Original Article

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Physiology Section

Effect of Mint Flavoured Chewing Gum in Observing Changes in Cognitive Function while Assessing Test Performance- An Interventional Study

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ABSTRACT

Introduction: Cognition is the mental process of acquiring knowledge and understanding through aspects such as awareness, perception, reasoning, memory and judgement. Chewing movement of jaw stimulates memory parts of brain by increasing blood flow and glucose delivery. Taste and odour of mint is also known to stimulate memory areas of the brain. The synergistic effect of chewing and flavour is expected to have a greater effect on cognition than chewing alone.

Aim: To assess the effect of use of mint flavoured, flavourless and absence of chewing gum on an individual's cognitive function among the medical undergraduates.

Materials and Methods: This comparative, interventional study, was conducted in the Department of Physiology at Velammal Medical College and Hospital, Madurai, Tamil Nadu, India, August 2019 to September 2019. Study involved 75 (39 females, 36 males) MBBS first year students, aged 18-20 years. Only students with cognitive score between 28-30 based on Mini-Mental State Exam (MMSE) score were included in the study and were divided into 3 groups. Group A (n=25) who were given mint flavoured chewing gum, Group B (n=25) given flavourless chewing gum and Group C (n=25) the control group, not provided with chewing gum. Baseline memory, Heart Rate (HR), Reaction Time (RT) and Stress Levels (SL) were recorded. Groups were taken into separate rooms where they were allowed to study a particular topic i.e Parkinson's disease for 30 minutes. Then they were allowed to take tests on standard Parkinson's questionnaire for 20 minutes and assessed based on the test performance. Group A and Group B were provided with chewing gums both during studying the topic as well as taking tests. Post intervention test performance (short term memory), HR, RT and SL were again recorded. Test performance was also assessed after one month to assess the effect of chewing gum on long term memory. One-way Analysis of Variance (ANOVA) and paired t-test were used to compare all the post test parameters between the three groups.

Results: A statistically significant increase in short term memory (p-value=0.001) and HR (p-value=0.001) were observed after intervention. Similarly, short term memory level of the three groups subjects statistically differed (p-value=0.001). When considering the reaction time (p-value=0.068) and stress level (p-value=0.927), there was no significant difference among the three groups after the intervention. Assessment of the test scores alone after one month (long term memory) showed a significantly higher score (p-value <0.001) in Group A when compared with the other two groups.

Conclusion: Mint flavoured chewing gum improves cognition as evidenced by improvement in test scores, alertness and attention. The performance in the flavour less chewing gum group was lesser than mint flavoured group, but significantly better than control group.

Keywords: Heart rate, Memory, Menthol, Reaction time

INTRODUCTION

Chewing gum is generally preferred for maintaining alertness and preventing sleepiness while studying or driving. It creates a sense of euphoria and helps rejuvenate especially flavoured ones. It tends to affect a range of cognitive functions including aspects of memory, selective and sustained attention, psychomotor speed and accuracy [1]. The chewing movement of jaw stimulates nerves and parts of brain leading to increase in cerebral blood flow [2]. This increased blood flow to brain enhances glucose delivery to memory associated regions improving both episodic and working memory [3]. Chewing also facilitates release of insulin which influences memory via central mechanism [4]. The process of mastication increases the sympathetic nervous system activity and decreases parasympathetic activity [5]. Chewing gums activates brain centres such as prefrontal cortex, middle frontal gyrus (Brodmann's area 9 and 46) in dorsolateral prefrontal cortex, right prefrontal motor cortex, precuneus, thalamus, hypothalamus and inferior parietal lobe which has an enhancing effect on memory [6]. Though the effect of chewing gum on cognition and memory was evaluated in previous studies, the results are still debatable [7-9].

Alertness refers to the ability to develop and sustain a state of mental readiness. Attention requires efficient perception, learning, memory, and reasoning. The parameters for measuring alertness and attention were heart rate and reaction time. Reaction time is the minimum time taken to respond to a stimulus and it helps in assessing the integrity of the nervous system. The effect of chewing produced changes in reaction time and Event Related Potential waveforms thereby improving the cognitive processing [10]. The role of chewing gum in altering alertness and attention has been proved in many previous studies [11,12]. Chewing of flavoured gum consistently increases the beta rhythm of electroencephalogram, which is supposed to be the rhythm associated with arousal and alertness [13]. However, few studies have also demonstrated the same arousal effect with flavourless and odourless chewing gum [6,10].

Stress induces the release of free radicals in the body and is considered to be the cause for various health related problems like atherosclerosis, endothelial damage, hypertension, asthma, irritable bowel syndrome, cancer [14]. Stress can impair the memory function [15]. The results of the previous studies on the effect of chewing gum on stress were controversial [16,17]. Few studies had reported a reduction in stress level under acute social stress, whereas no reduction in anxiety was found after chewing gum in other studies [16,17].

Smell is perceived in widespread areas of the limbic system including hippocampus, entorhinal cortex, orbitofrontal cortex and amygdala. Perception of taste occurs in the insular cortex. Integration of smell and taste sensation happens in the orbitofrontal cortex. All the above mentioned areas are associated with learning and memory [18]. It is expected that mint flavoured gums have an arousing effect in these areas both via taste and smell modalities. Though researchers were unable to point exactly why chewing gum boosts memory, attention and cognitive reasoning skills, the results of different studies clearly showed that it does. Chewing gum has similar effect to that of strenuous activity which boosts test performances.

Hence, it was hypothesised that mint flavoured chewing gum can improve memory by increasing blood flow and stimulating memory areas of the brain which could lead to improved test performance. The aim of the present study was to determine the effect of mint flavoured chewing gum on short and long term memory, alertness, attention and stress among the medical undergraduates.

MATERIALS AND METHODS

This comparative, interventional study, was conducted in the Department of Physiology at Velammal Medical College and Hospital, Madurai, Tamil Nadu, India, August 2019 to September 2019, after obtaining Institutional Ethical Clearance (IEC No: VMCIEC/24/2019).

Sample size calculation: Sample size was calculated with Cohen's D effect size fixed as 0.49 with 95% confidence level and 80% power. The minimum sample size thus calculated was 16.

Inclusion criteria: The study was initially explained in detail to all 150 first year MBBS students. Willing 126 first year MBBS students in the age group of 18-20 years, of both the genders, were enrolled for the study.

Exclusion criteria: The students were then screened and those with dental problems (undergoing orthodontic treatment, having fixed appliances), refractive errors, ophthalmic lesions, common cold, having difficulty in mastication (temporomandibular joint issues), under medication were excluded from the study. Smokers and those who have the habit of chewing gums regularly (more than 6/week) were also excluded.

Study Procedure

After the initial screening, baseline cognitive functions of 91 students were assessed using MMSE tool and only those with scores between 28-30 were included in the study [19]. Total 16 students were excluded, as the score was less than 28.

After obtaining informed voluntary consent from the remaining 75 students, the participants were randomly divided into three groups, three types of paper lots were created using alphabets A, B and C of 25 each. All the 75 students were instructed to select one paper lot and based on that, they were grouped accordingly.

- Group A (n=25) was the mint flavoured chewing gum group,
- Group B (n=25) was the flavourless chewing gum group
- Group C (n=25) was the control group which were not provided with chewing gum.

Wrigleys extra long lasting flavour (sugar free) peppermint gum (Illinois, U.S) was used in the mint flavoured group and Wrigleys gum base (synthetic rubber) was used in the flavourless chewing gum group. Group A and B were the interventional groups where exposure (chewing gum) was assigned.

Description of Intervention

The subjects were instructed to refrain from caffeinated drinks (and other stimulants) and exercise on the morning of the test. The test was conducted between 8 am-1 pm in the Department of Physiology. Demographic and anthropometric data including age, gender, weight and height was collected from all the 75 participants. Informed written consent was obtained from each participant. They were allowed to relax for 5 minutes after which visual reaction time and heart rate were recorded for all the students. They were then instructed to fill the stress questionnaire. As the topic chosen for the study was Parkinson's disease, a 10 minutes introductory lecture on this topic was delivered to all the 75 participants simultaneously. The students listened without taking notes. It was also informed to all the participants priorly that they will be placed randomly in either groups.

After that, they were divided into groups and sent to three separate rooms. Now group A was given one piece of mint flavoured chewing gum and group B was given one piece of flavourless chewing gum. They were told to chew constantly while reading. Group C was not given chewing gum. The participants were instructed to read the Parkinson's disease topic from Comprehensive Textbook of Medical Physiology by G.K Pal, for 30 minutes [20]. After a resting period of 10 minutes, they were allowed to take tests for 20 minutes on the same topic using a standard questionnaire simultaneously [21]. Group A were provided again with one piece of mint flavoured gum and group B with one more piece of flavourless chewing gum while doing the test. Immediately after the test, while group A and group B were still chewing, visual reaction time and heart rate was recorded and the post stress questionnaire was filled. After a period of one month all the groups were intimidated to take the same test with the same set-up and the test performance results were analysed. During this one month interval, the participants were restricted from chewing gums. After one month, they were allowed to take chewing gum only during the test performance.

Data Collection Method and Tools

- **Measurement of reaction time** [22]

Visual Reaction Time (VRT) was measured with the help of discriminatory and choice reaction time apparatus (Anand Agencies, Pune). The VRT for light stimuli with an accuracy of 0.001 second was measured in the sitting posture in a quiet room [22]. To record the baseline VRT for light stimulus (red), initially the subject was instructed about the complete procedure. The subject was asked to keep pressing the response button of the visual stimulus using the index finger of right hand. He should remove his finger immediately after he sees the stimulus. The value of VRT in milliseconds was displayed on the screen. Sufficient time was given for the participants to get acquainted with the procedure thoroughly. After the practice trial, once the patient felt comfortable, three readings were taken and the fastest response value was taken as the final reaction time.

- **Heart rate**

The Heart rate was measured with the help of masimo pulse oximeter to assess alertness [23].

- **Stress**

The Stress was assessed with the help of perceived stress scale questionnaire [15]. This scale includes 10 questions and the scores:

0-13 is considered as low stress,

14-26 as moderate stress

27-40 as high stress.

The participants read the Parkinson's disease topic from the book Comprehensive Textbook of Medical Physiology by G.K Pal [20].

- **Short and Long term memory**

Both short term and long term memory was assessed using Parkinson's disease questionnaire [21]. This included 20 questions on definition, causes, features and treatment of Parkinsons disease. The present study used a modified version of this questionnaire including the same 20 questions but for a score of 20 marks. The questions were of open-ended text type and each correctly answered question carried one mark.

STATISTICAL ANALYSIS

The data was entered into Microsoft excel and analysed using Statistical Package for Social Sciences (SPSS) version 20.0. Descriptive statistics like mean and standard deviation were used to represent continuous variables. One-way Analysis of Variance (ANOVA) was used to compare more than three groups on the basis of mean and standard deviation scores. Bonferroni multiple comparison test was used to compare the combinations of two groups in ANOVA. Paired sample t-test was used to compare the scores of before and after intervention. A 5% level of significance was considered statistically significant (p-value <0.05).

RESULTS

To ensure that all the selected participants (based on MMSE score) had the same level of heart rate, reaction time and stress before the beginning of the test, baseline equality verification was done. Statistical analysis was done to ensure that baseline parameter values were similar for all the groups before intervention. The p-value was non significant (p-value >0.05) among all the three group subjects, showing same level of heart rate, reaction time and stress [Table/Fig-1].

After the intervention, three groups' subjects' heart rates significantly differed (p-value <0.001). Especially, Bonferroni test revealed that the heart rates of control group subjects (A vs C has p-value=0.001 and B vs C has p-value=0.001) significantly differed compared to that of subjects of the other two groups. Similarly, short term memory level of the three groups subjects statistically differed (p-value=0.001). When considering the reaction time (p-value=0.068) and stress level (p-value=0.927), there was no significant difference among the three groups after the intervention [Table/Fig-2].

After the intervention, there was a significant improvement in the heart rates in group A (p-value <0.001) whereas there was no significant change in the heart rates in group B (p-value=0.665). In addition, reaction time of the subjects who use mint flavoured chewing gum had significantly reduced after the intervention (p-value <0.01). Similarly, the reaction time group A and B had significantly reduced after the intervention (p-value=0.006, p-value=0.001, respectively). However, stress level of the subjects was not significantly changed after the intervention in all three groups [Table/Fig-3].

Memory scores levels differed significantly across various groups after the intervention. Mint flavoured chewing gum group had high memory score compared to other groups [Table/Fig-4].

Overall, there was a significant change among the three group subjects in terms of heart rates, short term and long term memory levels after the intervention (p-value=0.001). Therefore, the intervention had the effect on the heart rates, short term and long term memory levels.

Group A and B had the similar level of effect on heart rate (p-value=0.371). However, group A had more effect on short term memory level compared to that of group B (p-value=0.029) after the intervention. When considered the within the group variations after the intervention, subjects who used group A had significant improvement in the heart rates and reduction in the reaction time. Therefore, group A was better than group B in terms of significant improvement in heart rate, short term and long term memory levels.

Parameter	Group A Mean±SD (n=25)	Group B Mean±SD (n=25)	Group C Mean±SD (n=25)	F-Statistic	p-value
Heart rate (beats/min)	83.00±10.09	86.72±15.63	78.80±10.20	2.614	0.080
Reaction time (milli seconds)	212.36±37.05	219.96±29.02	198.32±33.97	2.683	0.075
Stress level	19.12±9.08	19.64±6.50	19.52±7.11	0.032	0.969

[Table/Fig-1]: Comparison of heart rate, reaction time and stress level among the three groups before intervention.
One-way ANOVA *p-value <0.05 was considered statistically significant

Parameters	Group A Mean±SD	Group B Mean±SD	Group C Mean±SD	F-Statistic	p-value	Bonferroni, p-value		
						A vs B	A vs C	B vs C
Heart rate (beats/min)	93.36±10.55	88.20±15.63	76.08±7.46	14.342	0.001**	0.371	0.001	0.001
Reaction time (milli seconds)	193.84±29.04	197.44±23.77	178.16±37.52	2.799	0.068	1.000	0.224	0.088
Stress level	18.12±9.31	18.64±6.72	18.96±6.70	0.076	0.927	1.000	1.000	1.000
Short term memory level	13.80±5.80	10.54±3.63	7.40±3.09	13.600	0.001**	0.029	0.001	0.038

[Table/Fig-2]: Comparison of heart rate, reaction time, stress level and short term memory level among the three groups after intervention.
**p-value <0.01 will be considered statistically highly significant; STML: Short term memory level; One-way ANOVA, Bonferroni multiple comparison test

Parameters	Group A Mean±SD		Group B Mean±SD		Group C Mean±SD	
	Preintervention	Postintervention	Preintervention	Postintervention	Preintervention	Postintervention
Heart rate (beats/min)	83.00±10.09	93.36±10.55	86.72±15.63	88.20±15.63	78.80±10.20	76.08±7.46
	p-value=0.001**		p-value=0.665		p-value=0.021*	
Reaction time (milli seconds)	212.36±37.05	193.84±29.04	219.96±29.02	197.44±23.77	198.32±33.97	178.16±37.52
	p-value=0.006**		p-value=0.001**		p-value=0.002**	
Stress level	19.12±9.08	18.12±9.31	19.64±6.49	18.64±6.72	19.52±7.11	18.96±6.70
	p-value=0.244		p-value=0.223		p-value=0.265	

[Table/Fig-3]: Comparison of heart rate, reaction time and stress levels before and after the intervention within the groups while assessing the short term memory.
HR: Heart rate; RT: Reaction time; SL: Stress level; Paired sample t test; *p-value <0.05 will be considered statistically significant; **p-value <0.01 will be considered statistically highly significant

Group	N	Mean score of the test questionnaire (20 max)	Std. Deviation	F-value	p-value
Group A	25	8.2400	4.69734	8.681	0.001**
Group B	25	6.5800	2.64449		
Group C	25	4.0800	2.97097		

[Table/Fig-4]: Long term memory score after one month between the 3 groups.
**p-value <0.01 will be considered statistically highly significant; Statistical test used: one- way ANOVA

DISCUSSION

The act of mastication itself increases the blood flow to fronto-temporal cortex, caudate nucleus, thalamus, rolandic areas, insular cortex, cingulated gyrus and cerebellum as observed with xenon-enhanced computed tomography [24]. The temporomandibular joint movements due to chewing not only increases blood flow but also glucose delivery to mainly bilateral temporal cortical areas [2]. Since, the temporal cortex is associated with memory regions of the brain including hippocampus, activation of these areas occur. In the present study, test scores had increased significantly after chewing gum for 20 minutes in mint flavoured group indicating improvement in short term memory. Short term memory lasts for seconds to hours through processing mainly in hippocampus [25]. Since taste and smell centres are situated in the memory regions of the brain, chewing along with odour and taste of mint could have strongly activated memory areas of the brain improving the test scores in this group compared with the other two. This also explains the better performance in the flavourless chewing gum group compared with the non chewing control group. The results of the current study coincide with the results of the previous studies, where the test performance improved significantly in the gum chewing group when compared to the group which mimicked chewing movements and the group which did not chew gum [9,26]. But the present study results are contradictory to the results of a study done in 2008, where the chewing gum did not improve the short term memory performance scores [1].

Alertness and attention in the present study was checked by changes in heart rate and visual reaction time. A significant increase in heart rate was observed in mint flavoured group alone. This differs from the results of a chewing gum study where increase in heart rate was not observed, though there was increase in cortisol level and work performance [27]. The results of the present study is in accordance with many previous studies which had observed increase in heart rate due to chewing [1,9,27]. This was observed mainly during chewing and immediately after chewing. This increased heart rate by pumping more blood could have activated the memory regions of the brain. It could also be due to chewing associated increase in sympathetic activity and suppression of parasympathetic activity [4]. The decrease in heart rate in control group of present study could be due to increase in parasympathetic activity due to relaxation without any intervention.

In the present study, duration of visual reaction time decreased significantly within groups both in mint flavoured and in flavourless chewing gum group with no significant change between groups. This shows that an individual reacts faster to a visual stimulus due to the effect of mint flavoured chewing gum. The processing speed in brain had increased and this could be due to increased sympathetic activity and activation of ascending reticular activating system. The results of the present study coincide with the results of a previous study which showed quickened reaction time [12]. This quickening explains the increased activity in motor regions for alerting and executive networks especially anterior cingulate cortex and left frontal gyrus. Surprisingly reaction time significantly decreased in the control group and this could be due to the familiarity with the procedure when they did for the second time.

Stress scores did not change with chewing gum. In the present study, no stressful task was given to perform and post stress scores were assessed immediately after chewing gum for 20 minutes using a questionnaire. Regular gum chewing for 5 minutes, twice daily for 14 days had also resulted in significant decrease in stress level [8].

When all the three groups were assessed again with the same set of questions after a month for long-term memory, test scores were still significantly higher in mint flavoured group when compared with the other two groups. This could be due to stimulation of memory areas of the brain, mainly hippocampus, by the odour and taste of mint in the chewing gum. Hippocampus is essential for consolidating short term memory into long term memory and it was found that hippocampus is activated by mint flavoured chewing gum. The rate of chewing was not controlled and it was left to the choice of the participants as evidence indicates that more vigorous chewing does not modify the chewing effects on memory [27].

To confirm the effect of odour and taste in stimulating cognitive areas of the brain, a study was conducted by Hasegawa Y et al., where 25 healthy participants were divided into three groups-No taste/no odour chewing gum group, sweet taste/no odour gum group and sweet taste/lemon odour gum group. Cerebral blood flow was recorded during chewing using transcranial Doppler ultrasound and near infrared spectrometer while at the same time, bilateral masseter muscle activity was also monitored. Results revealed higher blood flow with sweet taste/lemon odour gum group compared to the other groups. This supports the additive role of both taste and odour in activating cognitive and motivational areas of the brain while chewing, than smell or taste alone [28]. A direct correlation was observed between peppermint oil aroma and improved memory by long term potentiation mechanism [29].

As it was recorded in a previous study that the effects of chewing gum started after 5 minutes of chewing and lasted for only 20 minutes, the present study participants were instructed to chew the gum for 20 minutes while studying and again for 20 minutes while doing the test [26].

Limitation(s)

The sample size was small. The results cannot be generalised as this study involved local medical students. Cross over between groups was not done. Heart rate and reaction time were not measured during long term memory assessment. Only subjective stress levels were assessed. Future studies may focus on measuring stress level after providing an exposure to acute stressor. Functional Magnetic Resonance Imaging (MRI) could be done to assess the changes in memory areas of brain. Further studies are also needed to study the long duration of gum chewing on memory.

CONCLUSION(S)

The present study results showed that mint flavoured chewing gum improved alertness and attention as shown by increase in heart rate and decrease in reaction time. Mint flavoured chewing gum improved memory as shown by the increase in test performance scores immediately as well as after one month. As participants chewed gum during learning and again during the test performance, their recall was improved by the taste and odour of mint which stimulated the memory areas of the brain. But the present study failed to show any improvement in stress level. Flavourless chewing gum improved memory, attention, and alertness when compared to the control group, without having any significant effect on stress level. Chewing mint flavoured gum before exams could help the younger generation perform better, as the amount of information to be processed and reproduced for students, especially medicos, is very huge. Mint flavoured chewing gums are cost-effective, easily accessible and can be chewed before the tests to improve cognitive function.

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