BEMIDJI STATE UNIVERSITY

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Mallampati Scoring and Its Relation to Obstructive Sleep Apnea

Biology

April 27, 2017

HONORS PROGRAM

Bemidji State University

Honors Program

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Abstract: According to the American Sleep Apnea Association potentially 80% of moderate to severe cases of Obstructive Sleep Apnea (OSA) go undiagnosed with even optimistic estimates stating that at least 22 million Americans are afflicted by the disorder.[9] These numbers are expected to continue to increase due to the rising rates of obesity in America.[30] As a result, reliable criteria that can help physicians accurately predict the presence of an underlying sleep disorder, whose symptoms are masked during the day, is highly sought after. The objective of this research is to begin defining these criteria via a literature review of articles that evaluate the correlation of the Mallampati Scoring System (MSS), a frequently cited tool with promise in predicting OSA, with other factors that have been established as predictors of OSA. These factors of interest include Body Mass Index (BMI), neck circumference (NC), and the Apnea-hypopnea Index.

Introduction:

The MSS is a common non-invasive pre-surgical examination performed to estimate difficulty of intubation. Insertion of cameras or supportive breathing devices into the nose and oropharynx is frequently a necessity in emergency medicine in order to compensate for diseases that target the functionality of respiration or the digestive tract, as a result mallampati scoring (MS) is used to help tailor anesthesia or pain-killer to each patient during surgery to avoid potential complications. An MS is calculated while a patient is awake and begins by the patient sticking out their tongue and the physician subsequently estimating how much the tongue obstructs certain soft tissues within the throat, including the uvula, the faucial pillars, and soft palate. Scores can range from 1-4, with 1 being the least severe and having full visualization of the base of the uvula, and 4 being the most severe, with only the hard palate visible. This score can be obtained in less than 15 seconds by a physician with no tools or prior preparation.[4]

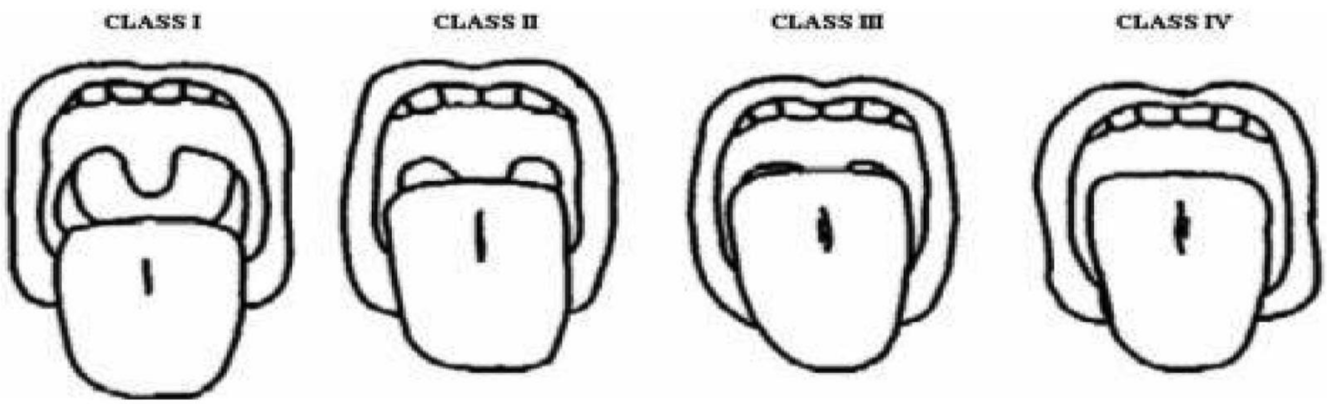

Figure 1 Above depicts the four possible classes a Mallampati Score organizes patients into. Class 1 is the least severe with clear visualization of the uvula above the tongue while Class 4 is the most severe with its complete obscurement.[6] The higher the MS, the more difficult the intubation.

Outside of MS's typical usage in surgical settings, general care practitioners are often unaware of the fact that it has potential in assisting in the diagnosis of Obstructive Sleep Apnea (OSA) patients.[3, 7]

Failure to recognize OSA arises due to difficulty of identifying symptoms in sleep breathing disorders when the patient is conscious in combination with the patient themselves often being unaware of those symptoms in the first place.

Before delving into MSS and its potential significance in helping recognize OSA, familiarity with the sleep cycle is necessary to understand the pathology of sleep breathing disorders. Below is a depiction of the sleep cycle and the length of each stage exhibited by **Figure 2** below:

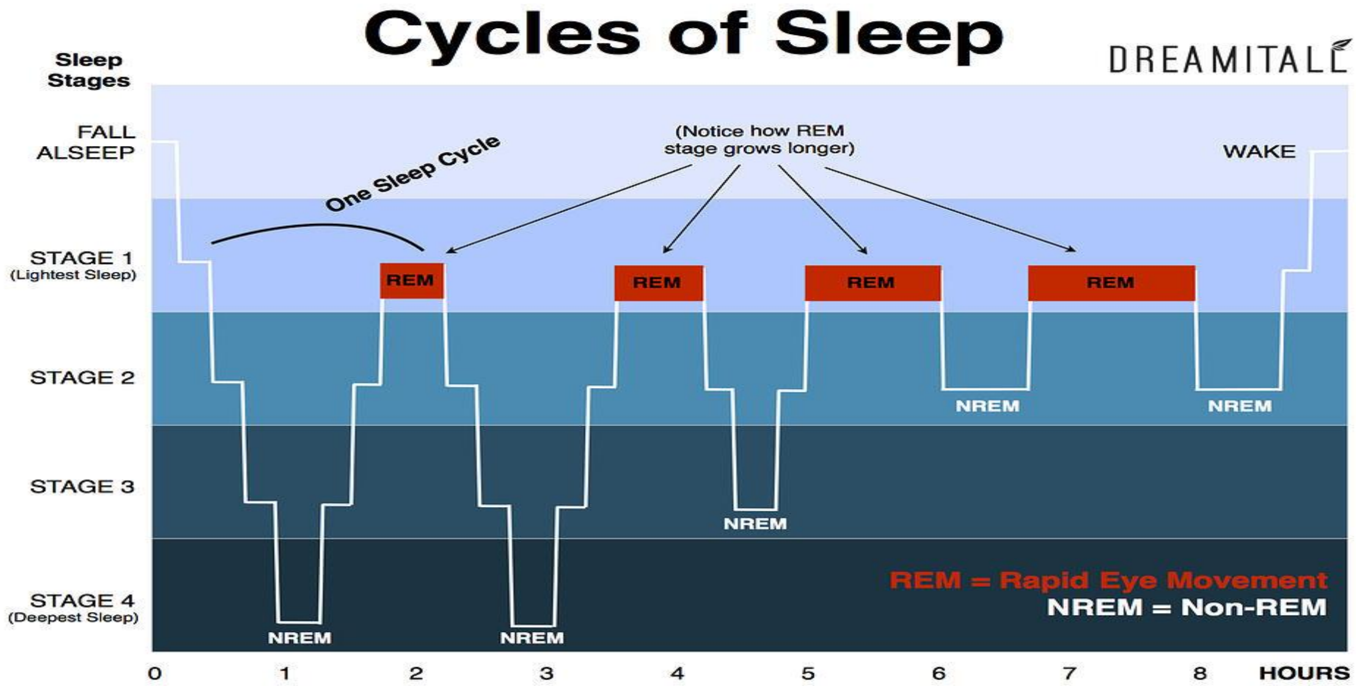

Figure 2 Illustrates the stages of the sleep cycle with the X-axis detailing time elapsed in the course of a night and the Y-axis showing the 5 stages of sleep and how easily awoken we are from these stages.[17]

The sleep cycle is divided into 5 stages, each stage characterized by brain waves and muscle movement that are monitored in a polysomnography (an overnight sleep study) via electrodes connected to the brain and many muscles of the body. Sleep begins at stage 1 and will steadily progress to REM over the course of roughly 90 minutes. After the completion of the REM stage the body reverses the process, lapsing back into stages 4, 3, 2, and finally 1, which accounts for a whole sleep cycle lasting around 3 hours as illustrated in **Figure 1** above. Only the first 5 minutes of sleep is spent in the first stage, which represents the gap between wakefulness and falling asleep. During stage 1 brain waves slow to produce theta waves in which awareness of ones' surroundings is lost but one remains easily awakened.[13] Stage 2 lasts 10 to 25 minutes and accounts for approximately 50% of our nightly sleep. It is characterized by spindle waves representing bursts of mental activity occurring between large, slow waves during which heart rate and breathing slow.[13] Stages 3 and 4 are the beginning of "deep sleep" where large and slow brain waves, termed delta waves, are present. During these stages the brain releases growth hormone to stimulate muscle repair and tissue growth.[13,16] Children and young adults spend about 20% of rest in this deep sleep, however as we age less and less of that time constitutes deep sleep until by age 60 it is only 10%.[13,16] Finally once REM begins the brain becomes highly active while the body, aside from the eyes, is largely paralyzed. It is hypothesized in REM that the brain not only eliminates unnecessary information, but commits to memory information accumulated throughout the day.[13] Each subsequent REM stage overnight will last longer than the previous and constitutes about 25% of sleep in young adults and remains relatively unchanged as we age.[13] Deprivation of this stage of sleep heavily impacts cognitive function and is shown to consist of a larger proportion of an individual's sleep cycle if they have a sleep deficit as well as lapsing into it more quickly.

This understanding of the sleep cycle lays the groundwork for understanding the pathophysiology of OSA. As an individual predisposed toward OSA lapses into the deep stages of sleep, their anatomically constricted airway, usually due to an enlarged tongue or shortened jaw, can ultimately lead to partial obstruction of the airway and a phenomenon, known as snoring arises as demonstrated by **Figure 3** below:

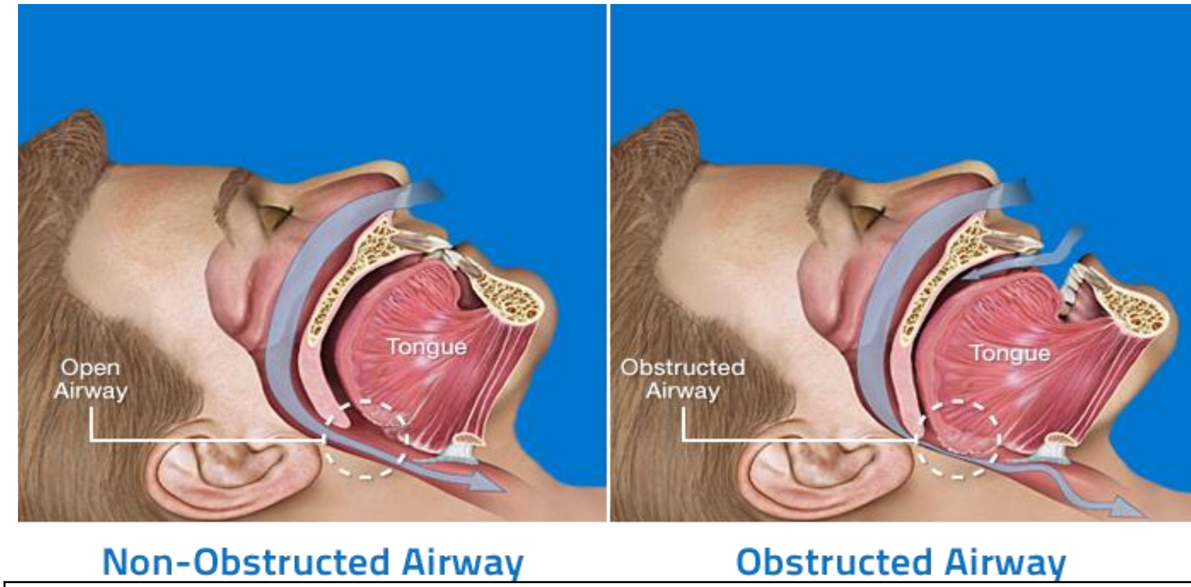

Figure 3: Demonstrates the obstruction of the airway via the tongue and how gravity can exacerbate it if we sleep on our backs.[24] It is important to recognize that a predisposition toward OSA is as much an anatomical predisposition as it is due unhealthy lifestyle.

Over time the continuous vibrations caused by snoring can lead to desensitization of the soft tissues to neuronal signaling around the pharynx, making them more resistant to stimulation, which ultimately leads to concerns such as inadequate dilation of the pharynx and a total obstruction of the airway (cessation of breathing) for a minimum of 10 seconds. This is referred to as an apnea, and mild OSA is diagnosed in individuals with a minimum of 5 apneas over the course of an hour alongside a symptom such as day time sleepiness or snoring.[15] The Apnea-Hypopnea Index or AHI is a measurement of these apneas that take course over an hour. Severity of an individual's OSA is naturally correlated to their AHI calculated during a polysomnography and provides the basis of OSA diagnosis. When unhealthy weight gain occurs in tandem with a family history of OSA, (indicative of the presence of predisposing anatomical features including a shortened neck, enlarged tongue, and retrognathia) OSA is more likely to result.

As BMI increases in an individual the proportion of fat in an individual's tongue near the oropharynx rises ultimately leading to greater likelihood of constriction of the pharynx.[25] **Figure 4** shown below will help put this into perspective:

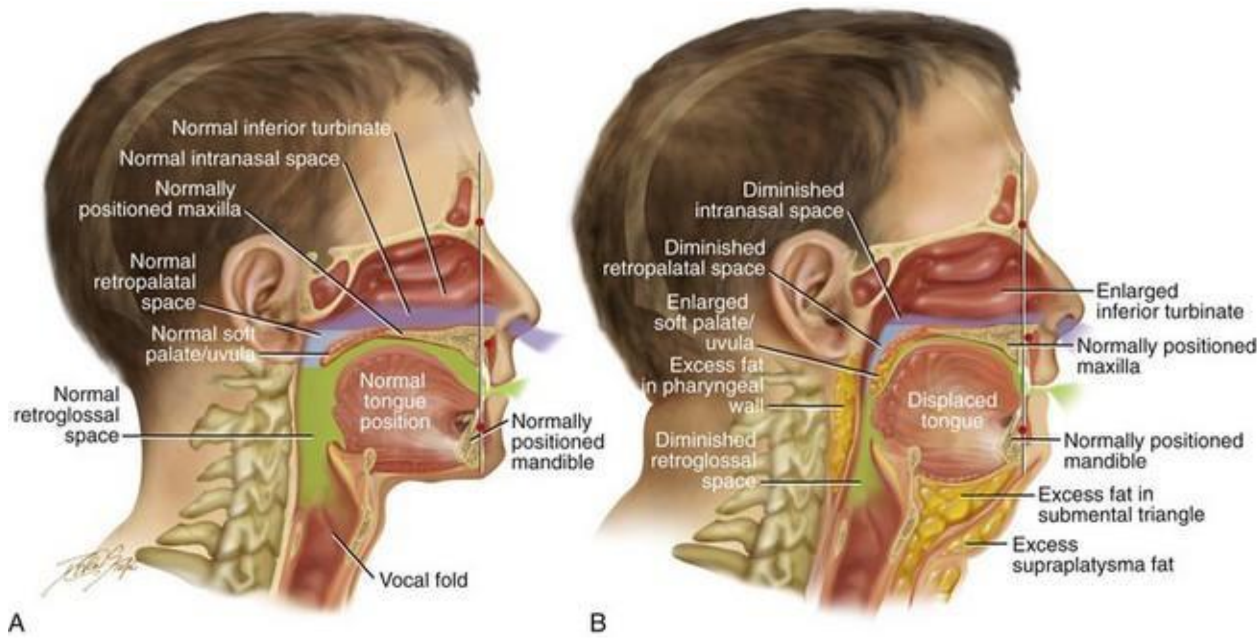

Figure 4: Shows the physiologic changes that occur around the throat due to increasing BMI and neck circumference, both of which are frequently cited predictors of OSA.[26]

Respiratory disorders such as OSA are generally far more common in men than women in part due to how weight gain is exhibited differently between the genders.[20] As men gain weight, extra adipose tissue is synthesized around the neck and abdominal region, whereas in women, extra weight is directed toward the lower extremities and buttocks.[19] This gain in weight around the neck region becomes a problem for males because two bulbs of fat surrounding the pharynx known as the pharyngeal fat pads will expand in size and as a result constrict the pharynx. Furthermore, the weight gain on the abdomen necessitates extra force needed in order for the diaphragm to expand during respiration and the pharynx to dilate.[19]

In the event of an apnea, the need for oxygen rises due to the presence of an obstruction and burst of cortisol is released awakening the patient and allowing for inhalation but at the cost of being deprived of REM sleep continuously throughout the night.[14] As an individual becomes sleep deprived, stress hormones begin to rise in the blood stream these people will become chronically fatigued, leading to a sedentary lifestyle and a greater likelihood of secondary cardiovascular disorders and a chronic rise blood pressure.[1] Due to OSA patient's unawareness of their symptoms they oftentimes acclimate to their chronic fatigue and live their lives half-functional both cognitively and physically. As a result, those individuals with severe OSA may find that resting on their side rather than in a supine position can help alleviate their symptoms as gravity no longer acts to push the tongue onto the back of the pharynx.

Though the symptoms may not be obvious, OSA negatively impacts the patient in a multitude of ways including chronic day time sleepiness, heightened probability for depression, and a great number of cardiovascular maladies such as chronic high blood pressure or coronary artery disease may arise.[8] In addition, OSA patients are also far more likely to be involved in car crashes or be unemployed for falling asleep on the job.

Treatment of OSA is dependent on the severity of it with the most severe cases being treated via continuous positive airway pressure (CPAP), a ventilator mask worn throughout the night. Less severe cases are typically treated either through oral appliances, weight loss, or sleeping on one's side. Although weight loss has been shown to be the most effective treatment against respiratory disturbances, chronic OSA and the subsequent deprivation of REM leads to physiologic changes in the body preventing it from benefitting from exercise as healthy individuals would due to lack of energy. With a working understanding of OSA and MSS, let's have a look at the methods employed in this study.

OSA is conclusively diagnosed with a polysomnography, an overnight study at a sleep clinic where an individuals' breathing and sleep cycle are closely monitored. Due to the procedure being inconvenient and time consuming an easily administered and noninvasive procedure is highly sought after as shown by a statement from Gonzales: "A single instrument that accounts for excessive daytime sleepiness, as identified by the Epworth Sleepiness Scale, snoring and high-risk characteristics, as recognized by the Berlin Sleep Questionnaire, and anatomical features of the oropharynx, as delineated by the MSS, does not yet exist."[4] MS and its association with factors that are correlated with a heightened predisposition toward OSA and its relative severity could play an important role in bridging the gap between patient and physician understanding of an undiagnosed sleep disorder as well as establish OSA status early on. In other words, should these factors be reviewed in conjunction with a MS during a physical examination, it could help the physician gauge whether follow up at a sleep clinic is appropriate for the patient. This is the biggest obstacle to be overcome in order to curtail the degree of undiagnosed OSA cases. Examples of these factors that are kept under careful scrutiny for all patients with OSA include Body Mass Index (BMI)[5], NC[28], and AHI.[9] This study is intended to begin defining criteria that are commonly demonstrated in patients with OSA so guidelines can be created to reliably and accurately predict underlying OSA disorders.

Methods:

Limited data can be found in the MSS correlation with these factors that are linked to severity and degree of predisposition a patient might have toward OSA. One such study by Johns that does investigate the usefulness of MS came to this conclusion: "Mallampati Scoring System (MSS) instruments have independently demonstrated clinical usefulness in identifying symptomology associated with high probability OSA."[19] As data such as this continues to accumulate about MS and its associations with OSA additional investigation becomes more warranted, clarifying how MS, if not as an independent predictor of MS, could be used as a predictor alongside other OSA predictors.

In order to establish these predictors as potential criteria in identifying OSA, a literature review of articles addressing the association between MS to factors that are predictive of OSA as well as to OSA itself were investigated. Factors that have shown promise include AHI, Body-Mass Index, and/or neck circumference. MS and its association with AHI showcases how with increasing MS, increasing severity of OSA is likely. Neck circumference and BMI correlations to MS begin to define how MS, NC, and BMI constitute predictive diagnostic criteria to gauge likelihood of underlying OSA. Each P value isolated in a minimum 95% confidence interval that establishes or does not establish a relation between MSS and these factors will be mentioned. Should an adequate number of studies isolate a positive correlation between the MSS and OSA predictors then this data would provide incentive to further investigate MS via its temporary incorporation into a patient's medical history to formally define criteria by which to reliably predict OSA without the use of questionnaires such as the Epworth Sleepiness Scale or Berlin Questionnaires.

Results:

The Liistro study conducted a complete physical examination on 220 patients and compiled measurements of MS, NC, height, weight, and AHI. Their findings indicate that MS in patients with nasal obstruction, a common occurrence among OSA patients, were correlated with AHI, Body Mass Index, NC.[5] Those patients with an MS of 3 or 4 were 1.95 times more likely to be at risk for OSA and those with nasal obstruction were 2.45 times more likely. However no reliable correlation was established between MS and OSAS in patients that did not possess a nasal obstruction as demonstrated by **Figure 5**:

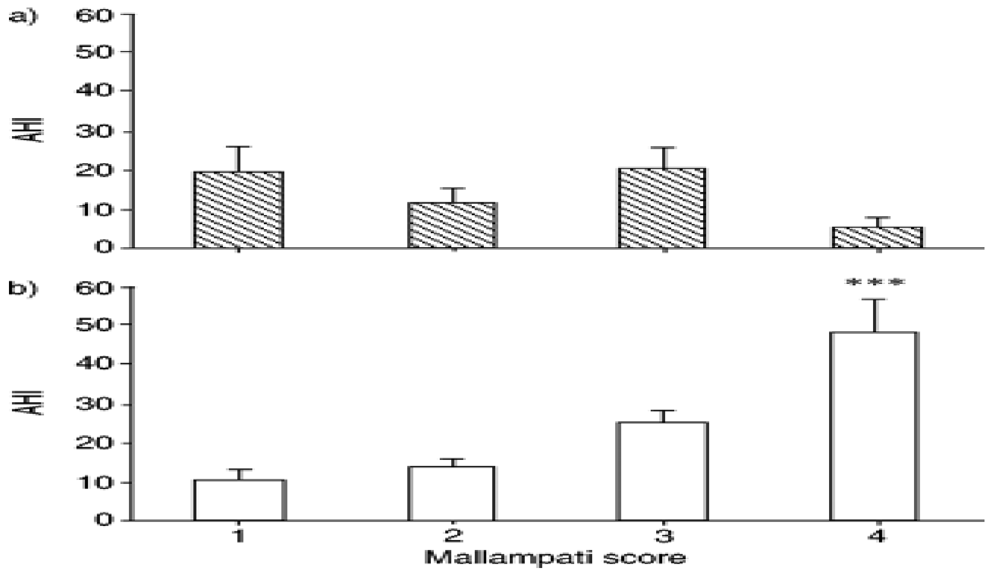

Figure 5: Demonstrates the Liistro studies correlation between MS and AHI. The top graph (a) is the population of patients without nasal obstruction while (b) below is the population of patients with nasal obstruction.[5]

The group with OSA had, on average, 4.6 kg x m^2 BMI, 3.1 cm NC, and 34.2 AHI greater than the group without.[5] Ultimately, they found; “simple and rapid elements such as the determination of MS and the estimation of nasal permeability are useful for the clinical examination of the patients suspected of obstructive sleep apnea syndrome.”[5] This study is useful to demonstrate that as BMI, NC, and AHI rise, one would expect an individual’s predisposition for OSA may rise.

Gonzalez conducted a study on 70 obese and 61 non-obese patients. He and colleagues hypothesized that a history of OSA, high MS, increased age, male gender, short neck, and abnormal upper teeth were all predictors of difficulty of intubation. Their findings showed that BMI, NC, and MS among their investigated factors were determined to be correlated, with statistical significance ($p<.05$), to difficulty of intubation (MS). NC showed as odds ratio of 1.373 and $p=0.0012$ while BMI was shown to have an odds ratio of 1.066 with $p=0.0497$ by comparison to MS. Although the odds ratio of BMI was not strongly positive and OSA in the study was evaluated only clinically and not via a polysomnography, this study establishes an association of MS, NC and to a small degree, BMI, with difficulty of intubation, a variable closely linked to severity of OSA.[28]

A study conducted by Hiremath found that; “difficult tracheal intubation (measured via MS) was associated strongly with OSA.”[12] They investigated 15 patients and separated their population into two groups based on their AHI. Among the 8 patients with OSA (AHI >10), they found on average that MS was 1.1 points greater and NC was 2.7 cm greater, with $P<0.01$, and $P<0.05$ respectively. Showing, much like the Liistro study, a positive correlation between MS, AHI, and NC, with an exception to BMI, which was similar among the two populations.[12]

Ahn and colleagues isolated a correlation between MS and AHI shown by their calculation of a spearman coefficient (R_s); R_s=.295 with a p=0.018. Furthermore a "strong positive correlation" between BMI and AHI was isolated with an R_s=.474 and p<0.001. Correlations between MS and NC were not evaluated in the study.[21] Among their conclusions was that "tongue volume is correlated with obesity, and OSA patients with higher BMI are likely to have greater tongue volume."[21] This study is relevant in that it establishes a correlation between MS, OSA, and BMI. However when comparing the two populations of OSA patients with non-OSA patients, MS was found to increase by only .3 points and concluded it was not statistically signficant, possibly owing to the fact that the intent of the study was not to establish a correlation between MS and OSA, but tongue volume and OSA.

In the Kumar investigation, 158 patients were evaluated, of which 90 had OSA and all were tested for AHI, MS, and tonsillar size.[22] They stated among their significant findings that "for every point increase in MS, the odds ratio of having OSA increased 6.75-fold, p<0.01." Neither NC nor BMI were investigated in the study. They found, "a significant correlation was found between MS, tonsillar size, and AHI." The study not only established MS as an independent predictor, but also showed a relationship between MS and AHI. A sample of their data demonstrating this association can be seen below in **Figure 6:**

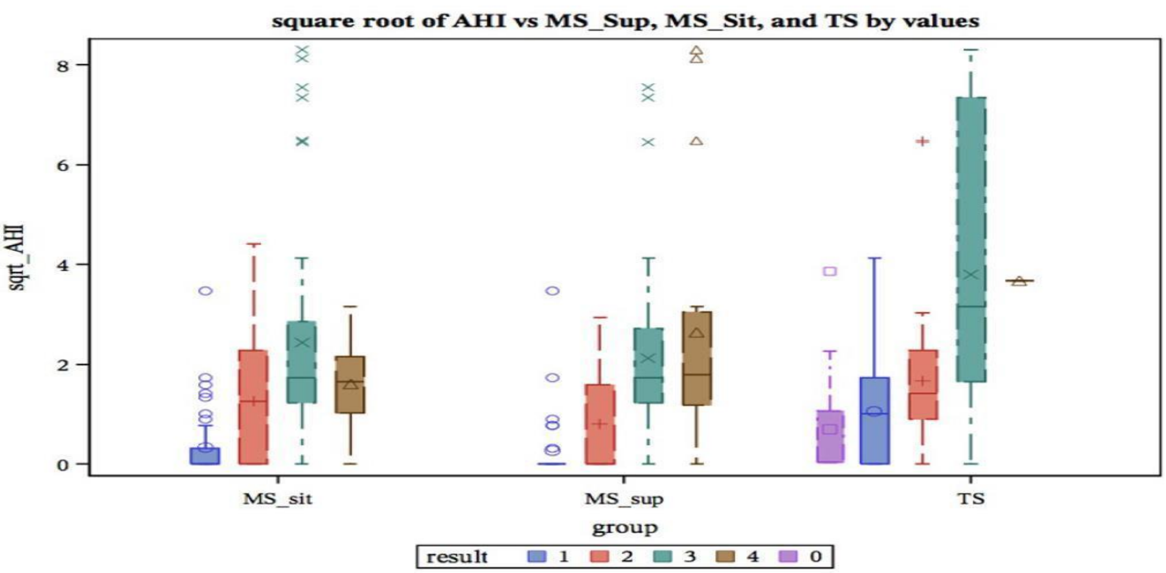

Figure 6: Shown are the results of the Kumar experiment wherein they measured (from left to right on the X-axis) Mallampati score in the sitting position, in the supine position, and tonsillar size. Observe the positive correlation as MS score increases on the x axis and AHI rises on the y-axis for mallampati scoring in the supine position.[22]

Similar to other studies, an investigation conducted by Kim and colleagues divided a population of patients into an obese group (N=123) and a non-obese group (N=125) in an endeavor to show differences in difficulty of intubation. Data showed that over double the number of individuals with a high MS of 3 to 4 resided in the obese group. Furthermore, on average NC was 4.4 cm greater and BMI was 6.4 kg x m^2 greater in the obese group.[29] This data showcases how with increasing NC and BMI, MS is also predicted to rise. However, the data in this study was not collected to establish a correlation to OSA and aid in its diagnosis.

A study by Nuckton and colleagues aimed to establish MS as an independent predictor of OSA. They found among their findings that "for every 1 point increase in MS, the odds of having OSA increased by more than 2-fold". Additionally, NC was also investigated and found independently associated with OSA. These relationships were established via odds ratios with MS to OSA being 2.5 per 1 point increase and NC to OSA being 2.0 per 2.5 cm increase. Although not a strong association, BMI was found associated to OSA with an odds ratio of 1.5 per 5-kg/m^2 increase. Odds ratios of MS to AHI >10 was determined to have an odds ratio of 1.8. The Nuckton study is frequently cited in articles relating to the reliability of MS as it was shown to be a reliable independent predictor of OSA. More reliable correlations were found between MS, AHI, OSA, and NC, and to less significance, BMI.[7]

Finally, a study conducted by Hukins included 953 patients in his analysis. Among his findings included "a statistically significant relationship between the independent variable of MS and the dependent variable of AHI (R_S=0.13) but MS explained only 1.7% of the variability in AHI." A correlation between AHI and BMI was additionally isolated with an R_S=.25. His findings also showed that a Mallampati class of IV was only 40% sensitive and 67% specific for AHI > 30 which classifies severe OSA. This study was included to demonstrate the point of contention that MS represents and its relationship to OSA. A great deal of variability in regards to the MSS performance as a predictive tool is seen across many studies likely due to varying demographics, especially weight, among the participants in each study.[31]

Discussion:

Sleep medicine remains a novel field with the first continuous positive airway pressure mask not utilized until 1981-1982. Furthermore, clinical studies that were "well designed with a large patient base" did not exist until 2000.[2] As a result research remains limited in regards to MS and its association with OSA. Studies showing that MS is not a reliable predictor suggest that MS is not a tool to be regarded independently when investigating OSA, but should be regarded as a part of a clinical presentation with many factors to be considered alongside it as is the case with OSA itself.

This study originally began with the hypothesis that MS is a reliable independent predictor of OSA. However, multiple studies had already been published that evaluated this correlation and came to different conclusions showing that MS is, or is not, a reliable independent predictor, especially in regards to more mild forms of OSA.[7, 28, 31] This however does not exclude the usefulness of the MSS in regards to the prediction of OSA. A new hypothesis was then formulated to make this work novel research and goes as follows: "Mallampati Scoring (MS), when interpreted alongside predictive factors of OSA in a physical examination, could serve as new criteria to reliably predict the presence of OSA." In review of the literature investigated in this paper and the data contained therein, additional investigation is certainly warranted in regards to correlations between MS, NC, and BMI, in turn, to that of OSA.

As several studies did conclude that BMI does not seem to consistently rise with relative severity or likelihood of OSA, its implementation as a part of a criteria to predict likelihood of OSA is questionable. It is possible that much like MS, BMI must be interpreted alongside several other criteria to have meaningful usefulness to identifying OSA. MS was consistently shown to be strongly correlated to AHI and NC when the factors were included in the studies.[7,12,29]

This research does not show that independently MS has use in diagnosing OSA, but could prove useful if implemented as a part of a battery of criteria that predispose an individual toward OSA. This literature review is intended to incentivize a study on a large scale that implements MS as a tool in the standard physical examination. By doing so one would anticipate that the 3-7% of adults believed to be afflicted with the disease would decrease.[23] More specifically, a hospital that institutes MS, BMI, and NC into its patient's medical history would expect that OSA diagnosis among their patient population might rise by comparison to previous trends. During this process, a connection between increasing BMI, NC, and MS and how these factors interact with each other as relative severity of OSA rises could serve as a foundation of new criteria that identify sleep breathing disorders.

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