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DISTRIBUTION OF HUMAN TONGUE FAT AND OBSTRUCTIVE SLEEP APNEA

by

Kerry Beth Baumann  
Lieutenant Commander, Dental Corps  
United States Navy

A thesis submitted to the Faculty of the  
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in partial fulfillment of the requirements for the degree of  
Master of Science  
in Oral Biology

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Naval Postgraduate Dental School  
Uniformed Services University of the Health Sciences  
Bethesda, Maryland

CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

Kerry Beth Baumann

has been approved by the Examining Committee for the thesis requirement  
for the Master of Science degree in Oral Biology at the June 2020 graduation.

Research Committee:

IMAMURA, GLEN, MASAO, 10882  
88510

Digitally signed by  
IMAMURA, GLEN, MASAO, 1088288510  
Date: 2020.06.10 13:36:00 -0400

Glen M. Imamura, DDS, MS  
Staff, Department of Dental Research  
Research Committee Chair, Naval Post Graduate  
Dental School

JONES, BRADLEY, ELLIOT, 1019  
72344

Digitally signed by  
JONES, BRADLEY, ELLIOT, 101902344  
Date: 2020.06.10 10:20:00 -0400

Bradley E. Jones, DDS, MS  
Chairman and Program Director, Oral and  
Maxillofacial Pathology, Naval Post Graduate  
Dental School

ORESTES, MICHAEL, IAN, 1274366  
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Digitally signed by  
ORESTES, MICHAEL, IAN, 1274366822  
Date: 2020.06.29 08:34:40 -0400

Michael I. Orestes, MD, FACS  
Program Director, Otolaryngology, Walter Reed  
National Military Medical Center

BROOKS, DANIEL, IAN, 1513778  
070

Digitally signed by  
BROOKS, DANIEL, IAN, 1513778070  
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Daniel I Brooks, Ph.D.  
Staff, Department of Research Programs, Walter  
Reed National Military Medical Center



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Digital signature of BAUMANN KERRY BETH 1400407777  
Date: 2020.06.10 08:25:04 -04:00

Kerry Beth Baumann  
Oral and Maxillofacial Pathology Graduate Program  
Naval Postgraduate Dental School  
June 2020

NAVAL POSTGRADUATE DENTAL SCHOOL  
KERRY BETH BAUMANN

2020

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ABSTRACT  
DISTRIBUTION OF HUMAN TONGUE FAT AND OBSTRUCTIVE SLEEP APNEA  
KERRY BETH BAUMANN  
M.S., ORAL AND MAXILLOFACIAL PATHOLOGY, 2020

Introduction: Obstructive Sleep Apnea (OSA) is prevalent in the United States, presents serious health risks and is directly correlated with obesity. Treatment options are limited by patient compliance and risks associated with surgical procedures. Adipose reduction may offer a less invasive treatment modality. Airway obstruction, related to tongue adiposity, represents a more accessible location to reduce adipose as potential treatment for OSA. Objective: This study compiled complete histologic profile of the entire tongue to determine the locations of adipose tissue. Methods: Six cadaver (3 full and 3 partial) tongues were sectioned into anterior, middle and posterior. These were further sectioned into medial and lateral. Finally, these 6 sections were divided (microscopically) into dorsal and ventral to produce 12 distinct regions. The tissues were histologically prepared and examined using light microscopy (2x or 4x magnification) to quantify the percentage and volume (mm<sup>3</sup>) of adipose. Data were analyzed using analysis of variance (ANOVA). Results: This study demonstrated the ventral portion of the tongue had a significantly higher (p<0.001) concentration of adipose tissue compared to the dorsal tongue and in particular within the middle and posterior thirds. Conclusion: The highest concentration of adipose was found in the middle and posterior thirds of the tongue, particularly in the ventral aspect. Knowledge of tongue adipose concentrations could provide crucial information to guide targeted therapies directed at tongue size to relieve airway obstruction in the treatment of OSA in the United States population including Active Duty and Retired Military personnel.

Directed by: GLEN M. IMAMAURA, DDS, MS  
Naval Postgraduate Dental School

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## LIST OF ABBREVIATIONS

Obstructive sleep apnea: OSA  
Apnea-hypopnea index: AHI  
Continuous positive airway pressure: CPAP  
Anterior: A  
Middle: MD  
Posterior: P  
Medial: M  
Lateral: L  
Dorsal: D  
Ventral: V

## CHAPTER I: REVIEW OF THE LITERATURE

### OBSTRUCTIVE SLEEP APNEA

Obstructive sleep apnea (OSA) is the most common form of sleep-related breathing disorders. Sleep disordered breathing encompasses any abnormality of respiration during sleep and includes snoring, OSA, central sleep apnea, hypoventilation disorders, and hypoxemia disorders (Folvary-Schaefer and Water, 2017). It is estimated that up to 18% of the population has OSA, with rates as high as 65% in patients who have experienced a myocardial infarction (Avinscal, 2017). OSA is defined as complete or partial obstruction of the upper airway during sleep. These respiratory events can be classified as either apneic or hypopneic and they result in a disruption of sleep as the patient is aroused to reestablish their airway and continue breathing. Apnea is defined as cessation of airflow despite inspiratory effort lasting at least 10 seconds. Hypopnea is defined as either greater than 50% airflow reduction, less than 50% airflow reduction with hemoglobin desaturation, or less than 50% airflow disruption with evidence of arousal (Mannarino et al., 2012). Common symptoms of OSA include snoring, gasping sounds, waking feeling un-rested, and sleepiness (“Obstructive Sleep Apnea, Active Component, U.S. Armed Forces,” 2009). OSA is a prevalent and costly health issue that may frequently be asymptomatic and therefore go undiagnosed.

Disruption of sleep has significant adverse cognitive and health-related effects. There are recognized associations between OSA and medical conditions including hypertension, diabetes, heart failure, coronary artery disease, stroke and neurocognitive and mood disorders (Mannarino, 2012). OSA increases the risk of morbidity and mortality, with severe untreated OSA related to a 46% increase in mortality over 8 years compared to a non-OSA patient. This increase is due mainly to cardiovascular complications (Avinscal et al., 2017). Cognitive impairment, with

reported difficulties with attention and concentration as well as fine-motor coordination and increased depression are all results of OSA (Mannarino, 2012). In addition to the health concerns, patients with OSA have an increased incidence of motor vehicle accidents (Rogers et al., 2016). Ellen et al. (2006) revealed patients who suffer from sleep apnea are involved in automobile crashes at a rate similar to those with moderate to severe dementia or those who drive while intoxicated, resulting in a crash rate two to three times greater than the general population.

### OSA: PATHOPHYSIOLOGY

The pathophysiology behind sleep disordered breathing is complex. As noted in the name, sleep apnea is caused by obstruction of the airway. Increased size and density of the tissue surrounding the airway can increase the risk of obstruction. Obesity is believed to have both direct and indirect effects on upper airway patency with weight gain resulting in increased tissue mass. This increase can be due to hyperplasia, hypertrophy or direct adipose accumulation (Brennick, 2014). In addition to physiologic obstruction, sleep disordered breathing can be caused by inadequate responsiveness of the upper-airway dilator muscles during sleep (Eckert, et al., 2013). The upper aerodigestive tract lacks skeletal support and remains patent through a balance of internal and external pressure balances (Mannarino, 2013). However, a disruption of this balance, caused by inadequate muscle tone or increased external pressure, can predispose a patient to obstruction. Patients are more prone to airway collapse when sleeping in a supine position. Sleep apnea syndromes can be classified as obstructive or central depending on how patients score on polysomnographic testing. The major difference between obstructive or central sleep apnea is the presence or absence of respiratory effort (Folvary-Schaefer and Water, 2017).

Tongue width and thickness may lead to airway obstruction (Lahav et al., 2009). Given the importance of the tongue and the documented association with weight gain and increase in tongue size (Brennick et al., 2014), it is easy to see how obesity is one of the most significant risk factors in the development of OSA. Studies have shown that a 10% weight gain can lead to a 6-fold increase in the risk of OSA (Mannarino et al., 2012). Studies have shown that patients with OSA have more adipose tissue in the upper airway region than do body mass index matched control patients (Li et al., 2012). In addition, a 2005 study by Weiss et al., demonstrated the prevalence and severity of tongue scalloping, a physical change in the shape of the lateral borders of the tongue due to pressure from the adjacent teeth, has a positive correlation with both increasing Mallampati score and is predictive of sleep pathology in severe patients (Weiss et al., 2005). Obesity is currently a national epidemic in the United States with almost 40% of the adult population falling into the obese category, while another 66% of adults are overweight and headed towards a diagnosis of obesity (Brennick, et al., 2014). The prevalence of OSA has increased significantly over the past decades. Part of this increase may be attributed to increased education and diagnosis of OSA, but a percentage is strongly linked to obesity.

#### OSA: DIAGNOSIS

The gold standard for diagnosing OSA is the polysomnogram or sleep study. This study measures the number of apneic or hypopneic events per hour, giving the apnea-hypopnea index (AHI). A patient is considered to have OSA when they experience 5 or more apneic or hypopneic events per hour of sleep with associated symptoms of daytime sleepiness or fatigue or 15 or more apneic or hypopneic events per hour of sleep regardless of reported symptoms. Daytime symptoms of OSA include morning headache, dry mouth on waking, depression and moodiness, and inability to concentrate. Common nighttime symptoms include snoring, choking,

snorting, gasping and insomnia (Mannarino et al., 2012). The severity of OSA is defined by

Classification	Mild	Moderate	Severe
Apnea-hypopnea events per hour	5-14	15-29	≥30

Table 1. Apnea-hypopnea index (AHI)

the AHI which compares the number of respiratory events to the total hours of sleep during a sleep study. Patients can be classified as mild, moderate or severe on the AHI (Table 1) which can help guide treatment options (Folvary-Schaefer and Water, 2017).

Polysomnography is expensive, inconvenient and uncomfortable for patients (Weiss, et al., 2005). Therefore, prior to prescribing a sleep study for every patient suspected of having OSA, there are subjective markers clinicians can assess to support ordering a sleep study. In addition to obesity, a physical examination should evaluate for tonsillar/adenoid hypertrophy, macroglossia, large neck circumference, and a Mallampati airway classification score (Weiss, et al., 2005).

This classification is based on soft structures which are easily visualized on a patient sitting upright with their mouth open as wide as possible and tongue protruded (Table 2). A strong association has been described between Mallampati grade III or IV and OSA (Avinscal, et al.,

2017). Additionally, the risk of OSA increases with age and appears to be more prevalent in African Americans and men (Mannarino, 2012).

	Structures Visualized
Class I	soft palate, fauces, uvula, pillars
Class II	soft palate, fauces, uvula
Class III	soft palate, base of uvula
Class IV	soft palate not visible at all

Table 2: Modified Mallampati Scores

## OSA: TREATMENT

Proposed treatments for OSA, range from behavioral changes, pharmacotherapeutics, surgical intervention, and devices to assist with maintaining airway patency. Behavioral changes encompass the least invasive method of treating sleep apnea. With the increased prevalence of

obesity; diet and weight loss are first line recommendations for patients suffering from OSA. However, weight loss is not always possible. Patients with a tendency for airway obstruction should avoid narcotics, as well as alcohol and other depressants. Medications used to increase respiratory drive, reduce airway resistance, or increase muscle tone are being investigated but currently lack sufficient evidence to become first line treatment options (Mannarino et al., 2012). Surgical treatment options include maxilla-mandibular advancement osteotomy and uvulopalatopharyngoplasty. However, these procedures come with their own risks and not every patient is a candidate for surgery. Less invasive treatments include vagal nerve stimulus, radiofrequency ablation, cryotherapy, Continuous Positive Airway Pressure (CPAP), and mandibular advancement devices. Cryotherapy is currently being investigated as a less invasive, long term solution for OSA.

CPAP is the treatment modality of choice for many patients. The pressure of the machine assists in keeping the airway open and ensures the patient continues to breathe throughout the night. CPAP is effective in reducing OSA symptoms, cardiovascular health concerns as well as some of the neurocognitive complications (Mannarino, 2013). Despite the success CPAP has shown, compliance with the CPAP machine has been found to be extremely low (Eckert, et al., 2013). Mandibular advancement devices and other oral appliances appear to provide benefits in treating sleep apnea and are better tolerated by patients once properly sized, fitted and adjusted (Mannarino, et al., 2012). Similar to CPAP, mandibular advancement devices must be worn nightly to provide benefit. Although both CPAP and mandibular advancement devices prevent the apneic episodes from occurring, neither address the cause of OSA.

Cryotherapy and cryolipolysis use cooling as a method of selective fat removal. The tissue is rapidly frozen and slowly thawed in repeated cycles (Davila, ML and Hofstetter, WL, 2013).

Adipocytes are more sensitive to cold than other tissue types, by applying cold, the amount of adipose can be reduced with little to no damage to surrounding tissue (Garibyan, et al., 2014). There has been discussion about whether or not the “freezing” causes cell death or simply decreases the cell size. Tatli et al. (2010) believe cryotherapy causes crystallization of cell contents which results in membrane disruption and ultimately cell death. Other studies point to the cold causing thermogenesis, with the observed fat reduction resulting from increased metabolism (Loap, S and Lathe, R, 2018). While the exact mechanism is still under debate, the final result is a reduction in fat with little to no adverse effects. The only reported adverse effects have been mild and well tolerated by patients, including erythema and mild swelling (River, et al., 2018). Cryotherapy is currently being used as a fat loss method for subcutaneous adipose as an alternative to liposuction (Garibyan, et al., 2014).

## TONGUE

The tongue is comprised of a variety of tissue types, including musculature, vessels, nerves, adipose, taste buds and minor salivary glands. It assists with mastication and speech, but also plays an important role in maintaining airway patency (Godoy et al., 2016). Airway obstruction can be caused by many factors, in particular, tongue width and thickness (Lahav et al., 2009). Research has shown that the tongue has a higher percentage of adipose tissue as compared to other muscles and a study by Nashi et al. demonstrated that the fat content and tongue weight increase linearly with increasing body mass index. The posterior displacement of a larger, adipose rich tongue is on mechanism that correlates the link between tongue size and OSA (Nashi et al., 2007). While tongue shape and size are not the only factors contributing to OSA, they are a significant and relatively accessible cofactor in contributing to airway collapse (Godoy et al., 2016). Other contributing factors to the development of OSA include narrow airway,

enlarged parapharyngeal fat pads, adenotonsillary hypertrophy, retrognathia, and displacement of the hyoid bone (Mannarino, et al., 2012).

A 2007 study by Nashi et al. on cadavers showed that while adipose tissue is encountered throughout the tongue, the posterior tongue consistently has more adipose tissue than the anterior tongue; with approximately 30% versus 11% respectively.<sup>5</sup> While this study included histologic examination, it only looked at representative areas on selected patients. The percentages reported were obtained from images of the tongue. The researchers converted the images to grayscale and each pixel was given a value based on shade intensity. A threshold of shade values were determined for adipose and the ImageJ software generated fat percentages based on pixel values in order to determine adipose levels in the anterior, posterior and sublingual regions (Nashi et al., 2007). Conversely, a rat study utilizing magnetic resonance imaging demonstrated significantly more adipose in the anterior versus the posterior tongue. However, the same study noted a homogeneous distribution of adipose tissue throughout the tongue when analyzed qualitatively in representative histological sections (Brennick et al., 2014).

Tongue adiposity has been analyzed using additional techniques. Godoy et al (2016) employed whole-body positron emission tomography/computed tomography to obtain tongue attenuation values to ascertain tongue fat content but did report percentages within the different regions. Magnetic resonance imaging revealed soft tissue and intramuscular fat distribution in subject's tongues. The images were subdivided into retroglossal and retropalatal regions and volumetric analyses performed to quantify the percentage fat. The study revealed more adipose tissue in the retroglossal region of the tongue of apneic patients (Kim et al., 2014). An additional study on cadavers looked at tongues grossly and histologically but only at representative areas of the

tongue. Histologically, it was determined that the anterior tongue (31.47%) had a higher percentage of adipose tissue than the medial (5.07%) and posterior (8.47%) tongue (Miller et al., 2002).

A number of studies have visually evaluated tongue size in relation to OSA but did not focus on the different anatomic regions of the tongue (Lahav et al., 2009; Turnbull et al., 2017; Do et al., 2000; Liegeois et al., 2010). Computed tomography examination is a method used to establish tongue adiposity in living patients. A study by Butler et al. (2012) used this method, but only analyzed a 1.0 cm section of the tongue.

The different methods of analyzing adipose tissue combined with the limited areas of the tongues examined has resulted in inadequate and often conflicting data regarding location and quantification of adipose tissue in the tongue. Therefore, the goal of this study is to compile a complete and thorough histologic examination of the entire tongue to determine location and percentages of adipose tissue. We believe this information can be used to guide treatment aimed at reducing tongue fat as a minimally invasive and simple treatment for select patients with OSA.

## CHAPTER II: MATERIALS AND METHODS

This study was reviewed and approved by the Uniformed Services University of the Health Sciences (USUHS), Bethesda, MD, Anatomical Material Review Committee and funded through TTW, under an USUHS grant.

Tongues were obtained from six cadavers and removed through a standard transcervical approach. The sample consisted of three whole tongues (labelled 1-3) and three half tongues (labelled 4-6) that were previously hemisected, anterior to posterior, at the midline (Figure 1a.). All specimens were measured in three dimensions (cm) and submitted in their entirety for histologic preparation. Figure 1b. and 1c. diagrammatically regionalize a whole tongue into anterior (A), middle (MD) and posterior (P) segments. These segments were further divided into one medial (M) and two lateral (L) segments (left and right lateral segment data in whole tongues were pooled and reported as L) resulting in 6 segments; AM, AL, MDM,

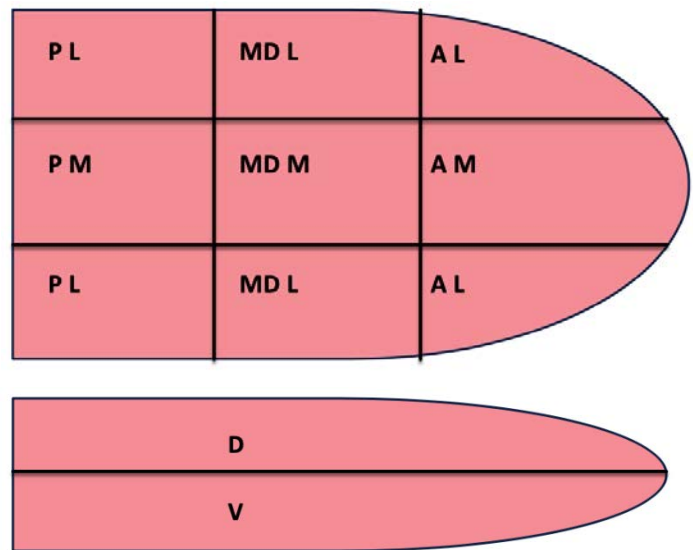


Figure 1a: Ventral surface of a whole tongue with visible adipose. Figure 1b: Diagram of a dorsal surface regionalization scheme into six segments: anterior medial (AM), anterior lateral (AL), middle medial (MDM), middle lateral (ML), posterior medial (PM) and posterior lateral (PM). Figure 1c: Diagram of Figure 1b rotated to reveal a lateral surface demonstrating further delineation into dorsal (D) and ventral (V) segments performed in microscopic field. This creates 12 distinct regions for evaluation.

MDL, PM, and PL. Each segment could be further delineated into dorsal (D) and ventral (V), performed during microscopic evaluation, producing 12 distinct regions (DAM, VAM, DAL, VAL, etc.) for evaluation. Data from hemisected tongues were similarly divided into 12 regions. This allowed for complete histologic evaluation of each of the six specimens.

The tongues were preserved and fixed in 10% buffered formalin. During preparation, surfaces were inked as follows; dorsal black, ventral red, lateral yellow. To differentiate hemisected specimens from whole tongues, the cut medial surface was inked in green (Figure 2. top).

Varying anterior to posterior lengths required cross sectioning of tongues between 14-20 times to properly fix and fit into cassettes (Figure 2. bottom). Therefore, the number of cross-sections, divided by 3, allowed for differentiating cross sections into A, MD, and P regions. Each tissue section underwent

histologic tissue processing. Paraffin embedded sections were serial cross sectioned (10um)

using a cryostat microtome (-20°C). The cross sections were mounted on glass slides and stained with hematoxylin and eosin. Variations in embedding, microtome sectioning, and histologic staining were controlled to the greatest extent possible by using a single experienced histologist to prepare the entire data set. A total of 200 slides were prepared.

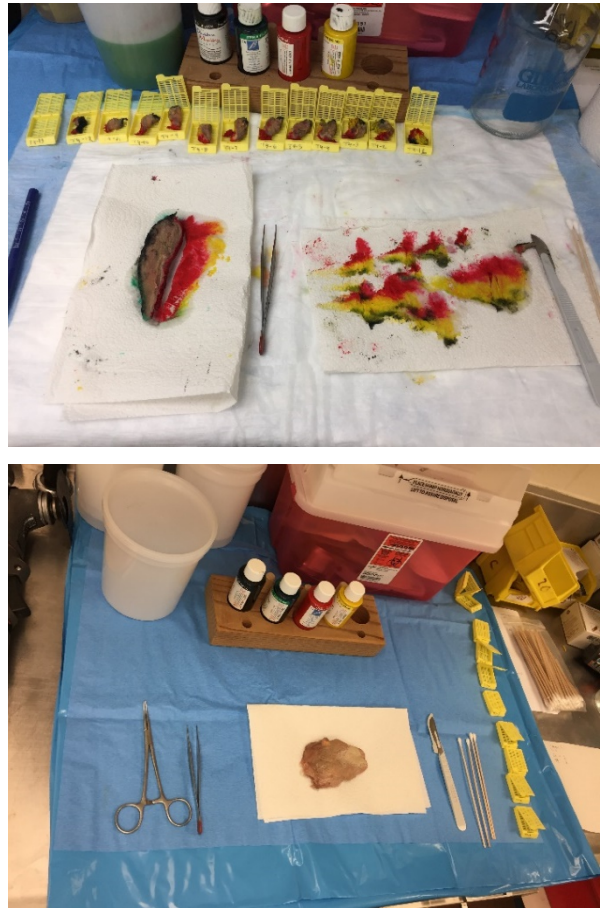


Figure 2: Top: The lab set up as the specimens were prepared. Bottom: The sections of tongue being prepared for processing.

An experienced, board certified Oral Pathologist and Oral Pathology resident independently examined each slide and determined an adipose percentage using a Nikon Eclipse E400 at either 2X or 4X depending on specimen size (Figure 3). The two observations were used to calculate an average adipose percentage for each slide. All data were recorded onto a Microsoft Excel spreadsheet and analyzed using analysis of variance (ANOVA). Average percentages of adipose tissue identified in each section were used to establish if adipose in the tongue was location dependent. To identify if these trends were statistically reliable, a fully interacted mixed effects model with fixed effects of M-L, A-MD-P and D-V and random effects of tongue was included for each effect. Because the number of tongues was somewhat low for a pooled analysis, similar analyses were run for each tongue individually. Because the sections across which adipose percentages were calculated were non-uniform in size, the total volume of adipose in each section was calculated by estimating the dimensions of a rectangular cuboid and multiplying that volume by the percentage of adipose tissue in the section. The tissue specimens on the slide were each measured in two dimensions (mm) at the greatest dimension of the slide, with the third dimension calculated by taking the length of the tongue and dividing it by the number of cassettes (14-20 depending on tongue length).

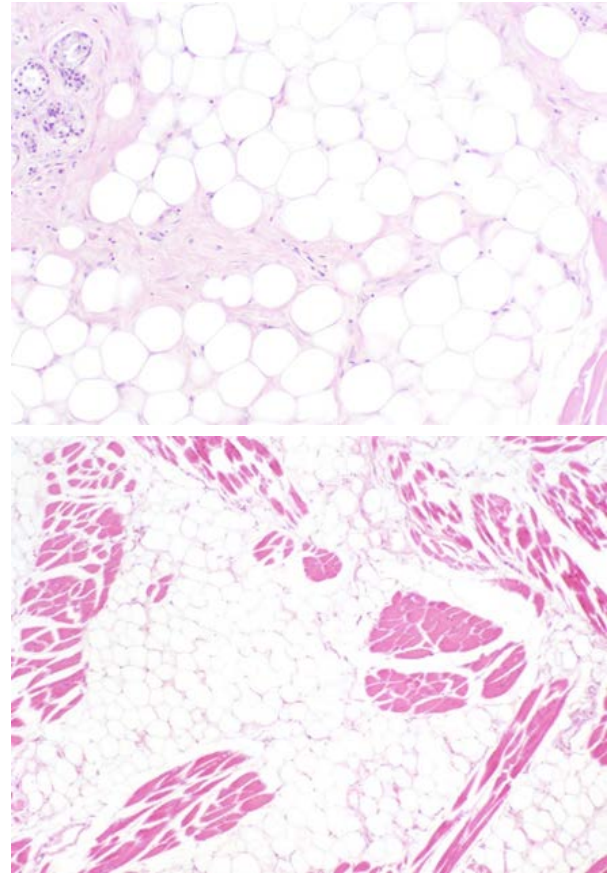


Figure 3: Top: 100X view of adipocytes. Bottom: 40X view of adipose cells and muscle.

### CHAPTER III: RESULTS

The dimensions for all tongue specimens are listed in Table 3, demonstrating the varying lengths and widths. The tongues ranged in size

	Tongue 1	Tongue 2	Tongue 3	Tongue 4 (partial)	Tongue 5 (partial)	Tongue 6 (partial)
Posterior to Anterior Length (cm)	9.0	10.0	10.0	10.0	9.5	10.8
Width (cm)	6	7.3	6.8	3.4	3	5
Dorsal to Ventral Length (cm)	2.6	2.5	2.5	2.5	3.0	2.9
Number of Slides	30	42	37	27	28	36

from 9 x 6 cm to 10 x 7.3

Table 3: Tongue measurements

cm necessitating a volumetric analysis as well as analyzing fat percentages. Table 4 lists the average fat percentages for each region of the tongue, as well as the upper and lower confidence intervals. The clearest difference between the adipose percentages is found between D-V. These individual tongue analyses revealed a consistent pattern of a larger percentage of ventral

	Average Fat %	95% CI Lower	95% CI Upper
<b>Dorsal</b>	25.5	24.3	26.8
<b>Ventral</b>	38.8	37.6	40.1
<b>Anterior</b>	29.5	27.4	31.5
<b>Middle</b>	33.7	32.3	35.2
<b>Posterior</b>	32.9	31.2	34.6
<b>Medial</b>	32.1	30.7	33.6
<b>Lateral</b>	32.3	31	33.7

Table 4: Average adipose percentages for regions of the tongue with upper and lower confidence intervals.

adipose (significant in six out of six models), whereas the difference between A-MD-P was more variable (significant in only three out of six models).

An analysis of tongue volume rather than percentage showed similar results. A pooled analysis of all tongues revealed significant differences in fat volume for the D-V and A-MD-P regions with p values of 0.01 and 0.001 respectively. The mean adipose volumes and upper and lower confidence intervals for each region of the tongue are found

	Mean Volume	95% CI Lower	95% CI Upper
Dorsal	603.4	565.6	641.2
Ventral	945.7	900.8	990.6
Anterior	505.6	461.5	549.7
Middle	887.9	841.0	934.8
Posterior	869.1	811.6	926.6
Medial	731.0	687.1	774.9
Lateral	809.9	765.8	854.1

Table 5: Mean adipose volume for regions of the tongue with upper and lower confidence intervals. .

in table 5 demonstrating the increased adipose volume in the ventral half and middle and

Comparison	Tongue					
	1	2	3	4	5	6
D versus V	<.0001	0.0002	<.0001	<.0001	0.0009	<.0001
A versus MD versus P	<.0001	<.0001	0.0002	0.0004	0.016	<.0001
M versus L	0.937	0.88	0.001	<.0001	0.0002	<.0001
D versus V:A versus MD versus P	0.047	0.912	0.759	0.643	0.048	0.038
D versus V:M versus L	0.937	0.718	0.084	0.005	0.256	0.082
A versus MD versus P:M versus L	0.926	0.935	0.637	0.135	0.526	0.099
D versus V:A versus MD versus P:M versus L	0.834	0.408	0.278	0.065	0.792	0.224

Table 6: P-values for individual tongue fat relationships.

posterior thirds. The individual tongue fat volume relationships are found in the Table 6 with statistically significant p-values highlighted. The data reveals a clear pattern in both the D-V axis as well as the A-MD-P axis. Both the D-V (p=0.001) and A-MD-P (p<0.016) are statistically reliable when analyzed with the same fully interacted mixed effects model as above. Some models showed M-L effects, although for three tongues the effect was in one direction

(significantly more lateral adipose), for one tongue the effect was in the opposite direction (significantly more medial adipose) and for two tongues there was no difference between the amounts of adipose tissue in the M-L axis. The M-L analysis can more easily be observed in Figure 4, which demonstrates a graphic representation of the tongue volumes for each individual tongue across each region. Again, the predominance of tongue adipose volume is seen in the middle, posterior and ventral surfaces.

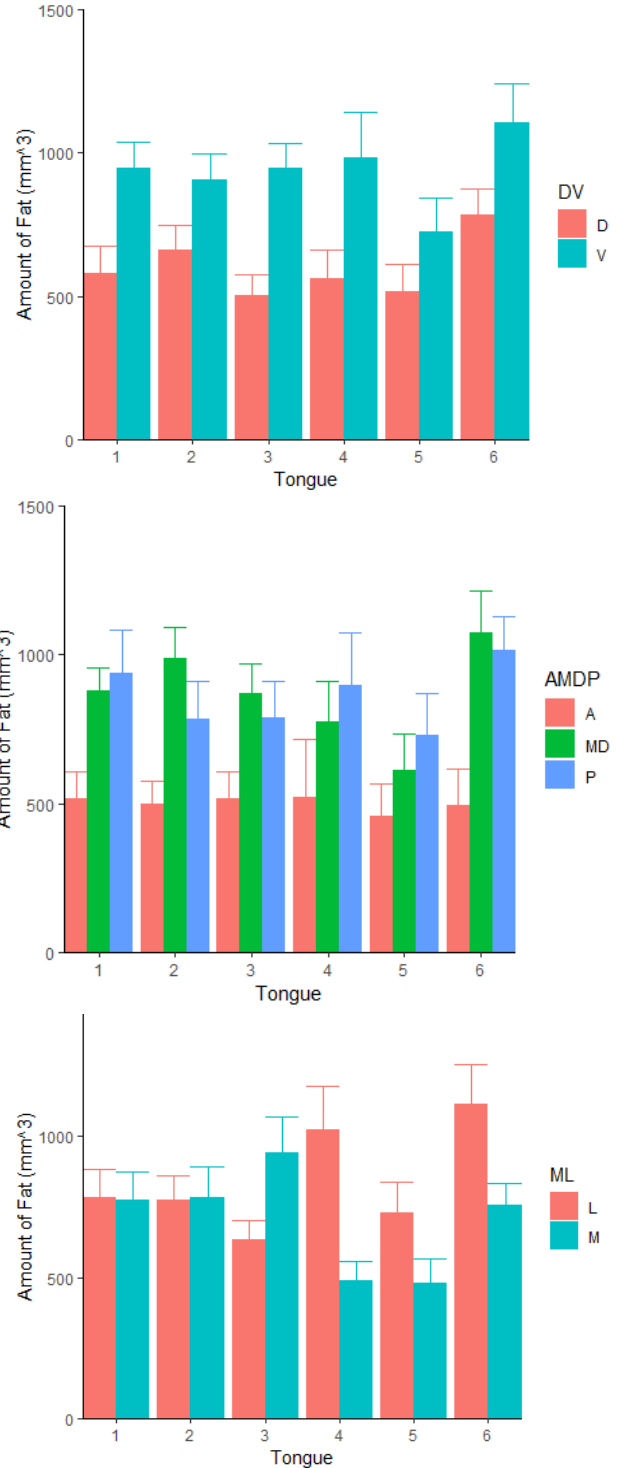


Figure 4: Note the consistently higher percentage of adipose on the ventral versus dorsal surface and increasing adipose volume in anterior to posterior direction. Surface abbreviations are as follows: D: Dorsal; V: Ventral; A: Anterior; MD: Middle; P: Posterior; L: Lateral; M: Medial.

## CHAPTER IV: DISCUSSION

Previous studies of tongue fat distribution utilized a variety of different techniques to quantitatively or qualitatively measure tongue size and adipose tissue. These studies have reported conflicting results as to amount and location of adipose tissue. Whether this is due to differing techniques or sampling locations is unclear. This study is the first to offer a complete and thorough histologic examination of the adipose tissue in entire tongues. To the best of our knowledge, there has not been a comprehensive examination of adipocyte distribution and quantification, with histologic analysis of multiple tongues in their entirety. In creating a slide for each tongue slice with individual measurements and microscopic analysis, we were able to gain a clear understanding of the composition and distribution of adipose tissue within the tongue, including percentage and volume. With levels of obesity and incidence of OSA increasing, this study offers a preliminary look at where to focus adipose reduction. This study has determined that the V, M and P aspects of the tongue are the areas with the largest amount of adipose tissue, and hence the best place to focus on fat reduction.

Finding new treatment modalities for OSA is important for the health and well-being of not just the American public, but in particular, the Active Duty Military population. Active Duty military members are sent throughout the world to work in hazardous conditions, requiring a high level of vigilance and the ability to make rapid life or death decisions. Anything that hampers the ability of a military member to make decisions or puts them or their crew at risk, is a threat to national security. Military members deal with irregular schedules, short periods of time set aside to sleep, and numerous interruptions in sleep. It has been recommended that at least 4.5 hours of sleep is the minimum time required to still be able to function in a deployed environment (Peterson, et al., 2008). It is not hard to see how a deployed service member with limited time to sleep can

greatly suffer from any condition causing repeated bouts of wakefulness. OSA hinders a person's ability to perform tasks associated with executive functioning; diminishing the ability to organize thoughts and successfully solve problems (Mannarino et al., 2012). This level of impairment can be extremely detrimental in a setting of war or conflict. In addition, many military members avoid seeking treatment due to the fear of documented OSA having a negative impact on their career and deployable status.

OSA, in addition to causing daytime drowsiness, decreased response times, and inability to concentrate, is also associated with a variety of other health problems and conditions. OSA has been found to be more prevalent in people with PTSD and mental health disorders (Mysliwiec et al., 2015). Cardiovascular disease also appears to be more prevalent in people who suffer from OSA, however, whether that is due to the OSA or the obesity that is associated with OSA, is unknown (Rogers, et al., 2016). Patients who suffer from OSA, in addition to complaints of daytime sleepiness and fatigue, also experience difficulty in attention and concentration as well as fine-motor coordination and increased levels of depression (Mannarino et al., 2012).

In addition to the concerns regarding the health and safety of Active Duty military members who suffer from OSA, it is also a problem with the retired military population. OSA is compensable by the Veterans Administration and patients prescribed the CPAP machine, can receive up to 50% disability costing the VA upwards of \$1.2 billion a year (Philpott, 2013; Rogers et al., 2016). Novel and less-invasive treatment options for OSA could help alleviate some of the high medical costs of the retired military population.

## CHAPTER V: CONCLUSION

Our research has demonstrated that the regions with the highest percentage of fat are the ventral, middle and posterior surfaces. Due to the higher percentage of adipose tissue in these areas, these would be the most beneficial places to target utilizing future treatment modalities specifically targeted at fat removal. Although this study had a limited sample size, the results were statistically significant. Future studies to determine if increases in adipose tissue correlates with increased incidence of OSA and development of novel technology to target selective removal of adipose tissue are needed for implementation.

Cryotherapy is a non-invasive, well-tolerated procedure that can reduce adipose.

Specifically in the tongue, This research has shown the region with the highest percentage of fat are the ventral, middle and posterior surfaces. Due to the higher percentage of adipose cells in these areas, these would be the most beneficial places to apply treatment modalities, such as cryotherapy, that aims are reducing fat levels.

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