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ORIGINAL ARTICLE

Reinforcement Sensitivity Personality Factors, BMI, and Lack of Inhibitory Control as Predictors of Trait Food Craving

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Abstract

The present work aimed to test how reinforcement sensitivity theory (RST) personality factors predict the intense desire to eat known as trait food craving (FC). A nonclinical sample of 208 adults (18–30 years old) of both sexes participated in the study. Participants answered online questionnaires assessing sociodemographic data (BMI), RST personality factors (BIS/BAS scales), impulsivity (BIS-11), and distress symptoms (DASS-21). We tested a path analysis model with RST factors as the main predictors, impulsivity (Barratt-11) and distress (DASS-21) as mediators, and sex and body mass index (BMI) as covariates. The path analysis model explained 22.3% of the trait FC variance. BMI and BIS factor (punishment sensitivity) predicted trait FC directly. Mediation effects were also observed. Lack of inhibitory control mediated the effects of BMI, BAS-Fun Seeking, and BIS on trait FC variance. The findings suggest trait FC is influenced mainly by BMI, BIS, and lack of inhibitory control. RST factors and BMI were unrelated in this study, but both seem to predict trait FC. We discuss how reward and punishment sensitivity, BMI, and impaired inhibitory control might influence the learning of craving reactions to food.

Keywords Reinforcement sensitivity theory · BMI · Inhibitory control · Trait food craving

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Introduction

Individuals with obesity often display cravings for foods rich in sugar and fats (Cepeda-Benito et al., 2000; Taylor, 2019). These cravings have been shown to hinder the efficacy of weight reduction interventions and are well-represented by a construct called trait food craving (FC) (Fabbricatore et al., 2013; Meule et al., 2011). Higher levels of trait FC are often observed in women, in individuals with obesity and overweight, and in patients with eating disorders like bulimia nervosa and binge eating disorder (Fabbricatore et al., 2011; Moreno et al., 2008; Potenza & Grilo, 2014). Despite its association with obesity, it is unclear how trait FC intertwines with other variables associated with obesity, such as personality, distress symptoms, and impulsivity.

Trait FC scales usually have two main components: lack of control over eating and emotional eating, two phenotypes linked to overeating behavior and similar to personality constructs like impulsivity and neuroticism. A review of 70 studies published by Gerlach et al. (2015) suggests that both impulsivity-related and neuroticism-related traits are associated with obesity onset and course. This is in accordance with emotion-based models of overeating (Turton et al., 2017). These models suggest that trait negative affect (e.g., neuroticism) increases distress and leads to impulsive behaviors as a strategy to attenuate negative emotions. In consonance with this model, individuals with susceptibility to stress or major depressive disorder have a higher risk of developing obesity (Luppino et al., 2010), and problems with impulse control are observed in people with obesity (Emery & Levine, 2017) and in people with high trait FC (Meule & Kübler, 2014). Thus, one might note that trait FC instruments assess relevant components that impact overeating, like problems in inhibitory control and stress reactivity, but instead of focusing on eating behavior, the main outcome is craving for palatable foods (Cepeda-Benito et al., 2000; Taylor, 2019).

A promising personality model to understand trait FC is the reinforcement sensitivity theory (RST) (Gray and McNaughton, 2000). According to the RST, two broad temperamental/personality factors influence how individuals learn and interact with the environment. On the one hand, individuals with high reward sensitivity have higher reactivity of the neuroanatomical system called behavioral approach system (BAS) and are more susceptible to appetitive conditioning and positive reinforcement and exhibit increased responses to appetitive stimuli in general (Pickering & Smillie, 2008). Therefore, a person with increased reward sensitivity is more susceptible to the reinforcement effects of a myriad of rewarding stimuli, not just food. On the other hand, people with high punishment sensitivity have a higher reactivity of the behavioral inhibition system (BIS) and the Fight-Flight-Freeze system (FFFS). Subjects with punishment sensitivity are more prone to aversive conditioning, show heightened fear reactions to aversive stimuli, and present defensive approach responses and anxiety reactions in conflict situations (McNaughton & Corr, 2008).

Although often treated as similar to impulsivity and neuroticism, reward and punishment sensitivity were conceived as psychobiological factors that explain impulsive and defensive responses (Gray and McNaughton 2000; Corr and Perkins 2006). This is the case because RST factors were created based on the assumption that trait reward and punishment sensitivity represent brain systems that mediate reinforcement learning processes. This assumption was tested in several experimental studies, with results showing that reward sensitivity self-report measures are often associated with appetitive learning and positive reinforcement, whereas self-reported punishment sensitivity associates with aversive learning and avoidance (see Leue & Beauducel, 2008, for a meta-analysis). Although RST propose specific and objective neurobiological and learning outcomes as an index of systems activity, reward and punishment sensitivity are frequently measured using self-report instruments (Corr, 2016).

RST factors and trait FC are well-studied in the eating behavior literature. However, the relationship between these factors is rarely explored. The authors of the present article found only two studies that tested for the association between trait FC and RST factors. A positive association between reward sensitivity and trait FC was found in Franken and Muris' study in a sample of healthy women (Franken & Muris, 2005). Fabbricatore et al. (2011) found that trait FC had a positive correlation with punishment sensitivity in a study with people with obesity and binge eating symptoms (Fabbricatore et al., 2011). Testing the association between RST factors and FC is important because craving reactions might be learned by conditioning (Meule, 2020). In fact, Sinha (2018) and Meule (2020) discuss that craving responses occur either as a reaction to the presence of hyperpalatable food or as a reaction to negative emotion induction, which suggests that both appetitive and aversive conditioning influences the acquisition of craving reactions.

The aim of this study was to test how reward and punishment sensitivity are associated with trait FC. Our two main hypotheses were (a) RST personality factors, mainly BAS/reward sensitivity, would successfully predict trait FC variance, and (b) these factors would contribute more than impulsivity and distress symptoms. A path analysis model was created to test our predictions, with RST personality dimensions as the main predictors and impulsivity (lack of inhibitory control and lack of planning) and distress factors (depression, anxiety, and stress) as mediators. BMI and sex were added to the model as covariates because of their known association with trait FC (Cepeda-Benito et al., 2000; Potenza & Grilo, 2014).

Method

Design

This study was cross-sectional, with a correlational design. It was approved by the Ethical Research Committee of the Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA) under the register number 66098817.5.0000.5345. Informed consent was obtained online from all volunteers.

Participants

Participants were recruited with online advertisements on university pages from social media. Age (below 18 or above 30) and use of psychotropic medication were considered exclusion criteria. All participants had between 18 and 30 years, but 63 subjects were excluded because they were using psychotropic medications. Thus, the final sample consists of 208 participants ($M = 22$ years, SD = 3.39), 88% of which were females ($n = 183$). Regarding demographic data, 89.9% of them were single ($n = 187$), 86.1% were white ($n = 179$), 13.9% were Black ($n = 29$), and 51% had a family history of obesity ($n = 106$). About 24% ($n = 50$) were on a diet during the study period. Mean BMI was 23.91 kg/m^2 (from 16.90 to 45.31 kg/m^2), and based on BMI scores, 6.3% of participants had underweight status ($n = 13$, BMI < 18.5 kg/m^2), 65.4% had normal weight ($n = 136$, BMI between 18.5 and 25 kg/m^2), 14.4% had overweight status ($n = 30$, BMI between 25 and 30 kg/m^2), and 13% were with obesity ($n = 27$, BMI > 30 kg/m^2).

Instruments

Biosociodemographic Questionnaire

Participants provided information on their age, sex, height, weight, diet ("are you on a diet to lose weight now? 1—yes or 2—no), family obesity ("in your family, does anyone have or has had problems with obesity?" 1—yes or 2—no), and use of psychotropic medication.

Trait Food Craving Questionnaire (FCQ)

This instrument assesses trait FC, subdivided into nine dimensions and 39 items. The FCQ was created in a study with 217 participants ranging from 18 to 44 years old (Cepeda-Benito et al., 2000). A Brazilian version was validated by Medeiros and colleagues (Medeiros et al., 2016). The internal consistency in the present sample, measured by Cronbach's alpha, was $\alpha = 0.97$.

Behavioral Inhibition System/Behavioral Approach System Scales (BIS/BAS)

The BIS/BAS scales have four factors divided into 20 items: a punishment sensitivity factor (i.e., BIS) and three reward sensitivity factors (BAS-Drive [BAS-D]: the pursuit of goals; BAS-Reward Responsiveness [BAS-RR]: positive reaction to reward stimuli; BAS-Fun Seeking [BAS-FS]): the need to have immediate reward and new sensations) (Carver & White, 1994). The Brazilian version of the instrument presents the original four-factor structure (Weydmann et al., 2020).

The Cronbach's alphas in the current sample for the four factors were moderate to low: BIS ($\alpha = 0.72$), BAS-D ($\alpha = 0.77$), BAS-RR ($\alpha = 0.62$), and BAS-FS ($\alpha = 0.58$).

Barratt Impulsiveness Scale (Barratt-11)

The instrument contains 30 items with 4-point Likert response scales. Malloy-Diniz et al. (2015) revealed a two-factor structure (lack of inhibitory control and non-planning) for the Brazilian version. Lack of inhibitory control encompasses difficulties in motor inhibition and attentional control, while non-planning is related to actions made without preparation and lack of long-term planning. The reliability for lack of inhibitory control and non-planning was, respectively, 0.81 and 0.70 in the current sample.

Depression, Anxiety, and Stress Scale (DASS-21)

The DASS-21 was developed to assess stress, depression, and anxiety symptoms in recent weeks. The Brazilian version was adapted by Vignola and Tucci (2014) with a population of 242 adults. In the present sample, Cronbach's alphas were high for all three factors: depression ($\alpha = 0.90$), anxiety ($\alpha = 0.86$), and stress ($\alpha = 0.90$).

Procedure

Data were collected online via SoSci Survey website with an approximate total duration of 20 min (Leiner, 2014). The time that participants used to fill the questionnaires was registered to control for careless responses ($M = 17.39$, $SD = 5.58$). Seven participants were excluded because they answered the instruments in less than 10 min (minimum = 8.86 min), a time considered dubiously fast in comparison with the 15 mn obtained in our pilot study.

Data Analysis

Descriptive statistics revealed that most variables were non-normally distributed. Accordingly, bootstrapping (2000 samples) was used on all parametric analyses (Wright & Field, 2009). Two participants reported inaccurately values of height, and their data were not analyzed. The Statistical Package for the Social Sciences v. 22 (IBM) for Windows was used.

Predictors of FC were investigated with a path analysis model using robust maximum likelihood estimator (MLR) in the Mplus 8.11 software. Our sample size was estimated based on the Kline (2011) recommendation of at least 200 participants for the testing of structural equation models. BIS/BAS factors were used as the main independent variables. Impulsivity factors of the Barratt-11 and distress variables of the DASS-21 were used as mediators. To control for sex and BMI, these variables were included as covariates. In all analyses, $p < 0.05$ was adopted for significance, and effect sizes were reported.

Results

Correlations

The descriptive statistics of the main variables and their correlations are shown in Table 1. Two-tailed Pearson correlation analyses were used to investigate the associations between all variables (Table 1). The main variables associated with trait FC were BIS ($r(201)=0.29$, $p<0.001$), lack of inhibitory control ($r(201)=0.35$, $p<0.001$), stress ($r(201)=0.32$, $p<0.001$), anxiety ($r(201)=0.28$, $p<0.001$), and depression ($r(201)=0.31$, $p<0.001$). As expected, an association between trait FC and BMI was observed ($r(199)=0.30$, $p<0.001$). Consistently with one of our hypotheses (a), a marginally significant correlation between reward sensitivity and trait FC was observed ($r(201)=0.14$, $p<0.05$).

Path Analysis

A multivariate regression model using robust path analysis was tested. The main predictors of trait FC were reward (BAS-D, BAS-FS, and BAS-RR) and punishment (BIS) sensitivity factors from BIS/BAS. Impulsivity (lack of inhibitory control and non-planning) and distress variables (stress, anxiety, and depression) were included as mediators in the path model. Sex and BMI were included as covariates. A two-step strategy was implemented for reaching the final model. First, all possible relationships between variables were tested (saturated model). Second, following recommendations from previous studies, nonsignificant coefficients with low effect sizes (e.g., lower than 0.10) were constrained to zero in each model in order to attain a more parsimonious representation (restricted model) of the data (Gunzler & Morris, 2015). After following this strategy, the final path analysis model yielded an excellent fit, $\chi 2(30)=31.89$, $p=0.372$, RMSEA = 0.02, CFI = 0.996, TLI = 0.993, with the hypothesized variables explaining 22.3% of the variance in trait FC scores. Significant parameter estimates for the final model are shown in Fig. 1. Impulsivity (lack of inhibitory control) partially mediated the connection between the predictors BIS, BAS-FS, and BMI on trait FC. BIS and BMI had a direct impact on trait FC variance. Sex was not significantly associated with any variable in the model.

Discussion

In the present research, a theoretical model of the effects of RST factors over trait FC variance was tested. Results from the path analysis indicate that our first hypothesis (a) was not confirmed since reward sensitivity effect sizes were lower than the effects of lack of inhibitory control, BMI, and punishment sensitivity. Hypothesis (b) was partially supported, with higher effects of BIS scores in comparison with distress variables but with only an indirect effect of a single BAS factor. Considering the path analysis results, the main predictors in the present

Table 1 Correlations between FC and the other variables

	M	SD	2	3	4	5	6	7	8	9	10	11
1. Trait FC	127.21	43.01	0.30**	0.14*	0.07	0.10	0.29**	0.35**	−0.01	0.32**	0.28**	0.31**
2. BMI	23.95	5.05	1	−0.02	−0.11	−0.12	0.05	0.16*	0.07	0.03	0.09	0.15*
3. BAS-D	9.84	2.51		1	0.16*	0.43**	0.01	0.00	−0.21**	0.04	0.06	0.02
4. BAS-FS	10.08	2.43			1	0.15*	−0.02	0.28**	0.37**	0.10	0.03	0.08
5. BAS-RR	17.68	2.01				1	0.19*	−0.01	−0.23**	0.06	0.08	−0.04
6. BIS	22.91	3.50					1	0.32**	−0.15*	0.41**	0.37**	0.29**
7. Lack of inhibitory control	41.66	8.03						1	0.38**	0.54**	0.36**	0.49**
8. Non-planning	16.53	4.02							1	−0.01	−0.04	0.05
9. Stress	19.48	11.69								1	0.73**	0.66**
10. Anxiety	11.55	10.53									1	0.64**
11. Depression	13.53	11.66										1

FC, food craving; *BMI*, body mass index; *BAS-D*, behavioral approach system, Drive subscale; *BAS-FS*, behavioral approach system, Fun Seeking subscale; *BAS-RR*, behavioral approach system, Reward Responsiveness subscale; *BIS*, behavioral inhibition system

*$p < 0.05$

**$p < 0.001$

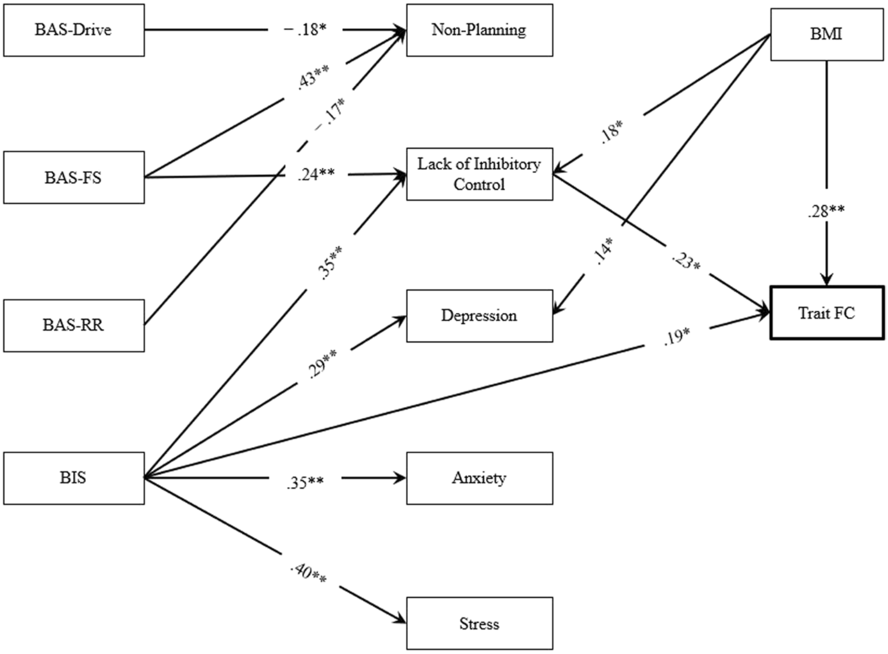

Fig. 1 Robust path analysis. Analyses were conducted controlling for correlations between mediators. Non-planning and inhibitory control ($r=0.35$**); inhibitory control and depression ($r=0.36$**); inhibitory control and anxiety ($r=0.26$**); inhibitory control and stress ($r=0.46$**); depression and anxiety ($r=0.59$**); depression and stress ($r=0.62$**); anxiety and stress ($r=0.69$**). Standardized regression weights (β) are presented for all significant values. Indirect effects for inhibitory control mediation were 0.081 for BIS, 0.055 for BAS-FS, and 0.041 for BMI (total indirect effect = 0.18): *$p<0.05$; **$p<0.001$

study were BIS and BMI, which exhibited both direct and indirect (by lack of inhibitory control) effects on trait FC and BAS-FS (mediated by lack of inhibitory control). Our initial analysis indicates that such a complex model addresses the multidimensional design of the trait FC questionnaire used (FCQ), which contains nine factors related to reactivity to food cues, eating to cope with negative emotions, lack of control over eating, and physiological drives to eat (Cepeda-Benito et al., 2000).

As expected, on both correlation and path analyses, BMI was related to increased trait FC. This association is expected, but Taylor (2019) pointed out that sample BMI is frequently not reported in studies with food craving measures. Reporting BMI is important not just to understand how craving reactions are related to weight but also to distinguish the effects of weight from the effects of other variables (personality in our case). The causal relationship between BMI and trait FC is uncertain. Craving seems to change less than BMI across time during weight reduction interventions, indicating an almost independent functioning (Buscemi et al., 2017). Although our study does not allow causal explanations, weight gain across time has detrimental effects that might explain the associations observed. Increases in BMI cause changes in metabolic functions, which may inflate craving reactions (Sinha, 2018). Also, evidence from human and animal models suggests that fat consumption downregulates dopaminergic functioning in brain areas relevant to impulse control, which might explain the common association between BMI and lack of inhibitory control (Emery & Levine, 2017; Horstmann et al., 2015). Notably, BMI was not associated with personality factors in our study, which indicates that BMI effects on trait FC are unrelated to reward and punishment sensitivity effects.

The correlation and the path analysis revealed different results concerning the relationship between BAS factors and FC. In the correlation analysis, BAS scores were marginally related to trait FC, a modest result in comparison with the results from Franken and Muris' study (Franken & Muris, 2005), which used a different instrument to assess BAS/reward sensitivity. Nevertheless, in the context of a multivariate model—where partial relationships are estimated after controlling for the influence of the remaining variables in the model—the BAS-FS factor predicted trait FC, mediated by lack of inhibitory control. BAS-FS represents the desire for rewarding experiences with immediate gratification and is associated with risk behavior (Carver & White, 1994; Voigt et al., 2009). In two independent studies, fast approach responses to food cues were observed in people with high levels of BAS-FS (May et al., 2016) and in individuals with high trait FC (Brockmeyer et al., 2015). Therefore, although BAS-FS and trait FC increase the reactivity to caloric food, craving responses may occur only when problems in motor impulsivity are present. This suggests that the need for immediate gratification and new reward experiences expressed by BAS-FS is insufficient to influence trait FC.

The multivariate model revealed the main effects of BIS on trait FC, suggesting a link between sensitivity to aversive stimuli and craving and showing a result similar to Fabbricatore et al. (2011). This was unexpected based on hypothesis (a), but the result seems to reflect an inner feature of trait FC since craving scores also correlated with distress symptoms in Table 1. The direct association observed in the path analysis suggests that BIS scores might have attenuated distress associations and captured the main effects due to similarities between BIS and distress measures. This is a viable explanation because BIS scores correlated with all distress symptoms and because BIS hyperactivity is thought to increase the odds of emotional disorders, with some evidence implying that a shared genetic mechanism is present in people with higher BIS scores and high emotional symptoms (Whisman et al., 2011). RST propose that individuals with higher BIS activation are more reactive to aversive conflict situations in which a behavioral response leads to either loss of reward or approach to an aversive stimulus (McNaughton & Corr, 2008). Therefore, direct effects of BIS on trait FC are likely to be related to the emotional eating factor of trait FC (e.g., items like "When I satisfy a craving, I feel less depressed"). We suggest that trait FC might occur as an adaptive response to decrease the anxiety derived from conflict situations in people with high BIS reactivity. Previous research (Meule & Kübler, 2012; Sinha, 2018) suggested that trait FC is not controlled mainly by the positive reinforcement effects of food but instead by its negative reinforcement effects. Therefore, our results seem to support the hypothesis of a negative reinforcement mechanism in trait FC. Given the evidence indicating that increased punishment sensitivity promotes learning by aversive conditioning and negative reinforcement (Leue & Beauducel, 2008), researchers could investigate in futures studies if high BIS scores facilitate the associations of negative emotions with craving responses.

Besides the main prediction of BIS over trait FC variance, an indirect effect was also observed mediated by lack of inhibitory control. The association of both factors with trait FC might have happened because FCQ includes items assessing both lack of control and emotional reactions to food (Cepeda-Benito et al., 2000). The indirect effect of BIS over trait FC indicates that craving responses could be an urgent reaction to attenuate negative emotions in individuals with a combination of high BIS and low inhibitory control. This phenomenon is sometimes referred to as negative urgency in the eating behavior literature and emotion-based models of overeating propose that impulsive responses are more prone in animals or humans stressed or with high stress reactivity (Turton et al., 2017). In previous studies, higher BIS scores were associated with a lack of inhibitory control in behavioral measures of impulsivity with a multitask performance, probably because demanding tasks shows presents more conflict situations (Eriksson et al., 2016; Leue et al., 2012). Coupled with the hypothesis from Dohle et al. (2018) that impulsive eating often happens as an escape response in situations involving high cognitive demand, one can assume that negative urgency should be frequent when subjects have higher BIS (e.g., low tolerance to conflict). However, further studies are needed to address whether craving and impulsive eating vary as a function of cognitive demand in subjects with high punishment sensitivity and problems with inhibitory control.

The limitations of the study are related to the sample, design, and instruments. The sample was composed of undergraduate students, mostly women, living in the southern region of Brazil, which might limit generalizations. The cross-sectional design with path analysis tests an a priori theoretical model, thus, further research should test this model with other samples. Regarding the instruments, the use of self-report measures provides a subjective index of individual differences. Although it was not the scope of this paper, objective measures of behavior would increase the validity of our data. In fact, the pressing demand for an RST scale to be considered valid and reliable is the correlation of self-report scores with objective outcomes like learning behavior or neurophysiological activity (Weydmann et al., 2021). The correspondence with objective behavior is one of the main criteria used to validate RST instruments, but even validated reward and punishment scales are susceptible to response bias (Weydmann et al., 2020). Only future studies will show if our results are replicated with objective measures of reward and punishment sensitivity and craving. Finally, the reliability scores of BIS/BAS scales were moderate to low, something that can attenuate the estimated relationships in our path model. Nevertheless, problems in the internal consistency of these scales are common, either because of response styles or because the BAS factors have only a few items (Pagliaccio et al., 2016; Weydmann et al., 2020). It will be useful to replicate our findings using other measures of reward and punishment sensitivity.

Conclusion

The results presented here can help broaden the understanding of how craving reactions are learned and impact overeating behavior. BMI, personality factors, and lack of inhibitory control might entail a bridge between normal craving reactions and the intense desire to eat known as trait FC. Particularly, the use of RST personality factors is useful because they provide a psychophysiological model of how the brain reacts to the environment and influences learning. In our study, BMI, reward, and punishment sensitivity were unrelated and differentially associated with lack of inhibitory control and trait FC, indicating that impulsive behavior and craving reactions are not associated just to weight. The longitudinal assessment of trait FC and RST personality factors in lean individuals can lead to relevant data about how conditioned craving reactions are learned and how they impact obesity onset.

Author Contribution In order to provide more information about the paper creation process, we declare the authors' contributions. We followed CRediT guidelines. Gibson Weydmann: conceptualization, methodology, validation, investigation, project administration, and writing the original draft. Nelson Hauck: validation, formal analysis, writing, reviewing, and editing. Roberto Decker: conceptualization, visualization, writing, reviewing, and editing. Heitor Holland: visualization, investigation, and data curation. Luciana Lopes Corrêa: visualization, investigation, and data curation. Alcyr Alves de Oliveira: resources; writing, reviewing, and editing. Lisiane Bizarro: methodology, writing, reviewing and editing, and supervision.

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Availability of Data and Material The authors might share data and scripts from statistical analysis with others when requested.

Declarations

Ethics Approval All procedures performed in this study were approved by the Ethical Research Committee of the Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA), register number 66098817.5.0000.5345, and are in accordance with the 1964 Helsinki Declaration and its revision in 2000.

Consent to Participate Online informed consent was obtained from all individual participants included in the study.

Consent for Publication The authors guarantee that all participants accepted data publication in the informed consent.

Competing Interests The authors declare no competing interests.

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