et al., 2005). Collectively, these previous studies showed that skeletal muscle strength and endurance of physically active adults were greater than skeletal muscle strength and endurance of non-active adults. Further, beneficial effects of physical activity on skeletal muscle strength and endurance are not exclusive to the muscle(s) being targeted during physical activity (Karavirta et al., 2011; Kraemer & Ratamess, 2004; Kraemer et al., 2002; Wilson et al., 2012), but are also shown to produce beneficial effects on indirectly involved muscle(s) (Fisher et al., 2011; Hamlyn et al., 2007; Munn et al., 2004; Tew et al., 2009). For example, although a physical activity such as squatting directly targets the leg muscles’ strength, squatting also benefits indirectly targeted abdominal muscles (Fisher et al., 2011; Hamlyn et al., 2007).

Similarly, Klettzien and colleagues (2013) reported that physical activity (i.e., treadmill running) indirectly benefits tongue muscle strength and endurance. They reported that the young and older rats that ran on the treadmill produced greater tongue strength and endurance
APPENDIX A (continued)

measures than young and older rats that did not exercise. As can be seen in Figures 5 and 6 (tongue strength) and Figures 9 and 10 (tongue endurance), tongue muscle strength and endurance, regardless of age, may be indirectly affected by physical activity similar to skeletal muscles.

Aging x Activity Level Interactions

Although statistical significance for age x activity group interactions were not reached as hypothesized, across all tongue muscle performance measures only non-active older adults demonstrated lower performance than young active and non-active adults suggesting a trend towards the expected interaction pattern of activity level and age. Previous studies on tongue strength have shown that younger adults typically produce greater tongue strength than older adults (Clark & Solomon, 2012; Crow & Ship, 1996; Logemann et al., 2000; Robbins et al., 1992). Failure to reach significance in the present study may be explained by the heterogeneity of the participants within each group compared to previous studies. That is, for the purpose of this study, highly active and non-active participants were selected via a screening process, whereas previous studies merely selected participants based on chronologic age. However, aging is a very individualized process and its rate of progression depends on many factors, one of which is the activity level (Caspersen, 1985; Paalanne, Korpelainen, Taimela, Auvinen, et al., 2009; Spirduso et al., 2005). Therefore, it is useful to differentiate between a chronological age and a biological age (an individual’s physiological well-being).

However, for tongue endurance, the lack of a significant age effect or age by activity level interactions on anterior and posterior tongue endurance is consistent with findings of
previous studies investigating age differences in tongue endurance (Adams et al., 2013; Crow & Ship, 1996; Stierwalt & Youmans, 2007). Collectively, these previous studies reported that tongue endurance (anterior, posterior) did not significantly decrease with age. By contrast, previous studies investigating skeletal muscles oppose our findings reporting that a loss in skeletal muscle endurance occurs with age (Cadore et al., 2014; Cruz-Jentoft et al., 2010; Fielding et al., 2011; Spirduso et al., 2005).

**Clinical Implications**

Previous studies have established that healthy tongue muscle strength and endurance are important to perform daily tongue functions such as swallowing, speaking, and maintaining upper airway patency (McHorney et al., 2006; Neel et al., 2006; Nicosia, 2000; Robbins et al., 2005; Stierwalt & Youmans, 2007; Yoshida et al., 2006). Furthermore, aging-related decline in tongue muscle performance is typical and may negatively impact tongue function such as swallowing or maintaining airway patency (Blumen et al., 2004; Clark & Solomon, 2012; Humbert & Robbins, 2008; Ney et al., 2009; Nicosia, 2000). The findings in our study reported that young and older adults in the active and non-active groups each produced tongue strength measures that fell within the healthy normative range of 40-80 kPa (Adams et al., 2013; Clark & Solomon, 2012; Crow & Ship, 1996). However, the non-active older adults’ tongue strengths (anterior, posterior) were approaching borderline levels for effectively performing everyday tongue functions ($M = 44.17$, $M = 40.25$, respectively). In fact, five of the 12 individuals in the older non-active group showed tongue strength levels at or below 35 kPa and two additional non-active older adults were bordering this level. Previous studies have reported that tongue
strength values declining below 35 kPa raises concern for complications such as dysphagia (Adams et al., 2013; Nicosia, 2000).

The findings in our study reported that active young and older adults each produced tongue endurance (anterior, posterior) measures that were approaching healthy normative ranges (e.g., 25-35 seconds for anterior tongue endurance, slightly lower measures for posterior tongue endurance) (Adams et al., 2013; Crow & Ship, 1996; Stierwalt & Youmans, 2007). In contrast, the non-active older adults’ tongue endurance (anterior, posterior) measures were indicative of an aging effect as their measures were much lower than each of the other groups. Furthermore, the non-active older adult groups’ posterior tongue endurance ($M = 9.17$) measure was associated with concerns for maintaining adequate tongue function (e.g., performance of 10 seconds or less) (Adams et al., 2013; Crow & Ship, 1996; Stierwalt & Youmans, 2007). In fact, nine of the 12 older adults in the non-active group produced tongue endurance (anterior, posterior) measures at or below 10 seconds.

**Potential Mechanisms that Could Explain Between-Group Differences in Tongue Muscle Performance**

Although little is currently known about the underlying mechanisms that could contribute to the between-group differences in tongue muscle performance, studies that have investigated tongue muscle activation during physical exercise in humans and tongue muscle fiber changes in response to exercise (treadmill running) in rats may offer insights. For example, Shi et al. (1998) reported that tongue muscle activation (genioglossus muscle) increases as an individual’s rate of respiration increases during exercise (i.e., stationary bicycling). Kletzien and colleagues (2013), therefore, speculated that the beneficial indirect effects of treadmill running on tongue strength
and endurance of rats may be attributed to increased tongue muscle activation necessary to maintain airway patency. Such findings suggest that physical activity requires a greater demand on the tongue muscles to activate and maintain airway patency compared to no physical activity. In so doing, the increase in tongue muscle activation benefits tongue muscle strength and endurance. Although the findings of our study could support such speculation, the linkage between respiratory-driven increases in tongue muscle activation and changes in tongue muscle performance is currently unknown. Respiratory-driven changes in tongue muscle fibers in humans may completely differ from those observed in rats due to the anatomical and physiological differences between these two species. For example, a human’s upper airway is an L-shaped structure and its positioning remains constant to the individual’s posture. A rat’s upper airway is described as rectilinear and is considered to be in an “upright” position when the rat is residing in its neutral supine posture (Barbizet, 1958; Lu & Kubin, 2009; Matsuo & Palmer, 2010). Secondly, during inspiratory respiration the tongue muscles of a rat typically remain atonic due to the hyoid bone being anchored to the trachea and providing upper airway stabilization, whereas in humans the hyoid bone is not anchored and is free moving requiring the muscles of the tongue to activate during inspiratory respiration to maintain upper airway patency (Barbizet, 1958; Lu & Kubin, 2009; Matsuo & Palmer, 2010; Mezzanotte et al., 1992; Series et al., 1989). These differences between humans and rats may impose different tongue muscle activation responses during physical activity.

**Limitations and Future Directions**

The findings of this study are one of the first to offer insight into differences in tongue muscle performance between physically active and non-active individuals; however, this was a
pilot study with a relatively small sample size as indicated by lack of adequate power to show significance in the presence of small effect sizes. Further, findings from this study must be generalized with caution when implying such information on individuals performing at other levels of activity (e.g., low-to-moderate activity, moderate activity, moderate-to-high activity). It is unknown if tongue muscle performance also differs from one level of activity to another level of activity. Additionally, the inclusion criterion only addressed the number of days one exercised and was void of identifying other exercise factors (e.g., mode, intensity, duration, and volume) shown to provide further distinction in one’s level of physical activity (Kraemer et al., 2002). This lack of information may have diluted distinguishing characteristics in the highly active group thereby limiting speculation of the indirect effect(s) of exercise on tongue muscle strength and endurance between groups.

One final limitation is that this study did not investigate the indirect effects of physical activity on tongue muscle performance in a pre-to-post paradigm based on a specific exercise. Such an experiment combined with more control over various other factors of exercise (i.e., exercise modes, intensity, duration, frequency, volume) would provide more direct insights in the potential indirect effect of exercise on tongue muscle performance. If such future findings continue to support an indirect beneficial effect of physical activity on tongue muscle strength and endurance, it could be useful for promoting and maintaining tongue function, as well as complimenting current tongue muscle rehabilitative methods.

Conclusion

Findings of this study suggest that individuals who are highly active have greater tongue muscle performance than individuals who are non-active, regardless of age. The finding that only
non-active older adults had lower tongue muscle performance than all other groups suggests that being physically active may slow aging-related tongue muscle performance decline. Future studies are warranted to delineate the underlying mechanisms that contribute to these between-group differences. Such insights may help in the future to identify new strategies to improve tongue muscle performance in individuals with tongue muscle performance loss.
APPENDIX A (continued)

REFERENCES


APPENDIX A (continued)


APPENDIX A (continued)


APPENDIX A (continued)


APPENDIX A (continued)


APPENDIX A (continued)


Antje Mefferd, PhD, CCC-SLP; Assistant Professor
Department of Communication Sciences and Disorders
401 E Ahlberg Hall
Wichita State University
Wichita, KS 67260-0075
Phone: (316) 978-7345
E-mail: antje.mefferd@wichita.edu

Purpose
The purpose of this study is to determine the effects of physical activity on tongue strength and endurance, and whether a higher physical fitness level also presents with higher measures of tongue strength and endurance. We know from studies that individuals with average and above-average physical fitness levels present with higher functioning levels in such tasks as walking, bending and reaching. However, we do not fully understand how physical fitness levels relate to tongue strength and endurance and such functions as eating and swallowing. Thus, the information obtained during this study will assist the investigators to determine specific factors that may play a significant role in tongue function. Such information may further direct future methods of therapy and exercise for persons at risk of declining tongue function.

Participant Selection
All participants will be recruited on a volunteer basis through the use of a promotional flier, and word of mouth. The study will include 160 healthy young adults (age 18-40 years) and 160 healthy older adults (age 60 and older). Participants within each age group will be further placed into one of two groups based on physical activity level (active, nonactive) for a total of four groups, 80 participants in each group, (1) young-active, (2) young-nonactive, (3) older-active, and (4) older-nonactive.

Given your interest in participating in this study, three short, yes/no and short answer, screening questionnaires will obtain important information pertaining to your health status, tongue and oral history, and physical activity level. These questions will provide the research team with an understanding of your individual background and will assist in determining your eligibility and group placement in the study (active or non-active). These questions will also assist in identifying if you may be at high risk if you were to participate in the study. Such findings will remove you from the study and you may be encouraged to see your family physician.

Explanation of Procedures
The research will take place at the Wichita State University Human Performance Laboratory (HPL), Heskett Center (Rm
214), 1845 Fairmount, Wichita, KS. If you decide to participate, you understand participating in the study is a one-time commitment lasting approximately 2 hour.

Data Collection
During this data collection session you will complete an exercise history questionnaire that addresses your past and current exercise habits and personal best performance in competitive events. Following the questionnaire tongue measurements to document your maximal tongue strength and endurance will be collected. You will place a disposable bulbus and/or transducer sensor with disposable cover sleeve into your mouth and press up against the roof of your mouth with maximal pressure for 1-2 seconds. You will repeat this measure 3 times. You will provide tongue endurance measures by maintaining 50% maximal tongue pressure on the bulbus and/or transducer sensor for as long as you are able.

During the study you will also provide a maximal upper-body strength measure using a handgrip dynamometry. Using your non-doninate hand you will squeeze the hand-dynamometer as hard as you can for 2 to 3 seconds and relax. You will repeat this measure 3 times. You will also have your maximal lung volume (breath) measured one time using spirometry. During the measure you will take a deep breath (inhale) and then forcefully exhale as much air as possible from your lungs into a disposable mouthpiece attached to the spirometer. Height, and weight will also be measured.

Following these measures you will have your cardiorespiratory (aerobic fitness level) measured. You will breath through a sterile mouthpiece attached to a MAX-IIa Metabolic System while riding a stationary bicycle. This test will last approximately 9-minutes with a maximum duration of up to 12-minutes. You will be provided a 3-minute warm-up and a 3-minute cool-down on the bicycle. You understand that you will need to maintain 50-rpm pedaling cadence throughout the test and a standardized resistance will be applied. During the test your oxygen and carbon dioxide levels, heart rate, blood pressure and RPE will also be continually monitored.

You will also have your bone mineral content, bone mineral density, and body composition measured. A Hologic Discovery A, Dual Energy X-ray Absorptiometry system will scan your whole-body while you lay in a motionless, supine position. The scan takes approximately 10 minutes to complete. For the scan you will be asked to wear a garment approved gown or attire, in addition to removing all metal accessories (i.e., jewelry, glasses). You will also be asked to provide a urine sample. The HPL is equipped with a private rest room where you will go to produce a urine sample in a specimen cup. You will hand the sample to one of the study investigators upon exiting the rest room. The urine sample will be used to determine hydration and pregnancy status.

Further, you understand you will be given breaks between all tasks performed during the session.

Before the data collection, you will be asked about your health, physical activity level and tongue/oral history. These questionnaires are for the research team to understand your individual background. The results of these questionnaires will determine group placement in the study.

Discomfort/Risks
The technology and the data collection methods are non-invasive. The procedures that we use to analyze physical fitness and tongue measures have been carefully designed to minimize discomfort and risk. You may experience minimal oral fatigue during the tongue strength and endurance, and handgrip strength measures. You will be encouraged to take breaks during the experiment to prevent fatigue. You may also experience light-headedness when you complete the maximal exhalation of air during the spirometry measure. You will be provided a chair to sit down on following the measure, if needed.

You may also experience fatigue, muscle ache and breathlessness during the aerobic testing. If you are known to experience hypoglycemia, you are encouraged to eat a high protein and carbohydrate snack 2 to 3 hours pre-assessment to
avoid such risk. This test also presents a small risk for musculoskeletal injury and cardiovascular problems. During this test we will closely monitor your heart rate, blood pressure and rate of perceived exertion to identify normal and abnormal responses to minimize such risks. Further, the clearance to participant based upon the physical activity readiness questionnaire greatly reduces the risk of experiencing such complications. At any time, the participant may stop due to discomfort.

The Hologic Discovery A, Dual Energy X-ray Absorptiometry system is an x-ray device that emits low radiation doses and presents minimal exposure to you. Use of this equipment for research purposes has been previously approved by the Kansas Department of Health and Environment and the WSU IRB. Due to the low-dose radiation involved with the DXA testing, female participants must not be and should not become pregnant nor breast-feed an infant while participating in this study. To minimize this risk, if you are a female participant, you will be administered a urine pregnancy test prior to the DXA scan. If your pregnancy test comes back positive, the study personnel will show you to a private room in the HPL and notify you of the test result. You will be disqualified from participating in the study and will be encouraged to follow up with your personal physician about the test result.

Benefits
This study will not directly benefit you; however, this research study will provide you with insight as to your current physical fitness, bone mineral content and density, body composition, and tongue function status. Further, this study will help us identify any physical fitness measures that may relate to tongue strength and endurance. As an individual's tongue function declines due to age or disease this study will identify any physical fitness measures that help maintain and rehabilitate tongue function for eating and swallowing safely.

Confidentiality
Any information obtained in this study in which you can be identified will remain confidential and will be disclosed only with your permission. The data from you will be associated with a unique code known only to the study’s research team and will be referenced only by those codes. Study-related files will be kept locked away when not in use by the research team.

Compensation or Treatment
You will not receive any monetary compensation for your participation in this study.

Wichita State University does not provide medical treatment or other forms of reimbursement to persons injured as a result of or in connection with participation in research activities conducted by Wichita State University or its faculty, staff, or students. If you believe that you have been injured as a result of participating in the research covered by this consent form, you can contact the Office of Research and Technology Transfer, Wichita State University, Wichita, KS 67260-0007, telephone (316) 978-3285.

Refusal/Withdrawal
Participation in this study is entirely voluntary. Your decision whether or not to participate will not affect your future relations with Wichita State University. If you agree to participate in this study, you are free to withdraw from the study at any time without penalty.

Contact
If you have any questions about this research, you can contact Antje Mefferd, PhD, Principal Investigator at 316-978-7345 or antje.mefferd@wichita.edu or Heidi VanRavenhorst-Bell, MEd, Co-investigator at 316-393-3339 or heidi.bell@wichita.edu. If you have questions pertaining to your rights as a research subject, or about research-related injury, you can contact the Office of Research Administration at Wichita State University, Wichita, KS 67260-0007, telephone (316) 978-3285. You are under no obligation to participate in this study. Your signature indicates that you have
read the information provided above and have voluntarily decided to participate.

You will be given a copy of this consent form to keep.

____________________________________________   ______________
Signature of Subject        Date

_____________________________________________   ______________
Signature of Person Conducting       Date
Informed Consent Discussion

1845 N. Fairmount, Wichita, KS  67260-0075
Telephone: (316) 978-3240  •  Fax: (316) 978-3291  •  E-mail: csd@wichita.edu  •  Website: www.wichita.edu/csd
APPENDIX C

Oral Health History Questionnaire

IDENTIFIER No. :

Do you currently wear dentures? Yes: _____ No: _____
If so, How long? ___________________

Do you currently wear any form of an oral plate? Yes: _____ No: _____
If so, How long? ___________________

Have you undergone any type of tongue/oral surgery? Yes: _____ No: _____
If so, How long ago? ___________________
Please explain: ____________________________
________________________________________________________________________________
________________________________________________________________________________

Have you ever been diagnosed with a disease or disorder that may negatively effect tongue function? Yes: _____ No: _____

Are there any other tongue and/or oral concerns to be aware of? ____________________________________________
________________________________________________________________________________
________________________________________________________________________________
APPENDIX D

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

### YES to one or more questions

If you answered YES to one or more of the questions, talk with your doctor by phone or in person before you start becoming much more physically active or before you take part in a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

### NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

### DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

### PLEASE NOTE:

- If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional.
- Ask whether you should change your physical activity plan.

**Note:** This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.
APPENDIX D (continued)

PAR-Q & YOU

Physical Activity Readiness Questionnaire - PAR-Q
(revised 2002)

Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes. A daily walk and add up your activities in periods of at least 10 minutes each. Start slowly… and build up.

Time needed depends on effort

Very Light Effect
- Walking
- Yoga
- Dancing
- Biking
- Swimming
- Flexibility
- Stretching
- Gardening
- Housework

Moderate Effect
- Light yard work
- Walking – brisk
- Aerobics
- Basketball
- Bowling
- Dance class
- Water aerobics

Vigorous Effect
- Jogging
- Fast walking
- Fast swimming
- Tennis
- Football

Marathon Effect
- Sprinting
- Racing

You Can Do It – Getting started is easier than you think

Physical activity does I have to be very hard. Build physical activities into your daily routine.
- Walk whenever you can– get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.

Benefits of regular activity:
- Stronger muscles and bones
- Improved mood
- Better self-esteem
- Better posture and balance
- Improved fitness
- Better circulation
- Improved mood
- Feel stronger
- Feeling more energetic
- Reduced risk of diseases
- Improved recovery
- Improved independence in daily living
- Reduced risk of diseases
- Improved immune system
- Weight control
- Reduced risk of diseases
- Improved mood
- Better memory
- Lower blood pressure
- Improved circulation
- Improved mood
- Weight control

Refer to the PAR-Q & YOU page of the Physical Activity Guide for more information.

© Reproduced with permission from the Minister of Public Works and Government Services Canada, 2002.
PHYSICAL ACTIVITY QUESTIONNAIRE

This questionnaire is designed to find out about your physical activity in your everyday life.

Please try to answer every question, except when there is a specific request to skip a section.

Your answers will be treated as strictly confidential and will be used only for medical research.
THE QUESTIONNAIRE IS DIVIDED INTO 3 SECTIONS

- **Section A** asks about your physical activity patterns in and around the house.
- **Section B** is about travel to work and your activity at work. It may be skipped by people who have not worked at any stage during the last 12 months.
- **Section C** asks about recreations that you may have engaged in during the last 12 months.

What is your date of birth? [ ] [ ] [ ]

What is today's date? [ ] [ ] [ ]

Your sex (Please tick (✓) appropriate box)? Male [ ] Female [ ]

**Section A  HOME ACTIVITIES**

**GETTING UP AND GOING TO BED**

*Please put a time in each box*

<table>
<thead>
<tr>
<th>Average over the past year</th>
<th>At what time do you normally get up?</th>
<th>At what time do you normally go to bed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>On a weekday</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On a weekend day</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GETTING ABOUT — Apart from going to work**

Which form of transport do you use most often apart from your journey to and from work?

*Please tick (✓) one box  ONLY per line*

<table>
<thead>
<tr>
<th>Distance of journeys</th>
<th>Usual mode of transport</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Car  Walk  Public transport  Cycle</td>
</tr>
<tr>
<td>less than one mile</td>
<td></td>
</tr>
<tr>
<td>1–5 mile(s)</td>
<td></td>
</tr>
<tr>
<td>More than 5 miles</td>
<td></td>
</tr>
</tbody>
</table>
### TV OR VIDEO VIEWING

*Please put a tick (√) on every line*

<table>
<thead>
<tr>
<th>Hours of TV or Video watched per day</th>
<th>Average over the last 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>less than 1 hour a day</td>
</tr>
<tr>
<td></td>
<td>1 to 2 hours a day</td>
</tr>
<tr>
<td></td>
<td>2 to 3 hours a day</td>
</tr>
<tr>
<td></td>
<td>3 to 4 hours a day</td>
</tr>
<tr>
<td></td>
<td>More than 4 hours a day</td>
</tr>
<tr>
<td>On a weekday before 6 pm</td>
<td></td>
</tr>
<tr>
<td>On a weekday after 6 pm</td>
<td></td>
</tr>
<tr>
<td>On a weekend day before 6 pm</td>
<td></td>
</tr>
<tr>
<td>On a weekend day after 6 pm</td>
<td></td>
</tr>
</tbody>
</table>

### STAIR CLIMBING AT HOME

*Please put a tick (√) on every line*

<table>
<thead>
<tr>
<th>Number of times you climbed up a flight of stairs (approx 10 steps) each day at home</th>
<th>Average over the last 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>1 to 5 times a day</td>
</tr>
<tr>
<td></td>
<td>6 to 10 times a day</td>
</tr>
<tr>
<td></td>
<td>11 to 15 times a day</td>
</tr>
<tr>
<td></td>
<td>16 to 20 times a day</td>
</tr>
<tr>
<td></td>
<td>More than 20 times a day</td>
</tr>
<tr>
<td>On a weekday</td>
<td></td>
</tr>
<tr>
<td>On a weekend day</td>
<td></td>
</tr>
</tbody>
</table>

### ACTIVITIES IN AND AROUND THE HOME

*Please put a tick (√) on every line*

<table>
<thead>
<tr>
<th>Approximate number of hours each week</th>
<th>Average over the last 12 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>Less than 1 hour a week</td>
</tr>
<tr>
<td></td>
<td>1 to 3 hours a week</td>
</tr>
<tr>
<td></td>
<td>3 to 6 hours a week</td>
</tr>
<tr>
<td></td>
<td>6 to 10 hours a week</td>
</tr>
<tr>
<td></td>
<td>10 to 15 hours a week</td>
</tr>
<tr>
<td></td>
<td>More than 15 hours a week</td>
</tr>
<tr>
<td>Preparing food, cooking and washing up</td>
<td></td>
</tr>
<tr>
<td>Shopping for food and groceries</td>
<td></td>
</tr>
<tr>
<td>Shopping and browsing in shops for other items (e.g. clothes, toys)</td>
<td></td>
</tr>
<tr>
<td>Cleaning the house</td>
<td></td>
</tr>
<tr>
<td>Doing the laundry and ironing</td>
<td></td>
</tr>
<tr>
<td>Caring for pre-school children or babies at home (not as paid employment)</td>
<td></td>
</tr>
<tr>
<td>Caring for handicapped, elderly or disabled people at home (not as paid employment)</td>
<td></td>
</tr>
</tbody>
</table>
Section B  ACTIVITY AT WORK

Please answer this section only if you have been in paid employment at any time during the last 12 months or you have done regular, organised voluntary work.

If not please go to page 9

TYPES OF WORK DURING THE LAST TWELVE MONTHS

- We would like to know what full or part-time jobs you have done in the last 12 months.
- You may have held a single job or have held two jobs at once.
- If you have changed jobs with the same employer, you should enter it as a change of job only if it entailed a substantial change in physical effort.

EXAMPLE

Someone who worked full-time for 6 months, then retired, rested for 3 months and then started a voluntary job for 6 hours a week, would complete the questions as follows.

<table>
<thead>
<tr>
<th>Name of occupation</th>
<th>Job 1</th>
<th>Job 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many hours per week did you usually work?</td>
<td>nurse</td>
<td>shop work</td>
</tr>
<tr>
<td>For how many months in the last 12 months did you do this work?</td>
<td>38</td>
<td>6</td>
</tr>
</tbody>
</table>

ACTIVITY LEVELS AT YOUR WORK

Now we would like you to take the total number of hours you worked per week in each job and divide them up according to your activity level.

Please complete EACH line

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting — light work e.g. desk work, or driving a car or truck</td>
<td>✓</td>
<td>6</td>
</tr>
<tr>
<td>Sitting — moderate work e.g. working heavy levers or riding a mower or forklift truck</td>
<td>✓</td>
<td>50</td>
</tr>
<tr>
<td>Standing — light work e.g. lab technician work or working at a shop counter</td>
<td>✓</td>
<td>2</td>
</tr>
<tr>
<td>Standing — light/moderate work e.g. light welding or stocking shelves</td>
<td>✓</td>
<td>2</td>
</tr>
</tbody>
</table>

The number of hours in each activity should add up to the number of hours that you worked in each job e.g. 6+30+2=38 (nurse)
What jobs have you held in the last 12 months, and how many months in the year did you do them?

Please complete EACH line

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of occupation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>How many hours per week did you usually work?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For how many months in the last 12 months did you do this work?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ACTIVITY LEVELS AT YOUR WORK

Now we would like you to take the total number of hours you worked per week in each job and divide them up according to your activity level.

Please complete EACH line

<table>
<thead>
<tr>
<th></th>
<th>Job 1</th>
<th>Job 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sitting — light work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting — moderate work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing — light work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing — light/moderate work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing — moderate work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing — moderate/heavy work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking at work — carrying nothing heavier than a briefcase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking — carrying something heavy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving, pushing heavy objects objects weighing over 75lbs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
STAIR OR STEP CLIMBING AT WORK
Please put a tick (✓) on EACH line where appropriate

<table>
<thead>
<tr>
<th>Number of times you climbed up a flight of stairs (10 steps) at work</th>
<th>AVERAGE OVER THE LAST 12 MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Job 1</td>
<td></td>
</tr>
<tr>
<td>Job 2</td>
<td></td>
</tr>
</tbody>
</table>

Please put a tick (✓) on EACH line where appropriate

<table>
<thead>
<tr>
<th>Number of times you climbed up a ladder at work</th>
<th>AVERAGE OVER THE LAST 12 MONTHS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>None</td>
</tr>
<tr>
<td>Job 1</td>
<td></td>
</tr>
<tr>
<td>Job 2</td>
<td></td>
</tr>
</tbody>
</table>

KNEELING AND SQUATTING AT WORK IN JOB 1
In an average working day in Job 1 did you
kneel for more than one hour in total? No Yes Don’t know
squat for more than one hour in total? No Yes Don’t know
get up from kneeling or squatting more than 30 times? No Yes Don’t know

KNEELING AND SQUATTING AT WORK IN JOB 2
In an average working day in Job 2 did you
kneel for more than one hour in total? No Yes Don’t know
squat for more than one hour in total? No Yes Don’t know
get up from kneeling or squatting more than 30 times? No Yes Don’t know
### TRAVEL TO AND FROM WORK

**JOB 1**

Please complete EVERY line

| Roughly how many miles was it from home to Job 1? |  |
| How many times a week did you travel from home to Job 1? |  |

Please tick (✓) one box ONLY per line

<table>
<thead>
<tr>
<th>How did you normally travel to Job 1?</th>
<th>Always</th>
<th>Usually</th>
<th>Occasionally</th>
<th>Never or rarely</th>
</tr>
</thead>
<tbody>
<tr>
<td>By car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By works or public transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By bicycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**JOB 2 (if appropriate)**

Please complete EVERY line

| Roughly how many miles was it from home to Job 2? |  |
| How many times a week did you travel from home to Job 2? |  |

Please tick (✓) one box ONLY per line

<table>
<thead>
<tr>
<th>How did you normally travel to Job 2?</th>
<th>Always</th>
<th>Usually</th>
<th>Occasionally</th>
<th>Never or rarely</th>
</tr>
</thead>
<tbody>
<tr>
<td>By car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By works or public transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By bicycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Section C  RECREATION

The following questions ask about how you spent your leisure time.

Please indicate how often you did each activity on average over the last 12 months.

For activities that are seasonal, e.g. cricket or mowing the lawn, please put the average frequency during the season when you did the activity.

Please indicate the average length of time that you spent doing the activity on each occasion.

EXAMPLE

If you had mowed the lawn every fortnight in the grass cutting season and took 1 hour and 10 minutes on each occasion.

If you went walking for pleasure for 40 minutes once a week.

You would complete the table below as follows:

Please give an answer for the AVERAGE TIME you spent on each activity and the NUMBER OF TIMES you did that activity in the past year.

<table>
<thead>
<tr>
<th>Number of times you did the activity in the last 12 months</th>
<th>Average time per episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Less than a month</td>
</tr>
<tr>
<td>Mowing the lawn</td>
<td>✓</td>
</tr>
<tr>
<td>Walking for pleasure</td>
<td>✓</td>
</tr>
</tbody>
</table>

Now please complete the table on pages 10 and 11
Please give an answer for the NUMBER OF TIMES you did the following activities in the last 12 months and the AVERAGE TIME you spent on each activity.

Please complete EACH line

<table>
<thead>
<tr>
<th>Number of times you did the activity in the last 12 months</th>
<th>Average time per episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Less than once a month</td>
</tr>
<tr>
<td>Swimming — competitive</td>
<td></td>
</tr>
<tr>
<td>Swimming — leisurely</td>
<td></td>
</tr>
<tr>
<td>Backpacking or mountain climbing</td>
<td></td>
</tr>
<tr>
<td>Walking for pleasure — you should not include walking as a means of transportation as this was included in Sections A &amp; B</td>
<td></td>
</tr>
<tr>
<td>Racing or rough terrain cycling</td>
<td></td>
</tr>
<tr>
<td>Cycling for pleasure — you should not include cycling as a means of transportation</td>
<td></td>
</tr>
<tr>
<td>Mowing the lawn — during the grass cutting season</td>
<td></td>
</tr>
<tr>
<td>Watering the lawn or garden in the summer</td>
<td></td>
</tr>
<tr>
<td>Digging, shovelling or chopping wood</td>
<td></td>
</tr>
<tr>
<td>Weeding or pruning</td>
<td></td>
</tr>
<tr>
<td>DIY e.g. carpentry, home or car maintenance</td>
<td></td>
</tr>
<tr>
<td>High impact aerobics or step aerobics</td>
<td></td>
</tr>
<tr>
<td>Other types of aerobics</td>
<td></td>
</tr>
<tr>
<td>Exercises with weights</td>
<td></td>
</tr>
<tr>
<td>Conditioning exercises e.g. using an exercise bike or rowing machine</td>
<td></td>
</tr>
</tbody>
</table>

Please continue on the next page
APPENDIX E (continued)

<table>
<thead>
<tr>
<th>Activity Description</th>
<th>None</th>
<th>Less than once a month</th>
<th>Once a month</th>
<th>2 to 3 times a month</th>
<th>Once a week</th>
<th>2 to 3 times a week</th>
<th>4 to 5 times a week</th>
<th>6 times a week or more</th>
<th>Average time per episode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor exercises e.g. stretching, bending, keep fit or yoga</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hours</td>
</tr>
<tr>
<td>Dancing e.g. ballroom or disco</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Competitive running</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jogging</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowling — indoor, lawn or 10 pin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tennis or badminton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Table tennis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Golf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Football, rugby or hockey (during the season)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cricket (during the season)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rowing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netball, volleyball or basketball</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horse-riding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snooker, billiards or darts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musical instrument playing or singing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice-skating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sailing, wind-surfing or boating</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martial arts, boxing or wrestling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

You have finished the questionnaire — Thank you
APPENDIX F

Date: November 20, 2013

Principal Investigator: Antje Mefferd

Co-Investigator(s): Heidi VanRavenhorst-Bell, Jeremy Patterson, Rosalind Scudder

Department: CSD and HPS

IRB Number: 2734

The Wichita State University Institutional Review Board (IRB) has reviewed your amendment application of the research project entitled, “The Relationship Between Physical Fitness Measures and Tongue Strength and Endurance”. The IRB has approved the project amendment according to the Federal Policy for the Protection of Human Subjects. As described, the project also complies with all the requirements and policies established by the University for protection of human subjects in research.

The following modifications have been approved:

1. Increase age range to 18-40.
2. Increase the total healthy young adult participants to a total N= 160 and increase the total healthy older adult participants to a total N=160.
3. Addition of an Exercise History Questionnaire to identify any differences in training habits that may influence the effect of one's physical fitness level and further impact tongue strength and endurance.
5. Extension of expected completion date to December, 2014.

This study will require continuation approval if the research project extends beyond April 18, 2014.

Please keep in mind the following:

1. Any significant change in the experimental procedure as described should be reviewed by the IRB prior to altering the project.
2. When signed consent documents are required, the principal investigator must retain the signed consent documents for at least three years past completion of the research activity.
3. At the completion of the project, the principal investigator is expected to submit a final report.

Thank you for your cooperation. If you have any questions, please contact me at ext. 6945.

Sincerely,

Michael Rogers, Ph.D.
Chairperson, IRB
### YMCA Submaximal Cycle Ergometer Protocol

**Summary**
- 2-4 consecutive stages
- Goal is to achieve a HR between 110 and 85% of age-predicted heart rate max
- Initial workload = 150 kg m min\(^{-1}\); Pedal rate = 50 rpm
- HR from initial workload determines second stage workload. Follow workloads under the second stage workloads.
- Each stage is a minimum of 3 minutes. If HRs between minute 2 and minute 3 of a stage are not within ±5 bpm, add 1 minute to the stage.

<table>
<thead>
<tr>
<th>Time</th>
<th>Instructions</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00 – 3:00</td>
<td>Pedal at 50 rpm with no resistance</td>
<td>Warm-up</td>
</tr>
<tr>
<td>3:00</td>
<td><strong>Reset Clock</strong></td>
<td></td>
</tr>
<tr>
<td>0:00</td>
<td>Start Test (maintain 50 rpm throughout test)</td>
<td>1(^{st}) Stage</td>
</tr>
<tr>
<td>2:00</td>
<td>Take Blood Pressure, HR, and RPE</td>
<td></td>
</tr>
<tr>
<td>2:50</td>
<td>Take HR and RPE</td>
<td></td>
</tr>
<tr>
<td>3:00</td>
<td>Adjust workload accordingly</td>
<td>2(^{nd}) Stage</td>
</tr>
<tr>
<td>5:00</td>
<td>Take Blood Pressure, HR, and RPE</td>
<td></td>
</tr>
<tr>
<td>5:50</td>
<td>Take HR and RPE</td>
<td></td>
</tr>
<tr>
<td>6:00</td>
<td>Adjust workload accordingly</td>
<td>3(^{rd}) Stage</td>
</tr>
<tr>
<td>8:00</td>
<td>Take Blood Pressure, HR, and RPE</td>
<td></td>
</tr>
<tr>
<td>8:50</td>
<td>Take HR and RPE</td>
<td></td>
</tr>
<tr>
<td>9:00</td>
<td>Adjust workload accordingly</td>
<td>4(^{th}) Stage OR</td>
</tr>
<tr>
<td>OR Stop Test</td>
<td></td>
<td>Recovery Cool Down</td>
</tr>
</tbody>
</table>
YMCA Submaximal Cycle Ergometer Protocol

Guide to setting workrates on the bicycle ergometer (Sudy, 1991 page 164). Note this figure has been modified to show the correct units.

<table>
<thead>
<tr>
<th>1st Workrate (all subjects)</th>
<th>150 kg.m/min 0.5 Kp</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR &lt; 80</td>
<td>750 kg.m/min 2.5 Kp</td>
</tr>
<tr>
<td>HR 80-89</td>
<td>600 kg.m/min 2.0 Kp</td>
</tr>
<tr>
<td>HR 90-100</td>
<td>450 kg.m/min 1.5 Kp</td>
</tr>
<tr>
<td>HR &gt; 100</td>
<td>300 kg.m/min 1.0 Kp</td>
</tr>
</tbody>
</table>

YMCA Sub-Maximal Bicycle Test Protocol

1. In order to familiarize clients with the 50-rpm pedal rate, start the metronome (if desired) and have them pedal with very little or no resistance.

2. Start the test by setting the first workrate to 0.5 KP (150 kg.m/min) and then starting the time clock. Take heart rate reading near the end of the second and third minutes of the first stage. A steady-state heart rate must be achieved before progressing to the next stage. If the difference between the second-minute heart rate and the third-minute heart rate is greater than 5 bpm, the heart rate has not yet reached a steady stage and a fourth minute should be added. It may even take five minutes for the heart rate to stabilize, especially in less conditioned subjects.

3. At the end of the first workrate use the guide above to determine the workrate setting of stage 2. Be conservative in the progression of the workrate in order to avoid driving heart rate too high. There is no need to hurry the test; each workrate (and hence steady state heart rate) is timed independently of others, so be careful to measure and record all data accurately.

4. Repeat the heart-rate monitoring guidelines used in the first stage for subsequent stages. Continue the test until two steady-state heart rates between 110-150 bpm have been recorded for two different stages. End the test by releasing all but 0.5-1.0 kg of resistance on the ergometer, allowing the client time to cool down (the heart rate should drop below 100 before the client stops cycling).

YMCA Submaximal Cycle Ergometer Protocol

Resting
HR ____________ bpm
BP ______________

Pedaling Cadence 50+ ______ rpm

Age: ________________ years

Goal Heart Rate:
110 bpm and ________ bpm (85% age-predicted max HR)

Stage 1 Work Output
____________________ kp*m*min

2-min
HR ______________ bpm
BP ______________
RPE _____________

3-min
HR ______________ bpm
RPE _____________

2-min vs. 3-min HR difference
_________________ bpm
(HRss within 5 bpm)

Continue Stage (if needed)
4-min
HR ______________ bpm

Stage 2 Work Output
____________________ kp*m*min

2-min
HR ______________ bpm
BP ______________
RPE _____________

3-min
HR ______________ bpm
RPE _____________

2-min vs. 3-min HR difference
_________________ bpm
(HRss within 5 bpm)

Continue Stage (if needed)
4-min
HR ______________ bpm

(If test is finished begin recovery measures. Otherwise, skip Recovery and proceed to Stage 3)

Recovery
3-min Active (Pedal no resistance)
HR ________________ bpm
BP ______________

3-min Stationary (seated in chair)
HR ________________ bpm
BP ______________
### YMCA Submaximal Cycle Ergometer Protocol

#### Stage 3 Work Output

<table>
<thead>
<tr>
<th>Work Output</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>kp<em>m</em>min⁻¹</td>
<td></td>
</tr>
</tbody>
</table>

2-min

- HR ___________ bpm
- BP ___________
- RPE ___________

3-min

- HR ___________ bpm
- RPE ___________

**2-min vs. 3-min HR difference**

- bpm
  (HRss within 5 bpm)

**Continue Stage (if needed)**

4-min

- HR ___________ bpm

---

#### Stage 4 Work Output *(If needed)*

<table>
<thead>
<tr>
<th>Work Output</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>kp<em>m</em>min⁻¹</td>
<td></td>
</tr>
</tbody>
</table>

2-min

- HR ___________ bpm
- BP ___________
- RPE ___________

3-min

- HR ___________ bpm
- RPE ___________

**2-min vs. 3-min HR difference**

- bpm
  (HRss within 5 bpm)

**Continue Stage (if needed)**

4-min

- HR ___________ bpm

---

#### Recovery

- 3-min Active *(Pedal no resistance)*
  - HR ___________ bpm
  - BP ___________

- 3-min Stationary *(seated in chair)*
  - HR ___________ bpm
  - BP ___________