Videogame competition as an anxiety trigger and their implications on the masseter muscle activation

La competición de videojuegos como desencadenante de ansiedad y sus implicaciones en la activación del músculo masetero

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Abstract

Introduction: stress and anxiety are body reactions that are related to mental or emotional variations, both have been linked to temporomandibular disorders. An imbalance in the masseter muscle can contribute to the loss of cervical lordosis. Videogames usually contribute to well-being, however, there have been reports of anxiety. **Objective:** to determine if a videogame competition can create emotional changes and affect the masseter muscle activation. **Material and methods:** thirteen university-level subjects were recruited. We measured heart rate and obtained the stress index. For surface EMG we instrumented the masseter muscle, and they answer the form Y1 of the State-Trait Anxiety Inventory. Subjects were randomized into groups of four and played in competition mode *Mario Kart*. **Results:** there exists a significant difference in values at the basal mean heart rate and in-game mean heart rate which went from 83 ± 15 bpm to 102 ± 14 bpm. Also, there was a significant difference when divided by gender the sample in their anxiety levels women 46.50 ± 9.38 point while men 35.06 ± 5.23. For sEMG average activation for both sides were 65 ± 40%. **Conclusion:** the results showed that when playing videogames in competition mode it can increase anxiousness in subjects that can trigger masseter muscle activation in levels above chewing something hard, which could lead to cervical posture problems in the future.

Resumen

Introducción: *el estrés y la ansiedad son reacciones corporales que se relacionan con cambios emocionales, ambas han sido ligadas a problemas temporomandibulares. El desequilibrio en la contracción del músculo masetero puede contribuir a la pérdida de la lordosis cervical. Usualmente, los videojuegos contribuyen al bienestar, sin embargo, existen reportes de ansiedad.* **Objetivo:** *determinar si una competencia de videojuegos puede generar cambios emocionales y afectar la activación del músculo masetero.* **Material y métodos:** *se reclutaron 13 estudiantes universitarios. A los cuales se les midió la frecuencia cardiaca para calcular su índice de estrés. Asimismo, se midió la activación muscular del músculo masetero de forma bilateral, además contestaron la forma Y1 del* State-Trait Anxiety Inventory. *Los sujetos fueron colocados aleatoriamente en grupos de cuatro y jugaron* Mario Kart *en formato competencia.* **Resultados:** *se encontró diferencia significativa entre los valores basales y durante la competencia en la frecuencia cardiaca, la cual fue de 83 ± 15 lpm a 102 ± 14 lpm. De la misma manera, existe diferencia significativa al analizar a los sujetos agrupados por género*

en los valores de ansiedad, en mujeres 46.50 ± 9.38 puntos y en hombres 35.06 ± 5.23 puntos. La activación muscular promedio fue de 65 ± 40%. **Conclusión:** *los resultados muestran que al jugar videojuegos en forma de competencia existe la posibilidad de incrementar la ansiedad en los sujetos, la cual puede provocar una activación en los músculos maseteros por encima de valores normales a morder algo duro, esto puede generar a la larga problemas posturales en la columna cervical.*

INTRODUCTION

Temporomandibular disorders are associated with the temporomandibular joint and its masticatory muscles; its ethology depends on different factors such as muscular hyperfunction, parafunctional habits, traumatic injury, hormonal influence, and internal joint derangement; which often results in somatic and psychological complaints that include fatigue, sleep disturbances, anxiety, postural changes, and depression.[1,2]

One of the parafunctional habits that has been related to temporomandibular disorders is bruxism, which is characterized by clenching or grinding the teeth, this is a condition that affects people of all ages (adults, children, and adolescents),[3,4] Several studies have estimated that the prevalence of bruxism in general population range between 5 to 90%, this variability might be explained due to a large number of under-diagnosed cases.[5,6] Besides the known risk factors for bruxism, occupational risk factors have been reported, such as the practice of competitive activities like sports.[7]

It is important to study the situations that cause bruxism, since, in addition to the well-recognized effects on teeth, it can affect masticatory muscles and postural muscles of the cervical spine, which may cause muscular pain and future chronic permanent changes and headaches.[8] There needs to be a biomechanical balance between the temporomandibular joint and the posterior neck muscles for maintaining head position stability, thus malposition of one can affect the function of the other,[9] which in the long term can lead to loss of physiological cervical lordosis, pain, and disability. The way of measuring muscular activity without interfering in the subject's movement or causing any pain is by using surface electromyography (sEMG), by measuring the electrical potential produced during muscle contractions, compared to other types of equipment used to measure subjects' posture or masticatory force, this equipment would let us measure without any interference, and in a non-controlled setting. Also, it has been reported that there are marked differences in EMG signal responding to different anxious stimulus.[10,11]

Some studies of jaw function suggest that the presence of psychological factors such as anxiety, depression, and somatic symptoms may play a role in high masticatory muscles activation.[3,6,7] Jaw muscles are susceptible to mental stress since it has been reported activation changes in them.[6] Heart rate variability is a non-invasive method that is able to discriminate between changes in the peripheral nervous system and central nervous system.[6]

Stress is defined as a body reaction that occurs when changes happen in our lives, these changes could be positive or negative and are related to physical, mental, or emotional variations. It can occur at different times; at university-level, sources of stress can come from academic work, personal situations, environment, and economic circumstances. In 2002 the incidence of bruxism in university students was 22%[12] and it has been reported that 46.9% of university students have temporomandibular disorders.

Even though video and computer games contribute to well-being and also help recover from stress by providing satisfaction, autonomy and competence.[13] Nowadays 72% of teenagers play videogames, being males the most active users (91 vs 70% for females). The relationship between playing videogames and anxiety has been neglected; Ohannessian reported that videogames have a different impact on males and females, while they reduce stress levels in males; in females, they tend to increase it.[14]

We wanted to determine with a group of students that are between the ages of videogame players, that a competition is capable of creating emotional changes, and therefore have an influence on the muscular activation of the masseter muscle, which could potentially have effects on subjects' posture.

MATERIAL AND METHODS

Subjects

College Students from the Biomedical Engineer Bachelor program at Universidad Iberoamericana in Mexico City were recruited. The inclusion criteria for this study were: being a college student, with time and the will to play a videogame, without any problems in

their mouth or muscles in their face (aphasia), and had previous experience playing *Mario Kart 8 Deluxe.* Participants that met the inclusion criteria and were willing to participate gave signed informed consent. The procedures of this study were not invasive, not dangerous, and did not provoke any type of pain or discomfort for the subjects. The study was approved by the Research and Ethics Committees of the National Institute of Rehabilitation – Luis Guillermo Ibarra Ibarra, in Mexico City with number of approval 06/21 AC.

Procedure

After agreeing to participate and obtaining their demographics, subjects were taken to a separate room one by one. This room was quiet and with low light, at their arrival, a Polar Heart rate monitor model H10 (Polar Electro Oy, Kempele Finland) was placed following Kemple's guidelines,[15] we asked the subjects to follow the instructions given by one of the researchers, these included to take deep breaths with their eyes closed for 1 minute with the objective of calming each subject down after the breathing exercises were done, we recorded the heart rate interval using the Elite HRV app (Elite HRV, North Carolina, USA),[16] then we obtained the Stress Index provided with the Kubios HRV Standard 3.3.1.[17]

Afterward, as it has been stated the use of EMG is a valid alternative to approached to diagnose bruxism;[18] we placed surface EMG (sEMG) sensors in the right and left masseter, following the guidelines given by Sabaneeff et al.,[19] we used a Trigno Mini Sensor (Delsys Incorporated, Massachusetts, USA) and its Software EMGWorks (Delsys Incorporated, Massachusetts, USA). Next a maximum voluntary contraction (MVC) was recorded using teeth clenching as proposed by Ferrario et al.[20] with cotton rolls placed between the molars for 1 second followed by 3 seconds of rest; this was performed three times. Live data acquisition plots were shown to the subjects in order to encourage them to perform their best. After the MVC none of the subjects reported pain or discomfort.

We randomized all the subjects into groups of four for the competition part. A *Mario Kart 8 Deluxe* (Nintendo EAD, Kyoto, Japan) for the Nintendo Switch (Nintendo PTD, Kyoto, Japan), and four Joy-Cons were used. The competition mode was Grand Prix in 150 cm^3, in which participants could select the character, vehicle (car, bikes or ATV), tires, and gliders, before starting. Subjects were given The State-Trait Anxiety Inventory (STAI) form Y1 to determine their anxiety

level; this form consists of 20 statements in which subjects indicate how they feel at that particular moment (scores range from 20 to 80 points). Subjects that were not competing at the time and subjects that did not were part of the study, were encouraged to stay and cheer for the participants in order to give the participants a feel of competition and to encourage them to try their best and win, the sEMG and heart rate activity were recorded using Elite HRV app while the Grand Prix lasted, on average we recorded 12 minutes per group. Once the competition ended, subjects were given the STAI questionnaire to determine if there were changes in their anxiety levels.

Data analysis and statistics

All sEMG raw data was processed as followed using MATLAB R2018B (MathWorks, Massachusetts, USA), for each signal we removed its offset by calculating the mean a subtracting it, then a low pass filter type FIR with a cut-off frequency of 200Hz was used to remove the noise and the short-term fluctuations, followed by a high pass filter type FIR with a cut-off frequency of 50 Hz for removing the motion artifact, followed by a band-reject filter with a cut-off frequency at 60 Hz (electrical noise removal); after this, the signal rectification was achieved and its envelope was computed calculating the RMS.

For the MVC data for each side, the maximum value was used for normalization; it was obtained by calculating the average of the highest value for the three tries. We defined a threshold at 20% MVC, since daily living activities in healthy subjects have been reported not to surpass that value.[21,22] Any event over that value would indicate an important activation at either side of each masseter muscle and would translate in response to a stressful event by clenching the teeth while playing, afterwards we averaged the number of events and %MVC per side for all the competition time for each contestant. The average heart rate, mean R-R variability, and stress index were given by the Elite HRV app. The score for each STAI test was obtained by adding the values for each answer. After a normality test of the data, t Student test of independent variables was used to determine if changes between basal values and the ones obtained while gameplay were significant. A correlation test was applied to events and physiological values. Finally, we performed a t Student test of independent variables to determine if there were differences based on the gender of the participants and the variables of

anxiety (STAI), stress index and mean HR, as it has been stated that playing videogames is significantly related to anxiety levels which also depends on the gender.[14] SPSS Statistics software for Windows, version 26 (IBM, Chicago, Illinois, USA) was used for all statistical analysis.

The first approach was to analyze the data as a group and then divide it by gender and by subjects that had an increase or decrease in their anxiety levels based on the results of the STAI questionnaire. As there is a difference in the anxiety levels when playing videogames related to gender.

RESULTS

Data of thirteen subjects (8 women and 5 men) with an average age of 19 ± 1 years was recorded. In *Table 1*, the basal values and the in-game/after values for the physiological values (STAI score, stress index, and mean heart rate) are shown. *Table 2* presents the physiological changes and muscle activation divided by subjects that decreased or increased their anxiety after the competition.

When applying the independent-samples t-test to compare differences between basal values and in-game/after values. There was a significant difference

in the values of basal mean heart rate (83 ± 15 bpm) and in-game (competition) mean heart rate (102 ± 14 bpm); t (24) = -3.30, p = 0.003.

The number of events (per side) that surpass the threshold of 20% MVC during the competition and its average is shown in *Figure 1*.

Figure 2 shows the average of the number of events for each subject with the changes in their physiological values.

Finally, when applying the independent-samples t-test to compare differences between gender in the variables for in/after competition, a significant difference in the anxiety levels after the competition was found for women (46.50 ± 9.38 points) and for men (35.60 ± 5.23); t (11) = 2.355, p = 0.038.

DISCUSSION

The relationship between bruxism and stress has been debatable over the years with different studies trying to determine their correlation, in which different questionnaires are applied to subjects to self-assess their symptoms regarding stress and bruxism.[3,12,13,23,24] To our knowledge, only the one made by Hidaka[6] exposed subjects to a stressful experience as they measured their muscle activity to

**Table 1:** Physiological values for subjects before and during/after competition.

Subject	Gender	Basal values			In/after competition values		
		STAI score	Stress index	Mean heart rate	STAI score	Stress index	Mean heart rate
1	Female	43	4.6	79	58	8.4	106
2	Female	35	7.6	69	53	7.0	89
3	Male	38	9.3	78	34	9.0	95
4	Male	50	4.5	79	38	7.6	94
5	Male	38	13.2	86	43	13.1	95
6	Male	27	9.5	99	29	13.2	119
7	Female	51	29.7	102	55	19.2	106
8	Female	36	20.5	101	36	12.2	103
9	Male	36	5.1	64	34	4.6	78
10	Female	38	5.2	74	43	11.3	106
11	Female	38	13.6	109	47	16.9	131
12	Female	34	9.8	79	31	11.3	92
13	Female	39	1.4	61	49	26.4	111

STAI = state-trait anxiety inventory.

Table 2: Anxiety related physiological changes.

State-trait anxiety inventory	Gender men (women)	Av. events	Av. maximum voluntary contraction	% Heart rate change	% SI change
Decrease	3 (2)	15 ± 7	58 ± 20	16 ± 7	6 ± 36
Increase	2 (6)	24 ± 17	77 ± 36	30 ± 23	251 ± 582

Data expressed as mean ± standard deviation. SI = stress index.
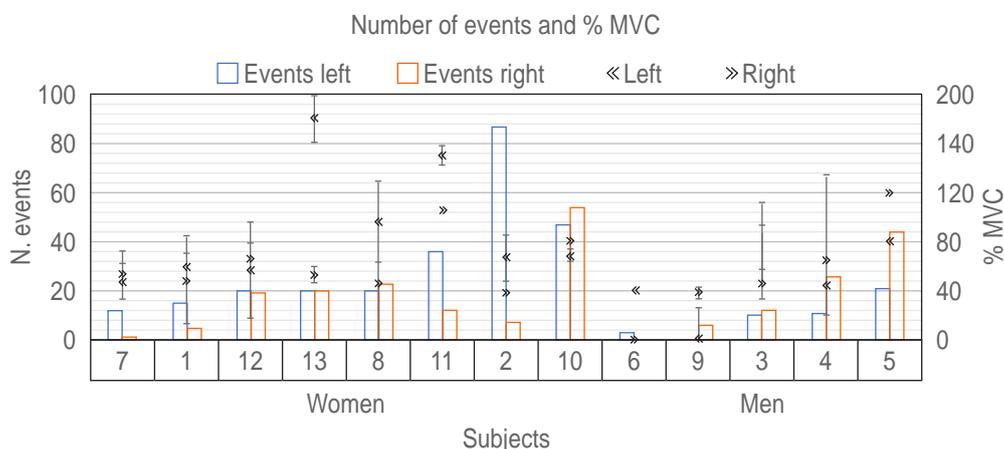
Figure 1: All thirteen subjects with the number of events (left side axis) that surpass the threshold are shown on bars for each side. Average %MVC (right side axis) with their respective standard deviation are shown with the arrows; the left side is shown in light gray, while the right side is dark gray. For subjects that did not have events surpassing the threshold (subject 6 right side and subject 9 left side), the %MVC is at 0%. Subjects are ordered by gender, first female, then male.

determine the relationship that exists between them. On the other hand, Ohannessian[14] stated that the relationship between playing videogames and anxiety symptomatology depends on gender, in which women tend to be more anxious during the videogame, while men tend to reduce anxiety levels while playing.

Our sample has 13 subjects at college level (8 women and 5 men); it has been reported that this kind of population tends to have high levels of stress, and also it has been stated that 83% of this population has bruxism.[1,12] For our sample, the average Anxiety Level based on the STAI questionnaire before competition was of 39 ± 6 points. This score is within the expected values for students of the same age, which on average were reported at 38 ± 11 points which means that this population has significant anxiety symptoms, as seen in *Table 1*.

After the competition, the average STAI went 3 points up to 42 ± 8 points, meaning that the videogame

competition did cause increased anxiety in the subjects. When dividing the results by gender, 60% of the male population decreased their anxiety levels after the videogame competition while women increased their anxiety levels by 75%, as seen in *Table 2*. Results provided by the independent t-samples showed that there was a significant difference in anxiety caused by playing videogames, in which women increased their anxiety levels and men decreased their anxiety levels after playing videogames. This is similar to what has been reported by Ohannessian.[14] Based on our results we could determine that for some populations, some men and for some women, the use of videogames is useful for recovery after stressful situations as it has been reported by Reinecke and Khawaja et al.[25,26]

Regarding the mean heart rate (HR), the group's average when being in a quiet and calm environment was of 83 ± 15 bpm, the normal values for this kind of

population have a range between 60 to 100 bpm, at competition the average had an increase of 19 ± 2 bpm, this variable was the only one regardless of the gender that had a correlation before and during the competition (p = 0.003), see *Figure 2* average events and heart rate change. Afterward, we divided by subjects that had increased and decreased anxiety levels as it is shown in *Table 2*, on subjects that decreased their anxiety levels after playing videogames, there was an average increase in their HR of $16 \pm 7\%$, while for subjects that increased their anxiety levels, the HR also increased by $30 \pm 23\%$, we can see that a HR increase was made after the competition regardless of the anxiety, which made us conclude that a competition mode feeling was achieved in all the subjects. In future work with a bigger sample size, it could be interesting to look for a positive correlation between anxiety and HR change, based on our results, since we know that this sample size is not representative of the population with bruxism. On the other hand, when dividing by gender, men had an average 81.20 ± 12.75 bpm previous competition, while being in the competition this increased to 96.20

± 14.65 bpm; for the women, the average HR was 84.25 ± 17.49 bpm before competition and during the competition, it increments to 105.50 ± 12.77 bpm, which means an increase of 19% in men and for women 25%. This change, based on HR, proves that women tend to increase their anxiety levels as shown by a bigger increase in HR compared to men, since it was a competition none of the subjects decrease their HR. The increase in heart rate reveals that all subjects regardless of their level of anxiety, determined by the STAI, had any kind of emotions, such as anxiety or stress while playing.

The stress index at rest, had an average value of 10.3 ± 1.4 points; while playing, it increased to 12.3 ± 4.6 points, on the overall sample, as seen in *Table 1*. When dividing by the subjects with increased anxiety, the change was on average $251 \pm 582\%$. While for the ones that decreased the anxiety, the change was on average $6 \pm 36\%$, as seen in *Table 2*. For these subjects the stress index had a change of between -8.3 and 3.1 points, these results relate with what has been reported by Lazarus,[27] in which stated that
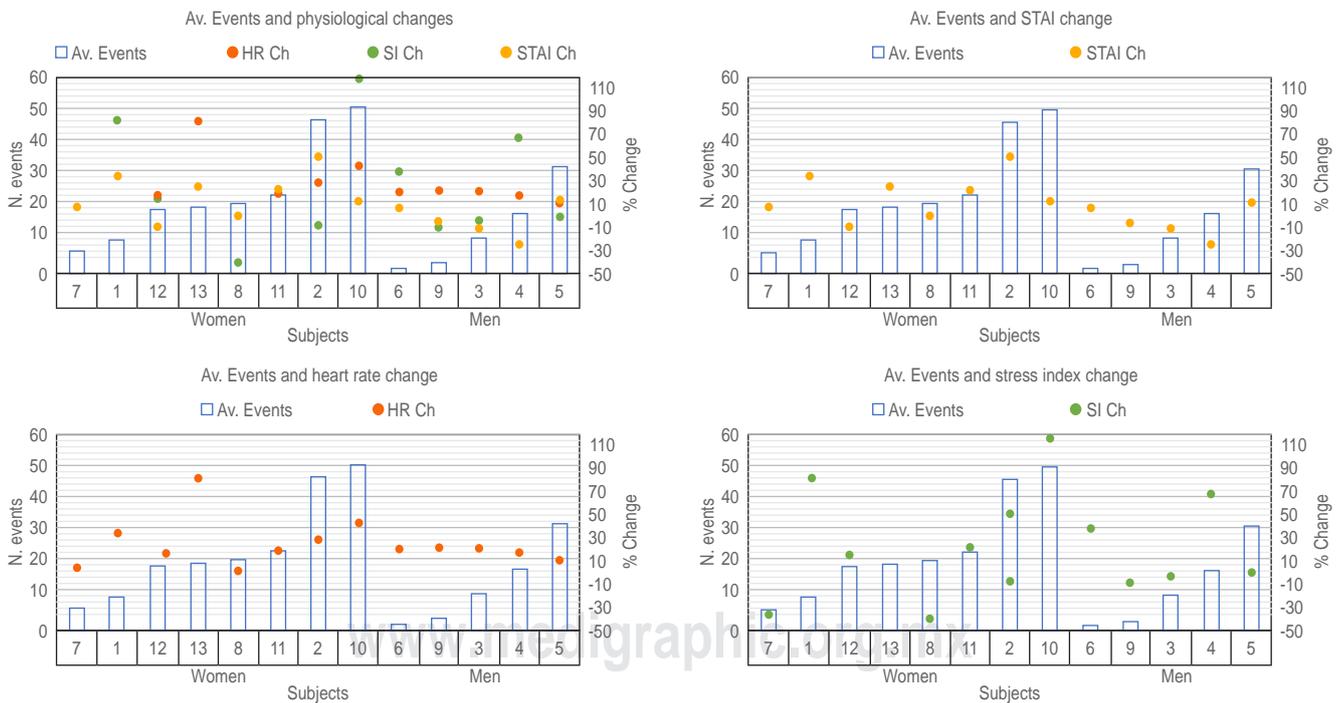
Figure 2: The average events number (left and right side) is shown with bars (left side axis), while the difference (basal values and in competition/post) is shown as follows: squares-difference in state-trait anxiety inventory test. Bullets-difference in %HR (obtained by calculating the maximum HR for each subject and determining the % of the mean HR). Diamonds-differences in the stress index. Subjects are ordered by gender, first female, then male.
Av = average. HR Ch = heart rate change. SI Ch = stress index change. STAI Ch = state-trait anxiety inventory change.

there is a positive correlation between stress and HR. When analyzing it by gender, the stress index at rest for men was of 8.32 ± 3.57 points, while at competition it increased to 9.50 ± 3.69 points. For women at rest, it was 11.55 ± 9.44 points, at competition the score went up to 14.08 ± 6.40 points.

For muscle activation a difference between sides exists; 23 average events occur on the left side while 16 for the right side, as seen in *Figure 1*. The %MVC's average for the left side was $79 \pm 49\%$ and $60 \pm 31\%$ on the right side. The subjects that reported 0 events on either side means that the activation recorded on their muscle did not go over the threshold stated value at 20% MVC. After dividing the analysis between subjects that decreased and increased the anxiety levels, the ones that showed less anxiety after the competition had on average 10 events on the left side and 16 on the right side, with an %MVC's average of 53% and 56%, respectively. While the subjects that increased anxiety levels had on average 30 events on the left side and 18 events on the right side with an %MVC's of 96% and 82%, respectively. Finally, when dividing the analysis by gender, women had an average of 32 ± 25 ($110.76 \pm 63.65\%$ MVC) events for the left side and 17 ± 16 ($64.45 \pm 23.07\%$ MVC) for the right side. While for men the average was 9 ± 8 ($55.53 \pm 40.59\%$ MVC) events for the left side and 17 ± 17 ($55.23 \pm 44.82\%$ MVC) for the right side.

The majority of subjects that exhibited an increase in their anxiety levels after the video game competition were women, with a bigger change in HR and Stress Index, with more activation events at the masseter muscle with a bigger %MVC than the ones that showed a decrease on their anxiety, which is in accordance to what has been presented by Martens et al.,[28] that states that there are indicators and changes in somatic dimensions when presenting anxiety such as heart rate, respiratory rate and muscle tension. In studies similar to this one, where they measure anxiety and HRV in tennis players during competition,[29] they also found that there are gender significant differences in these variables, something that is similar to our results.

Subjects that have presented temporomandibular disorders have shown postural changes such as: elevated shoulder, pelvic obliquity, and head anteriority; in subjects that the disorder is related to the muscles, they have found most of the changes in the posterior view.[30] Since in our study we found out that subjects tend to have muscle activation over 20% MVC at times that is classified higher than chewing something soft (gum), and the average of the activation with events is above 53% as in chewing something hard (peanuts),[22] having these types of high eccentric contractions in a continuous way that lead to fatigue in a continuous cyclic way could cause loss in muscle strength, decrease in the range of motion and muscle swelling, which can cause the disorders stated before and therefore present postural changes.[31,32] we can deduce that after long periods of time of playing videogames in a competitive way, the muscles could get tense enough to start creating some postural changes while playing.

Even though the experimental sample is small, changes were found in subjects when playing this kind of videogames in competition mode. We do believe that the competition mode played a pivotal role in the experiment since the subjects played against their peers and had public watching that was intended to generate stress or anxiety on them, with the objective of seeing the activation of the masseter muscle. It is necessary to perform this experiment with a bigger sample and considering different ages, videogames types, take into consideration if the subjects use videogames in their regular lives. Also, identify who plays as a form of relaxation, and design the experiment with a control group playing without competition mode. It is suggested to measure if there were effectively teeth clenching when the muscle activation occurs, and to measure the craniocervical posture while playing the videogame.

CONCLUSION

There is a relationship between being in a stressful or anxious situation, playing videogames in competition mode, and muscle activation at the masseter muscle above levels similar to chewing something hard or tough, which could cause teeth clenching. According to our results, in this sample playing videogames in competition mode generates more anxiety in women than in men. To some subjects, playing videogames causes a decrease in their anxiety level measured with the STAI questionnaire. Playing video games in a competition mode generates physiological changes such as increased heart rate and heart rate variability and muscle activation above 20% MVC, as seen in this experiment.

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