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ORIGINAL

Perception and sensory acceptance of sweet taste by individuals that who work/study on different shifts

Percepção e aceitação sensorial do gosto doce por indivíduos que trabalham/estudam em diferentes turnos

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ABSTRACT

Objective

This study aimed to evaluate the perception and sensory acceptance of sweet taste by individuals who work/study on different shifts.

Methods

Three groups of individuals were recruited: the Control group (individuals that study during the day and do not work at night), Group 1 (individuals that study in the evening) and Group 2 (individuals that work overnight). The individuals were submitted to a detection threshold test using sucrose solutions and a sensory acceptance test using a structured hedonic scale and a Just-About-Right scale for sweet taste in blancmange.

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Results

The detection thresholds were significantly higher for Groups 1 and 2. Individuals of Group 2 had a preference by blancmanges when having high sucrose concentrations, as well as had an ideal concentration of 10.50% sucrose against 5.95% sucrose for the Control group.

Conclusion

Our study shows a relationship between changes in the circadian cycle and the sensory perception and acceptance of sweet taste. More studies need to be performed to understand such relationships and their repercussions better.

Keywords: Circadian cycle. Detection threshold test. Sensory acceptance.

RESUMO

Objetivo

O objetivo deste estudo foi avaliar a percepção e a aceitação sensorial do gosto doce por indivíduos que trabalham/estudam em diferentes turnos.

Métodos

Foram recrutados três grupos de indivíduos: Grupo Controle (indivíduos que estudam durante o dia e não trabalham à noite), Grupo 1 (indivíduos que estudam à noite) e Grupo 2 (indivíduos que trabalham de madrugada). Os indivíduos foram submetidos ao teste de limiar de detecção utilizando soluções de sacarose e aos testes de aceitação sensorial utilizando escala hedônica estruturada e escala do ideal para o gosto doce em manjar branco.

Resultados

Os limiares de detecção foram significativamente maiores para os Grupos 1 e 2, sendo certo que os indivíduos do Grupo 2 tiveram preferência pelos manjares com altas concentrações de sacarose, assim como apresentaram uma concentração ideal de 10,50% de sacarose contra 5,95% de sacarose para o grupo Controle.

Conclusão

Este estudo mostra uma relação entre mudanças no ciclo circadiano e a percepção e a aceitação sensorial do gosto doce, mostrando que estudos mais aprofundados precisam ser realizados para entender melhor tais relações e suas repercussões.

Palavras-chave: *Ciclo circadiano. Teste de limiar de detecção. Aceitação sensorial.*

INTRODUCTION

Night activity, both work and study, has been increasing significantly in recent years. Although there has been an increase in night activity, human beings are naturally diurnal and their sleep-wake pattern is determined by the light/dark cycle. This phenomenon, called the circadian cycle, is regulated by a central clock in the brain and corresponds to a physiological cycle with periodicity of approximately 24 hours [1]. Working/studying at nighttime is related to the circadian cycle [2]. In 2017, researchers won the Noble Prize in Medicine for discovering the molecular mechanisms that control the circadian rhythm and demonstrating that the internal clock of plants, animals and human beings is responsible for readapting the physiology with high precision to the different phases of the day, regulating critical functions, such as behavior, hormone levels, sleep, body temperature and metabolism [3].

Circadian desynchrony is involved in several pathological conditions and the relationship between sleep and health is well established [4]. A similar relationship may be found between sleep and diet. A literature review by St-Onge *et al.* [5] shows that sleeping time and quality impacts energy intakes and diet quality, as well as the inverse, *i.e.*, diets, meals and foods can influence sleep regarding duration, efficiency and architecture. Moreover, some studies associate a bad sleeping pattern with inadequate nutrition, hypertension and obesity [6-9].

Few studies concerning the circadian rhythm/changes in sleeping patterns and sensory behavior were found [10-13]. Such studies show some relationships between circadian cycle/changes in sleep/sleep duration and the sensory behavior. Thus, there is much more to be researched in this field that is current and relevant, and no study comparing individuals that exercise their activities in different moments of the day/night was found. Therefore, we aimed to evaluate the perception and sensory acceptance of sweet taste by individuals that work/study on different shifts. We selected the sweet taste because it is linked closely to some pathologies, like obesity and diabetes *Mellitus*.

METHODS

The volunteer recruitment was performed from August, 2019 to March, 2020. The population investigated was divided into three groups: Control group (individuals that study during the day and do not work at night, recruited at Institute of Biosciences, Humanities and Exact Sciences/*São Paulo* State University 'Júlio de Mesquita Filho' (Ibilce/Unesp); Group 1 (individuals that study in the evening, recruited at *Faculdades Integradas de Fernandópolis*); and Group 2 (individuals that reverse the shifts, in other words, that work overnight, recruited at different hospitals; in this case, nurses, nursing technicians, receptionists, doctors and security were recruited). Thirty-seven individuals were recruited for each group. Although the desired number of volunteers to each group was fifty, their recruitment had to be discontinued due to the Coronavirus disease 2019 (Covid-19) pandemic. The volunteers filled out a questionnaire about demographic information, weight and height, pathologies, medication usage, alcohol consumption, study/work period, usual bedtime and hours slept per night/day. Regarding the inclusion criteria, only normal-weight individuals, i.e., with body mass index from 18.5 to 24.9kg/m2 were included in the study [14]. Moreover, the individuals were only included in each group if they had been in the same 'routine' for at least one year to guarantee their adjustment to those sleeping/waking and working/studying patterns as proposed by Silva *et al.* [15]. Exclusion criteria were individuals drinking any alcohol, pathologies related to food ingestion (diabetes, arterial hypertension, food intolerances, or allergies), pregnant women and use of medicines that could alter taste sensitivity. The Research Ethics Committee approved this cross-sectional study at the Ibilce of Unesp (Decision nº 3.047.435) and all the participants signed an informed consent form before enrolment in the study.

For the sensory analyses, sucrose of analytical standard was acquired from *Êxodo Científica* (*Sumaré*, Brazil), while whole UHT milk (Líder®) and corn starch (Maisena, Unilever®) were acquired at a local market. For Control group and Group 1, the sensory tests were performed in laboratory booths, under white light and at a temperature of 22°C. For the individuals in Group 2, the tests were performed in an adapted space at the hospital, under the same conditions as those of the laboratory. Two sensory tests were performed: (1) detection threshold for sweet taste: this test was carried out in two repetitions and, in both sessions, the procedure was the same. Following the geometric series of ISO 3972:2011 (Table 1), eight solutions with decreasing sucrose concentrations in distilled water were prepared [16]. The solutions were prepared 24hr before the tests, packed in plastic containers at around 8°C and served in quantities of 30mL at 26°C in odorless white 50mL plastic cups [17]. For each test, sucrose samples were presented in pairs (distilled water and solution). The first pair (one plastic cup with distilled water and another plastic cup with a solution of sucrose) of the most diluted concentration of sucrose was offered in that order to the individual, who had to indicate whether there was any difference between the two samples. In the case of a negative answer (no difference detected), the next plastic cup with solution along with one of distilled water was offered. The pairs of plastic cups were offered in ascending order of concentration until the individual detected a difference between the samples in two successive concentrations. When this occurred, the analysis was stopped and the mean of these two successive concentrations was taken as the detection threshold for that individual [17]. Individuals were instructed to rinse their mouth with distilled water and wait for 20 s before continuing the test. (2) evaluation of sensory acceptance of sweet taste: blancmange with different concentrations of sucrose were used as the food matrices to evaluate the acceptance of sweet taste. The amounts of sucrose added to the food matrix was taken from the ISO 3972:2011 (Table 1) concentration series, which are given as a mass/volume ratio, and were adapted to a mass/volume ratio, keeping the same geometric proportion used for the solutions [16]. Eighty grams of corn starch were added to each liter of milk at room temperature and the mixture was heated on a low heat until boiling. Then, one liter of this mixture was measured in a beaker and different quantities of sucrose were added as shown in Table 1. The mixture was homogenized with a glass rod and then separated into 30mL portions in white 50mL plastic cups, which were then refrigerated for 2hr before the sensory analysis to reach the desired consistency and cooled to a temperature of 18oC. Each individual received one cup with 30mL of blancmange with a disposable plastic spoon. The samples were presented in a balanced and monadic manner [18]. The sensory acceptance for sweet taste was assessed using a 9-point structured hedonic scale, ranging from 'extremely disliked' to 'extremely liked' and a 9-point Just-About-Right (JAR) scale, ranging from 'extremely less than ideal' to 'extremely more than ideal'.

Table 1 – Sucrose concentrations for the detection threshold test of sweet taste and acceptance test of blancmange. *Fernandópolis* (SP), *São José do Rio Preto* (SP), and *Votuporanga* (SP), Brazil, 2019-2020.

Detection threshold (g sucrose/L*)	Acceptance test (% sucrose**)
12.00	29.5
7.20	17.7
4.32	10.6
2.59	6.4
1.56	3.8
0.94	2.3
0.55	1.4
0.34	0.8
R=0.6	R=0.6

Note: *ISO 3972:2011 (ISO, 2011); **g sucrose/L blancmange. R: Geometric proportion (ISO 3972:2011).

Individuals from the Control group performed both tests from 9 h to 11hr or from 14hr to 16hr since they used to stay all day long at Ibilce/Unesp. Individuals of Group 1 and Group 2 performed tests from 18hr to 19 h before beginning class at *Faculdades Integradas de Fernandópolis* or working the night shift at the hospital, respectively.

The means of usual bedtimes were compared using the Student's t-test for independent variables, while the analysis of variance followed by the Tukey test (when pertinent) was performed for body mass index, age and sleep time. Moreover, the General Linear Model (GLM) was applied to sensory data: to the detection threshold, GLM was applied to have the group as categorical factor and age as a continuous factor; to the sensory acceptance, GLM was applied to have sample and group as categorical factors, as well as the interaction between such factors and age as a continuous factor. The Tukey test followed the GLM. These analyses were performed using the Statistica 7.0 software (StatSoft Inc., USA). Moreover, the results from the JAR scale as a function of stimulus concentrations was were fitted through a logarithmic function using the Excel 2016 software (Microsoft, USA). For that, the response 'y' was considered as 5, representing the 'ideal intensity' in the JAR scale, for obtaining the ideal sucrose concentration.

RESULTS

The groups (Table 2) were characterized similarly concerning the body mass index. For age, the mean increased from the Control group to Group 1 and Group 2. Because of this, age was considered a continuous factor in GLM. When asked about their usual bedtime (Table 2), individuals of the Control group and Group 1 slept at 23h18 min and 00hr12min, respectively; however, individuals of Group 2 presented no pattern in their answers since people who work overnight often work a shift scheme called 12/36hr, in which they work for 12 h overnight and rest for 36hr before the next shift. When they work the night shift, they sleep during the day, which may begin at 4hr or 8hr or even as late as 15hr. However, when they do not work and have a day's rest, they sleep during the night. Moreover, the sleep time decreased significantly from the Control group to Group 1 and then even more for Group 2 (Table 2).

Table 2 – Characterization of individuals in each group (n=37). *Fernandópolis* (SP), *São José do Rio Preto* (SP), and *Votuporanga* (SP), Brazil, 2019-2020.

Variables	Control	Groups	
		1	2
Sex			
Female	56.8%	59.5%	70.3%
Male	43.2%	40.5%	29.7%
Body mass index* (M±SD)	22.6±1.9**ns**	22.7±2.3**ns**	23.2±1.8**ns**
Age** (M±SD)	23.1±4.8**a**	30.8±11.1**b**	34.8±7.0**b**
Usual bedtime (M±SD)	23h18min±48min**a**	00h12min±56min**b**	-
Sleep time*** (M±SD)	431.4±50.7**c**	376.2±77.0**b**	319.5±91.7**a**

Note: *kg/m²; **Years; ***Minutes. Control group: individuals who study during the day and do not work at night. Group 1: individuals who study in the evening. Group 2: individuals who reverse the shift (work overnight). Ns: Non-Significance by the analysis of variance for the body mass index (p>0.05). Different letters in the same line for age and sleep time indicate significantly different means by Tukey test (p≤0.05). Different letters in the same line for usual bedtime indicate significantly different means by Student's *t* test (p≤0.05). M: Mean; SD: Standard Deviation.

The detection threshold was significantly lower for the Control group compared to Groups 1 and 2 (Table 3) and no significant difference occurred between Groups 1 and 2. Moreover, age did not affect the detection threshold of sweet taste (p=0.83). Therefore, regardless of the change in sleep pattern, a significant difference was found in the detection of sucrose, *i.e.*, individuals who change shifts or reduce their sleep time have lower sensitivity to sweet taste.

The sensory acceptance of the sweet taste of blancmanges was affected by sample and group, as well as by their interaction. However, age had no effect on the degree of liking (p=0.054) or the ideal intensity

Table 3 – Detection threshold (M±SD; n=37) for sucrose by different groups. *Fernandópolis* (SP), *São José do Rio Preto* (SP), and *Votuporanga* (SP), Brazil, 2019-2020.

Groups	Sucrose concentration (g/L)
	M±SD
Control	2.33±1.84**a**
1	4.78±3.12**b**
2	4.24±1.88**b**

Note: Control group: individuals who study during the day and do not work at night. Group 1: individuals who study in the evening. Group 2: individuals who reverse the shift (work overnight). Different letters in the same column indicate significantly different means by the Tukey test (p≤0.05). M: Mean; SD: Standard Deviation.

(p=0.087). Evaluating interactions between samples and groups, a divergent behavior was observed on the degree of liking to Group 2 in the function of samples (Figure 1A), despite the absence of significant differences (statistical results not shown). Until the sample with 10.6% sucrose, the degree of liking of Group 2 was below that of the other groups but it moved above the other groups for samples with 17.7% sucrose and 29.5% sucrose. This means that individuals in Group 2 prefer higher sucrose concentrations because the increase in sucrose content did not negatively affect the degree of liking, but it still increased.

For the ideal of intensity, there was a change in the ideal of the intensity of sweet taste from the concentration of 17.7% sucrose, stopping being near 'ideal intensity' (values close to 5) and reaching 'more intense than ideal' (means higher than 6) (Figure 1B). Thus, the increase in the sucrose from such concentration has become prejudicial to the sensory acceptance. Moreover, the behavior for the three groups was similar. Nevertheless, the ideal of the intensity of sweet taste for Group 2 was always below about the other groups. This indicates that the sucrose content was always less than the ideal for Group 2, showing, again, that this group prefers sweeter foods.

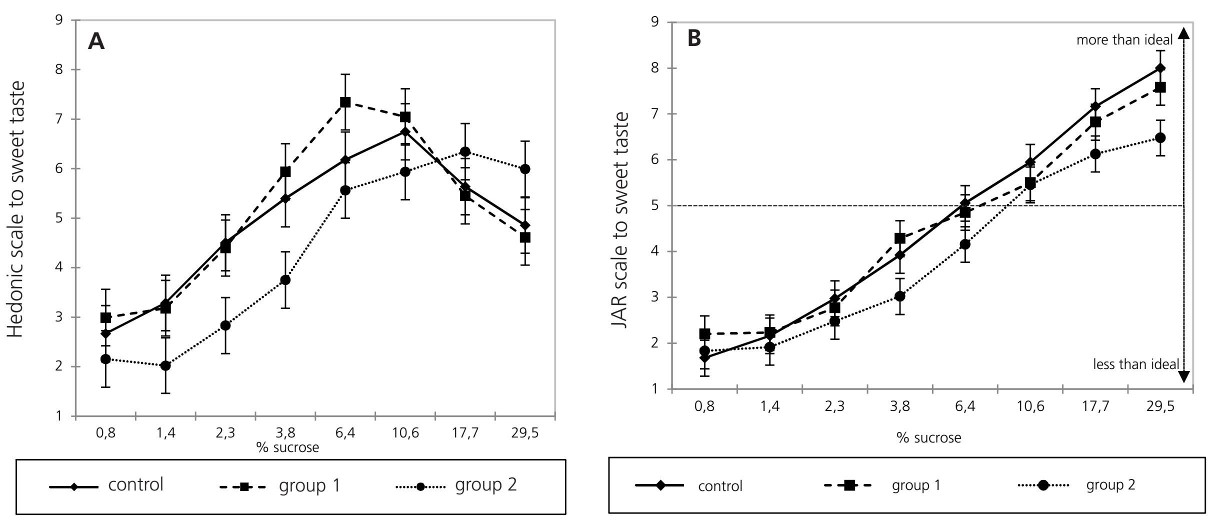

Figure 1 – Sweet taste acceptance through hedonic (A) and Just-About-Right (B) scales of the blancmanges considering the sample-group interaction (mean ± 95% confidence interval from n=37). *Fernandópolis* (SP), *São José do Rio Preto* (SP), and *Votuporanga* (SP), Brazil, 2019-2020.

Note: Control group: individuals who study during the day and do not work at night, Group 1: individuals who study in the evening and Group 2: individuals who reverse the shift (work overnight). The dotted line on the score 5 on Just-About-Right (JAR) scales indicates the middle of the scale (ideal intensity) and the arrows indicate scores in which the intensity is less or more than ideal. Different letters indicate different statistical means by the Tukey test ($p \leq 0.05$). Statistical results are not shown to sample-group interactions to not pollute the figure.

The results of the linear analysis corroborated for sucrose (Figure 2). The sucrose concentrations for having an ideal intensity of sweet taste (y=5) for the Control group, Group 1 and Group 2 are, respectively, 5.95%, 6.70%, and 10.50%. Thus, there is a difference between the three groups in the amounts of sucrose to have an ideal intensity of sweet taste. It increases from the Control group to Group 1 but even more so from the Control group to Group 2.

DISCUSSION

There are differences between groups composed by individuals that work/study on different shifts, standing out higher detection thresholds for Groups 1 and 2. In contrast, individuals of Group 2

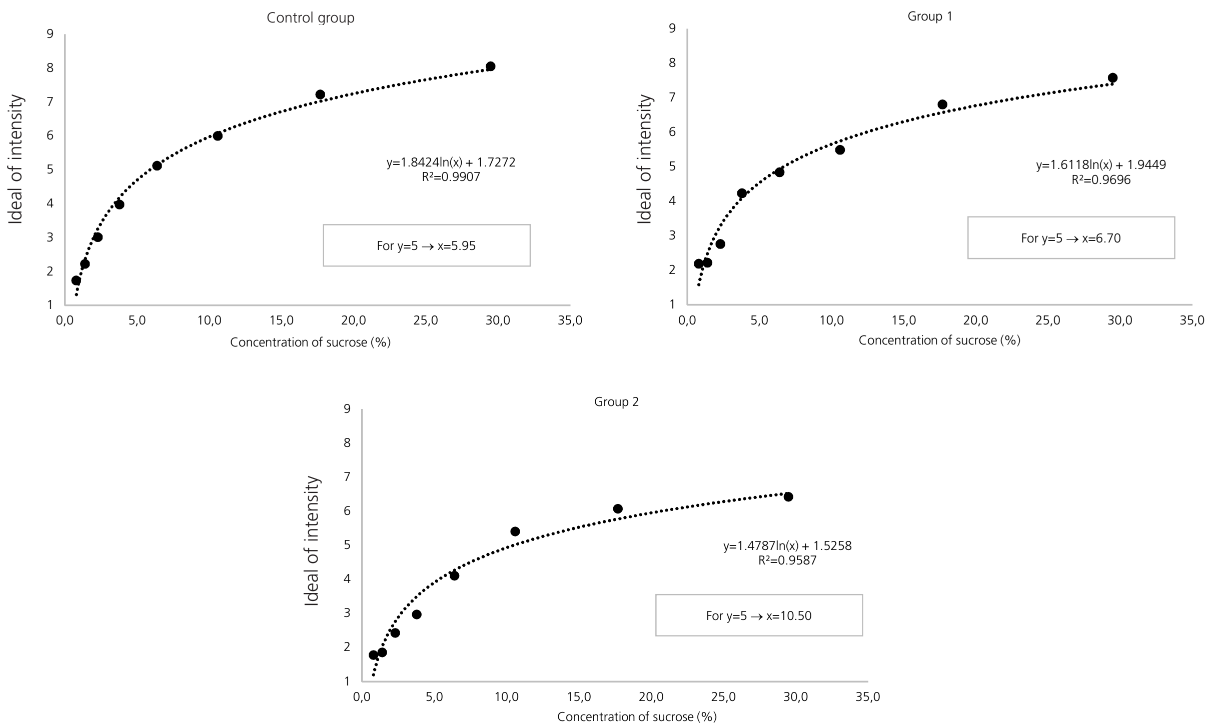

Figure 2 – Ideal of intensity of sweet taste in function of the sucrose concentration in the blancmange. *Fernandópolis* (SP), *São José do Rio Preto* (SP), and *Votuporanga* (SP), Brazil, 2019-2020.

had preference for blancmanges when having high sucrose concentrations. These results contribute to understanding the relationships between the circadian cycle and the sensory perception and acceptance of sweet taste, a relation that is important in that night activity, both work and study, has been increasing significantly in recent years.

For age, the mean increased from the Control group to Group 1 and to Group 2, which makes sense. Students who study during the day (Control group) are usually younger and recently graduated from high school. Among the students that study in the evening (Group 1), a lot of them work during the day, resulting in a longer wait to access higher education, which raises the average age. As for Group 2, all the individuals are professionals, justifying the higher average age. Thus, there is a natural variation in the age since the individuals present different profiles regarding their works and activities. And although age did not affect the detection thresholds, the significant difference in age between the Control group and the other two groups is a limitation of our study since the sensory perception may be reduced in the function of age, although a recent review showed that while tactile, auditory and visual perceptual abilities show clear signs of decline by the time human beings reach middle age, taste and smell sensitivity do not show any marked deterioration until individuals reach 60-70 years of age [19].

Sleep time decreased significantly from the Control group to Group 1 (around 55 minutes; p=0.014) and then even more to Group 2, which was on average reduced by a further 55min (p<0.0001). Pires *et al.* [20] also found similar results when comparing bus drivers that sleep during night versus bus drivers that sleep during the day, *i.e.*, bus drivers who slept during night slept from 40 to 60min more than those who slept during the day.

Few studies about the perception and acceptance of sweet taste due to sleeping have been found in the literature. No differences in sucrose perception were found in the function of the sleepiness [11]

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and no difference on the detection thresholds of sucrose was observed in individuals that slept less than 7hr or more than 7hr at the night before sensory testing, independently they were habitual long-sleepers or habitual short-sleepers [12], contrasting our study. Moreover, habitual long-sleepers, when slept during <7hr, preferred a higher concentration of sweet stimulus.

Similar to our study, an increase in preferred concentration for both sucrose and sucralose was observed in individuals after a curtailed night of sleep when compared to a habitual night of sleep [13]. Nevertheless, it is relevant to mention that the curtailed sleep was applied during one night, while, in our study, individuals were only included in each group if they had been in the same 'routine' for at least one year.

The recognition threshold for sweet taste varied during the day in humans with body mass index from 16.7 to 24.8kg/m^2, with the lowest thresholds in the morning (8hr) and the highest thresholds at night (22hr), which may be related to the variation of plasma leptin levels during the day [21]. Considering that the detection threshold was higher for Groups 1 and 2 compared to the Control group (Table 3) and that individuals of the Control group were assessed from 9 h to 11hr or from 14hr to 16hr and individuals of both Group 1 and Group 2 from 18hr to 19hr, our results may be related to the variation of plasma leptin levels. However, the individuals of that study had to have a regular sleep pattern to be recruited, different from our study and even with their findings of threshold detection varying during the day, it is not possible to affirm that an increase in the detection threshold for Groups 1 and 2 was due to the time of the day that the analyses were performed.

Even so, the time of performance of sensory analyses may be considered another limitation of our study. Although it is important to perform the sensory analysis sessions at the same time of the day for all individuals from all three groups, this was not possible due to the difficulty of individuals from different groups to adjust their schedules to those from another group, especially those individuals from Groups 1 and 2. However, each individual was always assessed at the same time of the day, and individuals from the same group.

The influence of increasing sugar consumption on glucose metabolism and its relation to sleep restriction has been investigated for some time. The effect of six nights of sleep restriction on glucose metabolism has been investigated and the researchers found a reduction in insulin sensitivity in the sleep-debt condition, which was accompanied by a significant increase in cortisol levels in a period of 24hr, primarily in the afternoon and at night [22]. Such findings have also been demonstrated in more recent studies. Nevertheless, sensory analyses were not performed in these studies [23,24]. Moreover, it is relevant to highlight that all these referenced studies looked at sleep deprivation for a short period, a maximum of ten days, while the volunteers with sleep restriction in this study (groups 1 and 2) have been in this situation for at least one year. Thus, these individuals may be subject to particularities of glucose metabolism, such as insulin resistance, leading to an increase in the detection threshold of the sweet taste.

CONCLUSION

The detection threshold for sweet taste was higher for Group 1 and Group 2, i.e., individuals in situations of changing shifts or reducing sleep time are less sensitive to sweet taste than individuals who study during the day, do not work at night and sleep significantly more. Moreover, individuals in Group 2 in comparison to the other groups had a preference for blancmanges with high sucrose concentrations. In conclusion, our study showed that changes in the circadian cycle impact sensory perception and acceptance of sweet tastes. More and deeper studies must be conducted to investigate such relationships and their repercussions.

CONTRIBUTORS

ACB CAMARGO was responsible for data collection, analysis and interpretation, writing and final approval. MBM CASTILHOS was responsible for statistical support, review, editing and final approval. AC CONTI was responsible for conceptualization, supervision, analysis, writing-original draft and final approval.

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