Potential Physiological Stress Response While Chewing Gum at Various Rates

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Abstract

This study examined the effects the rate of gum chewing has on physiological stress indicators, hypothesizing that a faster rate of gum chewing would increase stress and therefore enhance the stress response. Fifteen students, ages 19-27, were tested. Blood pressure, pulse, and EMG activity were measured as indicators of the stress response. These indicators were taken in one-minute increments while the subject was not chewing gum, chewing at their normal, comfortable rate, and chewing at an abnormally fast rate of 170 beats per minute, which was set by a metronome. As hypothesized, results showed that the faster rate of gum chewing produced an increased stress response. Continued studies are appropriate to fully characterize and further explore this relationship as well as potential discrepancies due to factors such as time and gender.

Introduction

Our research is searching for a link between gum chewing rate and stress levels. Previous research has shown that chewing gum reduced cortisol stress hormone levels in salivary samples, as well as had findings of improved self-reported mood in normal patients by utilizing a State-Trait Anxiety Inventory (Scholey et al., 2009 and Smith, 2010). We were curious about this topic because gum is a popular product on college campuses and there was relatively little conclusive evidence on its physiological effects. If gum is found to have positive physiological effects on the body, it could be an economically feasible and efficient treatment of stress in students (Cohen et al., 2003). Chewing any type of gum would be a healthier alternative to other detrimental stress-control behaviors like smoking, drugs, and excessive eating and drinking (Cohen et al., 1991).

Many people chew gum today for oral health benefits, without knowing the potential physiological effects and the numerous years of studies conducted on its ability to aid in concentration and stress relief. Despite evidence showing that chewing gum can produced an electroencephalograph (EEG) pattern immediately afterwards that was consistent with a state of relaxation, the majority of studies that have been conducted focused on cognition and performance (Morinushi et al., 2000). A 2007 study provides evidence that the act of chewing significantly reduced salivary cortisol following a stressor when compared to controls, further contributing to the potential mood altering properties of chewing gum (Tahara et al., 2007). Although further examination is required on the possible mechanism of stress reduction while chewing gum, it is believed that heart rate regulation is also linked to chewing gum (Farella et al., 1999; Wilkinson, Scholey, & Wesnes, 2002; Sholey et al., 2009). In our research, we hope to explore further physiological indicators of a stress response during gum chewing.

Our study addresses the following question: Does the rate of gum chewing affect physiological stress responses? We will measure blood pressure, pulse oximetry (oxygen saturation levels and pulse), and EMG as indicators of a physiological stress response. Increased blood pressure, heart rate, and muscle contraction (EMG) and decreased oxygen saturation are all indicative of a physiological stress response (Manuck et al., 1991 and Liao et al., 2005). Farella et al., 1999, utilized an EMG to examine masticatory muscle activity during chewing. Throughout the study conducted by Farella et al., 1999, heart rate and blood pressure monitoring during the act of chewing gum resulted in cardiovascular changes similar to the responses to muscular work in general. Based on these characteristics the fundamentals of muscle activity and work physiology should be taken into account when examining jaw muscle activity while using a EMG (Farella et al., 1999).

Our control conditions will be the baseline vitals at a standard chew rate (standardized by use of a metronome) and preliminary vitals without chewing gum. By setting a baseline chew rate, we will control for the effects that the outside level of physiological stress could have on the subject's chew rate. Measuring vitals while the subject is not chewing gum will provide a control to show whether the act of gum chewing itself, regardless of rate, changes physiological stress indicators. A consistent brand, type, amount, and flavor of gum will be used. In order to standardize the texture of the gum and get the subject's jaws acclimated to chewing, we will have them chew for a 15 second preliminary period before taking measurements while chewing gum. We hypothesize that faster chewing gum rates will increase stress responses because an unnaturally faster rate of chewing will act as an external stressor on the body. Based on this, we predict the stress response will be manifested as increased heart rate, increased blood pressure, decreased oxygen saturation of the blood, and increased muscle tension when the subject is chewing at the faster rate, as compared to vitals at the baseline chewing rate.

Materials

The subjects will be presented with a consent form that will convey the purpose of our study, the relative risks and benefits of the study, as well as confidentiality protection and contact information. This will ensure that full disclosure is presented to the subjects prior to their consent of participating in the research. A chart will be used to record results at specific time periods, which will allow for efficient data collection. An EMG device will be used and plugged into the computer to record changes in muscle tension using the BioPac software. The three electrodes for the EMG will be placed on the test subject's face, with the positive end of the electrode placed on the right side of the jaw bone, the negative end of the electrode placed on the left side of the jaw bone, and the ground electrode placed on their forehead. A pulse oximetry device will be placed on the right pointer finger to record changes in the subject's heart rate and oxygen saturation. Due to the ambiguities in hearing and the level of heartbeat sounds that arise from using a stethoscope and blood pressure cuff to hear specific levels of heartbeat, a digital blood pressure cuff will be used. The digital readout will allow for a more standardized blood pressure measurement and allow us to remove the listening aspect from the experiment. A consistent brand, type, amount and flavor of gum will be used for the experiment. A metronome set to 170 beats per minutes will be used to standardize the fast chewing rate.

Methods

Each of the trials took place between 8:00am and 10:30am on a Wednesday. Testing was conducted using pulse oximetry to determine oxygen saturation and heart rate, blood pressure was measured with a digital blood pressure cuff, and an EMG was used to determine muscular tension of the jaw. We began this experiment by assembling our experimental instruments. The flavor of the gum was spearmint (artificially flavored), and the quantity of gum was a set amount of 1 piece or ~1.5g. The type of gum was held constant (Wrigley's Orbit, sugar free, WM. Wrigley Jr. Company, Chicago, IL 60642) with ingredients consisting of: sorbitol, gum base, acacia, glycerol, natural and artificial flavors; less than 2% of: mannitol, aspartame, soy lecithin, colors (titanium dioxide, blue 1, yellow 5), acesulfame K, sodium bicarbonate, carnauba wax, BHT (to maintain freshness). Phenylketonurics: contains phenylalanine (See Fig. 2) ("Orbit Gum").

A consent form was issued to the subject stating the purpose, risks and contact information needed for the experiment. After consent was granted, the following instruments were applied to the subject and the experimental procedure began: a blood pressure cuff, a pulse oximeter (pulse ox), and an EMG. The EMG was used to examine the intensity and rhythm of mastication throughout the duration of gum chewing.

The test subject placed both arms on the table. A pulse oximeter was put on their right hand and the blood pressure cuff on their left wrist. Then the three electrodes for the EMG were placed on the test subject's face, with the positive end of the electrode placed on the right side of the jawbone, the negative end of the electrode placed on the left side, and the ground electrode placed on their forehead. The first step of the experiment was the subject sitting still for one minute while their baseline vitals were taken. Subjects were instructed not to clench their jaw during this time, in order to get adequate baseline levels for comparison to normal chew and fast chew rates later on.

A time period of one minute was chosen for each of the tests to limit the time commitment necessary from the subjects and allow us to get a reasonable amount of data in the class time we had. After discussion within the group, we decided that although longer tests would more ideal, one minute for each test would be long enough for physiological changes to present and be measured. The initial EMG test ran for a total of 60 seconds, and pulse ox measurements were taken starting at zero seconds and repeating every 15 seconds for one minute. The subject's initial blood pressure was measured at zero seconds for the first test. The digital blood pressure cuff on their left wrist was positioned at heart level. The subject's initial vitals were important as a control to allow us to determine if the act of chewing gum itself, regardless of rate, could cause a physiological change on muscle tension, blood pressure, oxygen levels, and heart rate.

After the first minute of initial vitals, all of the testing equipment remained attached to the test subject, subject's vitals were measured at their normal chew rate (the rate at which they chew comfortably without outside influence). After everything was checked for proper connection, the test subject was given the standard piece of chewing gum and allowed to acclimate to it for 15 seconds. The EMG test was again run for 60 seconds, taking pulse ox measurements and recording starting at zero seconds and repeating every 15 seconds for one minute. The test subject's blood pressure was be measured 45 seconds into the minute. After the minute of normal chewing, the subject was allowed to rest for another 60 seconds in order to restore chewing strength for the next test.

With all of the testing devices still attached to the test subject, a metronome set at 170 beats per minute was used to standardize the "fast" chew rate for each test subject. The test subject was asked to match their chew rate with the timing of the metronome. Fifteen seconds were allotted for the subject to become acquainted with this "fast" chew rate. Afterwards, we began testing for the normal 60-second interval. The EMG test was run for a total of 60 seconds, taking pulse ox measurements and recording starting at zero seconds and repeating every 15 seconds for one minute. The test subject's blood pressure was measured at 45 seconds into the "fast" chew rate. After the minute of fast chewing, the test was concluded and measuring devices removed from the subject. The total time allotted for the testing was four minutes and 30 seconds (see Fig. 1).

Results

Changes in pulse, blood pressure (systolic and diastolic), and EMG activity were documented for each 60-second interval (baseline vitals, normal chew rate, fast chew rate). Significant changes ($p < 0.05$) in pulse (beats per minute) were recorded between baseline and normal chew rate in a paired t-test (see Appendix 2). Significant differences were also found between normal and fast chew rates, as well as between initial and fast rates (Table 1). Significant changes in systolic blood pressure were found between baseline and normal chew rates as well as between initial and fast chew rates using a paired t- test (see Appendix 2). Changes in systolic blood pressure between normal and fast chew rates were not significant ($p = 0.6682$). The only significant change is diastolic blood pressure was seen between the normal and fast chew rates using a paired t-test (see Appendix 2). Changes between initial and normal chew rate ($p = 0.8257$) and initial and fast chew rates ($p = 0.1012$) were not found to be significant. Pulse oximeter readings showed no significant changes across the three tests for each individual (See Appendix 2).

Significant changes in EMG activity were observed between baseline and normal chew rates, baseline and fast chew rates, and normal and fast chew rates using a paired t-test (see Appendix 2). Mean EMG data was calculated utilizing the BIOPAC system (See Fig.3 - Fig.6). A positive, linear increase ($R^2 = 0.97373$) was observed between mean EMG and time, as the experiment progressed from baseline to normal and fast chew rates (see Graph 1 & Table 1). A positive, linear relationship ($R^2 = 0.95003$) was observed between mean pulse and mean EMG (see Graph 2). An increase in chew rate (as indicated by an increase in mean EMG) correlated with an increase in mean pulse, indicates that a fast chew rate was sufficient enough to generate a physiological stress response.

Discussion

Contrary to the results of previous studies conducted by Cohen et al., 2003, Scholey et al., 2009, and Smith, 2010, our results indicated that the act of chewing gum itself induced a stress response in the subjects. According to several studies conducted by Carlson et al., 1993, Sloan et al., 1994, and Melamed, 1996, cardiovascular factors such as heart rate and blood pressures can be influenced by physiological factors and stressful tasks. Based on this, the experimental setup of chewing gum at a normal rate as well as chewing gum at an induced rapid rate could be considered stressors on the body. The cardiovascular changes were indicated by increases in systolic blood pressure and pulse between the initial (non-chewing) state and the normal chewing rate. Chewing gum at a fast rate increased the stress response to even higher levels than chewing at the subject's normal rate, as indicated by increases in pulse and diastolic blood pressure between the normal and fast chewing rates. Thus, our hypothesis that faster chewing rates would increase the physiological stress response in our subjects was supported by the data collected. The data, mentioned above, indicating increased stress due to the act of chewing gum alone (differences between initial and normal chew rate), was not predicted but gave interesting insight into the effects of gum chewing in general, regardless of rate. These measurements were taken initially as a control, but given their significance the information gained could be the basis for further studies, as discussed below.

Pulse oximetry data was collected from each subject during all three minute-long trials, and data analysis showed that these values remained extremely constant for each individual throughout each trial, as expected. Though chewing gum was shown to have physiological effects, it could not be expected to create any significant level of hypoxia in a healthy individual. Thus, the pulse oximetry consistencies across the resting test and both chew rates indicated that relative homeostasis was maintained due to the other compensatory measures through which change was observed.

Though the data collected demonstrates that chewing gum created a physiological stress response in the study participants, more studies are needed to determine the context of these stress responses compared to other external stressors. For example, it could be possible that chewing gum would be a stressor in a relatively relaxed person (as our subjects presumably were), but it could serve to maintain or even decrease the physiological stress indicators in a hyper-stressed individual. Thus, further studies would be necessary to further investigate the effects of gum chewing in individuals that are in stressful environments before a conclusion regarding this facet of the experiment can be drawn.

To further clarify our results, more studies involving a greater number of participants and a longer time over which the tests are run are necessary. This would specifically be useful to clarify our results regarding blood pressure, since different changes were observed in the diastolic and systolic pressures, which was unexpected. As mentioned above, significant changes were observed in the systolic pressure between initial and normal and initial and fast chew rates, but not between normal and fast chew rates. This indicated that the act of chewing itself induced a physiological stress response, but the rate of chewing did not affect this response significantly. However, significant changes in diastolic pressure were only observed between the normal and fast chew rates, which was inverse to the systolic results. This seemed paradoxical to our group, as we had expected systolic and diastolic pressures to change similarly. The most logical explanation for this dichotomy was that the first minute of fast chewing created a stress response in which norepinephrine constricted systemic blood vessels, increasing the diastolic pressure. However, if the test had been run longer, the slightly delayed effects of epinephrine could have become apparent, increasing the ventricular stroke volume and thus the systolic pressure as well. After enough time, the vasodilator effects of epinephrine could potentially bring the system back to resting vital signs. If this conjecture is true, we can be certain that normal and fast chewing both affect systolic and diastolic blood pressure, but a longer measurement time would be necessary to see their full effects since they are offset in timing.

The significant increases in EMG activity may just be attributed to increased jaw movement due to chewing rather than an actual stress response. Based on previous studies conducted by Bakke et al., jaw muscles, even though they are relatively small muscles in the overall scheme of the body, actually induce general circulatory changes during the act of chewing (Bakke et al., 1996). Many of these changes in general circulation are characteristic of increases in both heart rate and arterial blood pressure, similar to the findings of Taylor et al., 1988, while examining the effects during sporadic exercises similar to the rate of chewing gum. Based on the methods used by previous studies, EMG's only require short instances of recorded muscle activity to obtain adequate data during the opening and closing of the mandible. However according to Ottenhoff et al., 1992, jaw-elevator muscle activity is necessary in order to overcome the resistance contained in the density of food, or gum in this case. Furthermore, with the increasing resistance of the bolus, or hardness factor of the gum, EMG activity is increased as well (Karkazis and Kossioni, 1997). Based on the findings of these studies, further research on the potential effects that harder gum as compared to softer gum can have on the activity of EMG's as well as potential cardiovascular effects is warranted.

As seen throughout the experimental results, changes in cardiovascular responses occurred at the beginning and throughout the duration of chewing tasks. According to Berne and Levy, 1993, these fluctuations indicate a nervous system origin that is capable of being controlled or mediated by mandible muscles and their corresponding receptors, as well as by a central command center integrated into cardiac regions of the brain. As of now, studies by Blomqvist et al., 1981 indicate that the exact role that this central command center places in the mediation of cardiovascular changes based on the exercise of chewing is not fully understood. According to our results the potential impact that a central command center could have on increasing changes in cardiovascular responses, especially due to a specific stressor, indicates a necessity for further research on this topic.

Furthermore, possible gender differences could arise due to the fact that maximal muscle strength is generally higher in adult men as compared to adult women as a consequence of increased body and muscle mass (Astrand and Rodahl, 1986). The current study utilized data from both male and female test subjects, but future studies could be conducted on examining the potential variances, due to muscle mass and fatigue, based on different genders.

After taking note of the ambiguities that arose from different practice runs, we now know that it is extremely important to ensure that the blood pressure cuff remains at heart level while taking measurements, and that subjects maintain a strong chew pressure during the fast chew section of the experiment so the EMG picks up the chews. We believe that it is more important to have full chews at near 170 beats per minute, versus very small chews at exactly 170 beats per minute. These slight discrepancies among tests and subjects could be sources of some error in our data that would need to be considered and addressed in future studies.

In conclusion, our hypothesis was supported by several physiological measures, showing that the rate of gum chewing has a positive effect on physiological stress indicators, and thus could be considered a stressor itself. The data also showed that the act of chewing gum itself, regardless of rate, had an effect on these same physiological indicators, which was not foreseen. With these results in mind, there are many directions for future studies that would further elucidate the relation between gum chewing and physiology.

After completing the original study in which participants chewed gum at the fast chew rate for one minute, we conducted a small pilot study to further examine the physiological response specifically after the fast chew rate to see how long it would take to return to normal vitals. We had a small group of new participants who were asked to chew at the fast rate for five minutes after the one minute testing periods for initial rest period and baseline chew rate (see Appendices 3-5). In this pilot study we decided to extend the time for the fast chew rate to five minutes to allow ample time for the physiological effects to arise and to enable us to measure how they changed in the time after the subject stopped studying. This study was performed to see how the previous gum chew rate affected physiological stress responses after a prolonged chew time. Several of the tests showed that while resting after chewing gum at the fast chew rate, physiological responses dropping below their normal, non-chewing levels (see Appendix 3-5). This could indicate that gum chewing initially increases the stress response in people who chew the gum, but then it causes them to become more relaxed after they have finished chewing. This could stem from a relaxation of the facial muscles that can become tense when individuals are stressed, or the gum chewing cessation causes individuals to have the illusion of becoming more relaxed because they are no longer exerting themselves physically in some capacity. This could be related to exercise induced relaxation for the same reasons; cessation of chewing could produce an exaggerated decrease in physiological stress response. If the low stress levels persist for an extended period of time, it could indicate that gum chewing actually has useful anti-stress capabilities. The results of both our main study and this short additional study suggest that there is significant potential for further studies and promising results that could provide information to guide future gum consumers.

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