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Qualitative Analysis of Alcohol's Acute Effect on Vocal Range

Cover Page Footnote
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Abstract
Alcoholic beverages are the most popular human-produced drinks in history. Whether it is wine, beer, or hard liquor, alcoholic beverages are included in all aspects of society. In terms of its effects on individuals, alcohol is deemed to be a poison to the body, and drinking too much can destroy your liver and your body as a whole. This puts public speakers, political leaders, and specifically singers in an odd position when it comes to balancing casual alcohol consumption and retaining their vocal health. Scientific study of this subject is necessary, as well as close consideration of the effects of alcohol on singer's lives and careers. There is already extensive research pertaining to the chronic effects of alcohol on the body. In terms of acute alcohol ingestion, research does not exist to the same level of detail or quality. The effect of alcohol on vocal range, both chronic and acute, has not been studied thoroughly. Alcohol has many negative effects on the voice. In this study, we suggest that acute alcohol ingestion may decrease the vocal range of individuals.

Pharmacology of Alcohol

Holistic comprehension of alcohol's acute effects on the body must include the pharmacology of alcohol (POA). Pharmacology is defined by the British Pharmacological Society as "a vibrant area of biomedical science that studies drug action (how medicines and other drugs work and are processed by the body)". The POA is deeply studied and broken down into four main sections, but the last two may be grouped together: absorption, distribution, and elimination (metabolism and excretion). Absorption and distribution are mostly relevant to this study, due to the fact that we are studying alcohol's effect upon interacting with the body. As this is a qualitative study, the rate of metabolism and excretion are not so relevant. For these reasons, we will look at how alcohol mechanistically affects tissues and organs, then, in the next subsection, apply this to the biology of the voice.

Quick absorption of ethanol (what we know as the ingestible alcohol in libations) occurs from the stomach by diffusion. The higher the alcohol content, the quicker diffusion is. Gastric absorption is the fastest on an empty stomach because food dilutes the ethanol. As soon as the ethanol remaining enters the duodenum (initial part of the small intestine), it is quickly absorbed

into the bloodstream. Before reaching the major organs and extremities, ethanol travels through the liver where a large percent of it is disposed of for excretion.

Ethanol diffuses very quickly and easily through aqueous sections of the body. It enters the brain through the blood-brain barrier with great ease. In addition to this, it cannot mix with lipid soluble components. It doesn't accumulate in adipose tissue, like many other drugs. Rate of distribution of ethanol is determined by the blood supply and water content of the specific tissue.

Excretion of alcohol is primarily completed by the liver. Ethanol becomes oxidized to acetaldehyde primarily in the liver by one of three major enzymes: alcohol dehydrogenase, catalase, and the microsomal ethanol-oxidizing system.

Metabolism of other compounds during alcohol dehydrogenase operation seizes because massive amounts of nicotinamide adenine dinucleotide plus hydrogen (NADH) is being used in the liver. NADH is also used in many metabolism steps throughout the body. The rate limiting step of breaking down alcohol is regeneration of NAD (nicotinamide adenine dinucleotide) for alcohol dehydrogenase. The large necessity for NAD to handle such a great amount of ethanol may even force the liver to steal the necessary amounts for other NAD-requiring intermediates, like lactate. Major metabolism of fats, hormones, and carbohydrates is affected (Goldstein, 1983). The result of alcohol consumption is a decrease in metabolism of any sort of mucous or protective coating in the body of the singer.

Something to mention is that many of the effects discussed in this study, like lowered NAD availability, are due to relatively high blood alcohol levels. Such low quantity of quality studies revolving around alcohol's effect on vocal range requires a broader overview of this subject. To our knowledge, it is not known to what extent BAC correlates to what level of effects.

Moving to cell membranes, it was found that alcohol has two major effects. According to the fluid mosaic model, the animal cell membrane is composed of a fluid, semi-liquid, semi-solid lipid bilayer. Ethanol was found to act in these membranes from a study conducted by Seeman in the 1960s. Further research using methods such as nuclear magnetic resonance, electron paramagnetic resonance, and fluorescence polarization showed that alcohol actually increased what is known as membrane disordering (Goldstein, 1983). With increased membrane disordering, this has larger effects on a cluster of similar cells, called tissue, like the vocal folds. The second effect observed by researchers was ethanol could lower the temperature at which lipid bilayers transition between the gel and liquid crystalline states. This is actually an indicator of membrane disordering (Goldstein, 1983). Enzymes and other proteins work and exist at very specific ranges; therefore, as a difference in environment occurs, difference in enzyme activity in the vocal muscles must, as well. In addition, alcohol has been shown to modify signaling proteins (Higashi et al., 1996) and ion channels (Dopico, 2003). Modifying these lead to further changes in a variety of signaling pathways that mediate many of the essential processes in the human body (Jung et al., 2011). This is further support to show how alcohol disrupts homeostasis. In the next section, these disruptions will be applied to the biology of the voice to introduce some ways in which the vocal range may be reduced.

Biology of 'the Voice'

After delving into the POA in terms of cell membranes and tissues, we shift toward the vocal muscles and the basic biology of the singer. Both males and females have very similar vocal muscles. What makes women sound higher pitched and less resonant is their thinner vocal folds and smaller body cages. The thicker the vocal folds, located in the larynx, the deeper a sound that

can be produced (McKinney, 2005). A more tangible example of this phenomenon is how guitar strings work. The highest pitched string is always the thinnest, so the thicker the string, the lower the pitch. Besides for those two slight differences, the near identical bodies (male and female) are treated as one in the same. From women and men to make a higher pitch, the vocal folds will become longer and thinner. For a deeper pitch, vocal folds become thicker and shorter. Trained singers know this and test their limits with exercise, just like any other muscle.

There are three vocal subsystems that are used to describe what is involved in singing: the air pressure subsystem, the vibratory subsystem, and the resonating subsystem. The air pressure system includes the diaphragm, the chest muscles, the ribs, the abdominal muscles, and the lungs. The diaphragm helps to increase the amount of air allotted into the lungs by pulling down/ extending the breathing cavity. The chest muscles perform a similar function while allowing air to resonate in the body cavity. The ribs help provide structure to the breathing cavity. The abdominal muscles provide the support for pushing breath up out of the lungs. Lastly, the lung is the organ of respiration. These contributors to the air pressure system all help breath move towards the vocal folds. Alcohol is a known depressant, which means it slows the central nervous system and breathing. When breathing slows down, this decreases the support to the air pressure system. This, along with decreased NADH in the body, more easily tires the singer and the vocal folds (McKinney, 2005).

The vibratory subsystem includes mainly the larynx, and more importantly the vocal folds. These muscles lie parallel to the floor in the neck and smack against each other to vibrate. They vibrate the breath, changing the air movement to sound waves, producing a 'pitched sound.' (McKinney, 2005).

The larynx consists of multiple components that must be looked at in detail to view how many ways alcohol can affect the vocal range. The laryngeal cavity is the tube-like, mucus-lined opening where air passes through. Superior to (above) this, is the pharynx and opening to the mouth. Posterior to this (coming after) is a continuation of the trachea. On each side of the laryngeal cavity exists mucus bulges called the laryngeal ventricles. Tubular extensions of the ventricles called laryngeal saccules are thought to be the source of the mucus glands that lubricate the vocal folds. Alcohol disrupts many processes involved in synthesis, which means that regeneration of mucous are slowed from the laryngeal saccules (Mandal, 2014). The larynx also has different ligaments, one being the conus elasticus. This ligament extends superiorly from the cricoid cartilage and attaches anteriorly (toward the front) to the thyroid cartilage and posteriorly (closer to the back) to the vocal processes of the arytenoid cartilages. The vocal folds are superior to the submucosal membrane, and of course, covered in mucus. This mucus is protected by a more specific layer called thick stratified squamous epithelium. The epithelium function is to protect the lower mucus layers and also the vocal folds from stressful breathing and speech ("Larynx Anatomy", 2017). Alcohol will disrupt the fluidity of these connective tissues' membranes, meaning that the flexibility of the vocal fold ligaments will decrease. This will, in turn, decrease the vocal range (Mandal, 2014).

The resonating subsystem then takes this 'buzzy sound' and converts it to a more specific tone and timbre, making one's own voice. What makes different singers different is how they understand their own biology, how they use their body, and how they take care of their instrument (McKinney, 2005). The resonating subsystem does not affect pitch, so it is not relevant to our study.

Dehydration

Alcohol has been deeply studied throughout modern history and is a well-known diuretic. A diuretic is defined as any ingestible food or drink that encourages formation of urine in the kidneys (Mandal, 2014). In other words, a diuretic will increase the frequency of urination. Diuretics lower the amount of water and sodium in the bloodstream and the body (Mandal, 2014).

Murray (1932) has studied alcohol's effect on human subjects, and found that alcohol is a diuretic that is better defined as an "exaggerated water diuresis." This refers to a significant increase in the overall production of urine. This identification of what changes from a diuretic shifts the attention toward a holistic body process, and away from the main sources of urine production, the kidneys. She also states that this process is rapid and powerful, meaning that this is a strictly acute situation. Murray (1932) postulates many other ways in which alcohol may be affecting the "water shift" in the body: (1) Alcohol increases hydraemia more than water and, therefore, can overcome the impermeability due to pituitrin. (2) Alcohol inhibits the secretion of the pituitrin's capillary substance. (3) Alcohol directly inflates capillary permeability. (4) Alcohol increases blood flow and volume of the kidney. Whether it is a combination of all of these mechanisms or maybe one, alcohol dehydrates major organs and tissues in the body by lowering the amount of water and sodium in the bloodstream and the body. The next question is how this relates to creating sound.

This dehydration can lead to weaker air pressure and vibratory systems. Extrapolating, alcohol disrupts the body's natural mucous and coatings of organs in those subsystems. In a NATS (National Association of Teachers of Singing) podcast, Dr. Wendy LeBorgne discusses how alcohol affects the vocal folds and the larynx. She states that not only does alcohol dehydrate the

voice, but this dehydration causes a few issues: "if your vocal folds are dehydrated, one, you get a thicker, stickier mucous on the vocal folds, and two, dry things do not vibrate quite as well as lubricated things" ("Alcohol and Your Voice," 2018). If the vibratory system cannot vibrate as it should, this will affect the range of pitches a singer can obtain while intoxicated.

Alcohol Affects Behavior

One thing that is very well known is that alcohol affects cognitive function. Although not thought of initially, this has many negative, rapid impacts on the voice. Dr. Robert T. Sataloff describes, as it is known from commercials, even a small amount of alcohol affects fine motor control. Singers are just like athletes in that they create adjustments and judgments based on specific, regular performance. Any impairment of neurological control would alter the precision of the singer (Sataloff, 2015). In other words, intoxication affects cognitive control of singers. The extent of intoxication for a specific BAC (blood alcohol concentration) is likely to depend on the individual. If an individual cannot control any of the three vocal subsystems during a performance, this could lead to negative consequences like hoarseness, throat pain, and hypervascularity ("Taking Care of Your Voice," 2015). These symptoms can be felt within hours if a singer is not performing correctly due to intoxication.

The lack of effective thought processes leads to overuse of the voice and the three vocal subsystems. At loud venues, it is very likely that excessively loud singing or speaking may occur to combat the loudness in the room. Most of the time, it is unknown to the individual that they are being relatively loud.

One of the most common issues seen by otolaryngologists is vocal nodules. These can be genetic or one can have a genetic predisposition to them. Either way, they are mostly caused by

overuse or misuse of the voice (Won et al., 2016). A large misuse of the voice is screaming which is aggressive flapping of the sides of the larynx against each other. Screaming can be combated with positive decisions while intoxicated. One of the easiest ways to take care of the voice is simply hydrating. Drinking water keeps your whole body in a better state, and clean water keeps the vocal folds hydrated and healthy. What is recommended is six to eight glasses of water a day. To keep the voice hydrated, avoid alcohol. This is a diuretic, which causes the body to lose a lot of water by increased defecation and urination. If drinking alcohol, the body will require even more water to keep proper amount of hydration. Alcohol also irritates mucous membranes in the throat, affecting the usage of the voice by changing the lubrication of the larynx ("Taking Care of Your Voice," 2015).

The United Kingdom National Health website provides an article that demonstrates that alcohol is a diuretic and therefore makes you lose fluid, making you dehydrated (Dehydration). What was not discussed before was that the larynx will overwork while dehydrated to make up for the lost moisture to reach pitches that cannot be obtained. This can lead the larynx to become damaged with redness and possible scarring. Some of the major short-term effects of alcohol is lowered inhibitions, meaning less control over breath control, and more vocal abuse. This lack of coordination and lowered sensations means poorer decisions for proper vocal health during performance. If drinking in a nightclub or concert, people may not realize how loudly they are talking or how much effort they are actually putting into talking, singing, or even screaming. Over time, this overuse of the voice can have other impacts like vocal nodules ("Dehydration," 2017).

All of the results of misuse or overuse of the voice may cause pain. This severely limits singers from performing to their greatest extent while also shortening their vocal range.

Chronic Effects

Although this research is primarily used to open up the discussion about alcohol's short-term effect on vocal range, there are many chronic studies that are relevant to this subject. From the extensive research done on alcohol's effect on the human body, much exists on the effect of alcohol on the subsystems relevant to our research.

There are many things that are shown to directly harm the vocal muscles over time. Upper respiratory infections and inflammation due to gastroesophageal reflux (acid reflux) can respectively cause excessive coughing (the vocal folds aggressively smack together) and burn the vocal folds from acidic stomach juices overflowing from the esophagus (Johnson, 2018). Misuse and mistreatment of the voice by screaming or ineffectively balancing the three vocal subsystems can also lead to disastrous effects on the vocal muscles.

The largest effect of alcohol studied and observed by doctors around the world is cancer. Alcohol increases the likelihood of cancers of the pharynx, larynx, and all other parts of the body. A study published in 2009 found that tobacco and alcohol use increased the risk of cancer in the head and neck (Hashibe et al., 2009). These cancers can be located on the vocal folds or brain sections involved in motor skills, which affect the vibratory subsystem. This shows how one's vocal performance could be easily affected by prolonged alcohol use. Another study was conducted that also focused on the effects of alcohol on the pharynx, oral cavity, larynx, and esophagus. The study stated that drinking 50 g of alcohol a day increases the likelihood of gaining these forms of cancers by two or three times compared to non-drinkers (Baan et al., 2007). These studies support the notion that alcohol increases the chances of cancer, which decreases the effectiveness of the vocal muscles.

There are specific settings that are generally known to encourage alcohol consumption. One commonly studied setting is college campuses with Greek life, where binge drinking is very prominent. A study in 2004 suggests that binge drinking in college leads to a higher chance of alcohol abuse or alcohol-related medical problems (Jennison, 2004). This shows the long term alcoholic effects that could result in degradation of the larynx or vocal performance organs. This is significant because it provides evidence that alcohol can affect any and all careers. Most occupations rely on speech to communicate to others in some way or another, so the chronic effects are not only relevant to singers.

A study conducted in 2013 tried to get an overview of how alcohol plays a role in cancer deaths on a large scale in the United States. This study shows how deadly alcohol can really be. What they found was that consuming alcohol resulted in 3.2% to 3.7% of all American cancer deaths. Female cancer deaths were attributed mainly to breast cancer (56% to 66%), while male cancer deaths show 53% to 71% upper airway and esophageal cancer. In total, alcohol-attributable cancers were found to be in 17.0 to 19.1 YPLL per death. Daily consumption of up to 20 grams of alcohol was found to account for 26% to 35% of alcohol-attributable cancer deaths (Nelson et al., 2013). This can be used to show how organ failure or cancer growth can occur on the subsystems relevant to our study. The last point relating alcohol to cancer likeliness shows how important decreasing alcohol consumption is in the prevention of cancer. According to these statistics, men are more than half as likely to develop a cancer on a muscle involved in singing. Alcohol, at least for men, can literally destroy a singer's career and life. For those that survive, the surgery or scar tissue involved will forever change the way the singer interacts with their body.

A major organization, The International Agency for Research on Cancer, released a book in 2012 that has a holistic view of cancer, and what causes it. In the book can be found *A Review*

of Human Carcinogens. This section deals with cancers of the lungs. It states that pain can develop in the muscles surrounding the abdominals (which is in charge of breath support) ("Consumption," 2012). These specific organs that are affected by drinking alcohol can directly influence and detract from proper breath support. Without proper breath support, singers will rely more on the vibratory and resonating subsystems to make up for the pain felt in the air pressure system. This can lead to numerous issues regarding the secondary muscles to singing.

In terms of the larynx, the *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans* released multiple studies in 2010 relevant to alcohol's effect on cancer. One of the many examples on Table 2.10 shows The Honolulu Heart Program study (Chyou et al., 2010) that was based on 7995 American men of Japanese ancestry who lived in Hawaii. In this study of 93 cases of cancers of the oral cavity and pharynx, esophagus and larynx, a strong dose–risk relationship with alcoholic beverage consumption was found with a relative risk of 4.7 for ≥25 oz/ month of total alcoholic beverage intake, compared with non-drinkers ("Consumption," 2010). Through numerous studies, it is clear, that alcohol has a large effect on death rates due to laryngeal cancer.

Summary and Results

In this study, we examined the factors that may indicate that acute alcohol ingestion results in a decreased vocal range. Those reasons that were already discussed are as follows:

1. Lowered availability of NADH that is used in synthesis reactions throughout the body.
2. Increased membrane disordering in membranes and tissues that alter the environment of many important enzymes that have specific situational work conditions.
3. Decreased breath support due to decreased breathing rate and heart rate.
4. Decreased ease of stretching the vibratory subsystem.

5. Dehydration of the vocal subsystems due to diuretic properties.
6. Behavior is altered, affecting the decisions regarding smart vocal health. Misuse and overuse of the voice.

To what extent the range is diminished has not yet been studied. At what minimum blood alcohol content is the range diminished has not yet been studied. There is hope that more quantitative research will be conducted in the future.

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