



Child's body mass index and mother's obesity: the moderating role of physical fitness

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Abstract

The aim of this study was to verify the association between children's body mass index and their mother's obesity, considering children's physical fitness as a possible moderator. Cross-sectional study developed with 1842 children and adolescents, aged seven to 17 years, from Santa Cruz do Sul-RS, Brazil. Body weight and height were assessed to determine body mass index. Cardiorespiratory fitness was determined by the 6-min walk/run test and muscular strength through the lower limb strength test. Mother's perception of obesity was self-assessed. Moderation was tested through a SPSS program extension. Results indicated that higher children's body mass index ($p < 0.001$) and lower levels of cardiorespiratory fitness ($p = 0.001$) and muscular strength ($p = 0.035$) were associated with mother's obesity. Likewise, higher body mass index ($p < 0.001$) and lower cardiorespiratory fitness ($p < 0.001$) in adolescents were associated with maternal obesity. Moreover, physical fitness moderates the relationship between body mass index and mother's obesity in children (cardiorespiratory fitness: $\beta = -0.006$; 95% CI = $(-0.010, -0.001)$; muscular strength: $\beta = -8.415$; 95% CI = $(-12.526, -4.304)$) and in adolescents (cardiorespiratory fitness: $\beta = -0.004$; 95% CI = $(-0.008, -0.0008)$; muscular strength: $\beta = -2.958$; 95% CI = $(-5.615, -0.030)$).

Conclusion: increasing physical fitness is an important strategy to protect youths from high body mass index, when their mothers are obese.

What is Known:

- Mother's obesity is associated with their children's body mass index.
- Parents' obesity is associated with their children's physical fitness

What is New:

- Cardiorespiratory fitness and muscular strength are moderators in the relationship between mother's obesity and BMI of their children.
- Children and adolescents with high cardiorespiratory fitness and muscular strength levels are protected against elevated body mass index, considering mother's obesity

Keywords Body mass index · Mother's obesity · Cardiorespiratory fitness · Muscular fitness · Children · Adolescents

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Abbreviations

BMI	Body mass index
CRF	Cardiorespiratory fitness
LLS	Lower limb strength
SPSS	Statistical Package for Social Sciences
UNISC	University of Santa Cruz do Sul

Introduction

Obesity in children and adolescents is a public health concern worldwide [1, 2]. Prior data have indicated that obesity in childhood tracks into adolescence and into adulthood [3, 4]. Likewise, obesity is associated with an increasing prevalence of several noncommunicable diseases, such as dyslipidemia, hypertension, and type 2 diabetes [5]. Moreover, a systematic review study showed that obese children and adolescents are more likely to suffer from depression and depressive symptoms [6].

Parent's obesity has been considered an important risk factor for being overweight, once children whose parents are obese have a high body mass index (BMI) [7]. Additionally, previous studies have indicated that compared with fathers, mothers have a greater impact on children's BMI [8, 9], conceivably because there is an increase in childhood obesity when mothers are obese [10]. In addition, children's lower muscle fitness and lower cardiorespiratory (CRF) physical fitness is associated with their parents' obesity [7, 11].

Taking these aspects into consideration, the present study intends to address new evidence from the perspective of trying to understand if a relationship between BMI and physical fitness of children/adolescents and their mother's obesity is observed. In addition, another literature gap we intend to fill is the level of physical fitness that children and adolescents must achieve to protect them from high BMI levels when their mother has obesity. Therefore, the aim of the present study was to verify the association between children/adolescent's BMI and their mother's obesity, considering children/adolescent's physical fitness as a possible moderator.

Methods

This cross-sectional study was developed with 1842 children and adolescents, aged seven to 17 years (mean and standard error 11.41 ± 0.06) from students of public and private schools in the urban and rural areas of the city of Santa Cruz do Sul-RS, Brazil. Children were selected by conglomerate. In 2004, a survey was conducted in this city, which indicated the number of schools ($n = 50$) and students ($n = 17,688$) enrolled. From this, a sample size calculation was made considering the population density of schoolchildren in all regions of the city (south, north, east, west, center) including public

(municipal and state) and private schools. Then, schools were randomly selected and invited to form a cohort and the evaluations were developed in the following years: 2004–2006 (Phase I), 2007–2009 (Phase II), 2011–2012 (Phase III), 2014–2015 (Phase IV), and 2016–2017 (Phase V). This study was approved by the Human Research Ethics Committee of the University of Santa Cruz do Sul (UNISC) under certificate number 1.498.305. Mothers or legal guardians of the children and adolescents signed free and informed consent forms.

The sample size calculation for the present study was done through to the software G*Power version 3.1. A weak effect size ($F^2 = 0.02$), a statistical power of 0.90, and alpha (type I error rate) of 0.05, with six predictors, were considered. The minimum number of children and adolescents was established as 878. However, to avoid probable difficulties with sample loss, an increase of 5% was assumed, totalling 922 in each age group (children and adolescents).

The following inclusion criteria were determined: informed consent obtained from all individual participants; children and adolescents aged between seven and 17 years. The exclusion criterion was to present any physical incapacity or health problem that makes it impossible to execute the physical fitness tests.

Measures were taken in 2016/2017 at the University of Santa Cruz do Sul by trained researchers. Body weight and height were assessed using an anthropometric scale with a coupled stadiometer (Filizola®, precision of 0.01 kg and 0.01 cm, respectively). The evaluated participants were bare-foot and in light clothing. Then BMI was determined by dividing weight (kg) by height (m) squared.

Physical fitness was assessed according to *Projeto Esporte Brasil* procedures [12]. CRF was determined through the 6-min walk/run test. The students were divided into groups, appropriate to the dimensions of the sports court. The importance of maintaining a constant running pace was emphasized to the participants, avoiding walks and sprints, and they were oriented to run as long as possible. Students were informed when the test reached 3 and 5 min. Through a sign, at the end of the test, the students interrupted the test remaining in the place where they were, so the distance reached (in meters) during the 6 min could be recorded. Then, the estimation of CRF was obtained by multiplying the number of laps by meters covered. Muscular strength was determined through the lower limb strength (LLS) test. The test was carried out with a measuring tape fixed to the floor. The participants were positioned immediately behind the starting line, with feet parallel and knees partially flexed. At the signal, they were instructed to jump with both feet at the same time as far as possible [12].

Information regarding the perception of mother's obesity was obtained by a self-reported questionnaire, in which there was a table where mothers could indicate the presence of cardiac, pulmonary, or circulatory diseases before the age of 55 years. Obesity was one of the included diseases. The

questionnaire was sent via the children, to be answered by their mothers. The possible answers were yes and no. This information was obtained from 1842 mothers.

Sexual maturation was assessed according to Tanner's criteria [13], using images of development of breast stages for girls, genital stages for boys, and pubic hair for both. Children and adolescents were asked to indicate the image accordingly to their current stage. Five sexual maturation stages were considered and then categorized into prepubertal (stage I), initial development (stage II), continuous maturation (stages III and IV), and matured (stage V). This kind of measure avoids possible embarrassment by the evaluated and is validated as an appropriate measure of sexual maturation [14–16].

Socioeconomic status was assessed by the questionnaire of the Brazilian Association of Research Companies (2015) [17], considering the head of household's educational level and the quantity of certain items they have, such as a car, washing machine, bathroom, among others. A score was obtained according to the answers; thus, the sum of these scores indicated the family's social class: A1, A2, B1, B2, C1, C2, D–E, with A1 the highest and D–E the lowest class.

Statistical analyses

Data were analyzed with descriptive statistics, presenting mean, standard error, and frequency. Categorical variables were transformed into dummy variables and the chi-squared test was used to examine differences between children (6 to 11 years) and adolescents (12 to 17 years). For continuous variables, the independent two-tailed *t* tests were used.

PROCESS macro, which is a program extension for the Statistical Package for Social Sciences (SPSS) version 24.0 (IBM Corp, Armonk, NY, USA) was used for moderation analyses through linear regression models. The mother's obesity was considered as an independent variable, and children's and adolescent's BMI was the dependent variable, while CRF and muscular strength were the moderator variables. The models were defined as follows: (1) linear associations between CRF and BMI; (2) linear children's/adolescent's BMI and mother's obesity; (3) linear associations between BMI and interaction of CRF*mother's obesity. The same models were considered for LLS as a moderator. The Johnson-Newman technique was applied, in which CRF and muscular strength were classified according to tertiles. This technique also allows the determination of the point at which the relationship between children's BM and maternal obesity ceases to exist for CRF and LLS [18]. All analyses were adjusted for sex, sexual maturation, and socioeconomic level. The probability value $p < 0.05$ was considered to be significant for all analyses.

Results

A total of 1842 children and adolescents (42.7% boys) participated in the study. The mother's obesity was observed in 8.0% of the sample. Adolescents presented higher mean values for height, weight, BMI, and LLS than children (Table 1).

An inverse linear association between children's CRF and muscle strength with mother's obesity is seen in Table 2. For adolescents, this relationship was observed only with CRF. The mother's obesity was also positively associated with her children's BMI in both groups (children and adolescents). Furthermore, children and adolescents' CRF and LLS were associated with BMI.

When analyzing the moderation effect of CRF and muscular strength in the relationship between mother's obesity and their children's BMI, the results suggest an interaction for CRF and the mother's obesity with BMI in both groups (children and adolescents). The same was observed with muscular strength, both in children and adolescents (Table 3).

Considering the interaction between the mother's obesity with CRF and muscular strength, we seek to find the point from which CRF would be able to protect children and adolescents from high BMI, considering the presence or absence of mother's obesity. In Fig. 1, it is shown that children aged between six and 11 years, whose mothers were obese, were more likely to have a high BMI. An association was observed in low (672.27 m) and medium (833.74 m) CRF. The same was found for muscular strength, at low (0.96 m) and medium (1.19 m) points. For children who have high CRF and muscular strength, the association was no longer observed, suggesting that children who reached more than 945.66 m and 1.31 m in the CRF and muscular strength tests, respectively, were protected from high BMI.

Adolescents whose mothers were obese were more likely to have high BMI; thus, an association was observed in low (711.23 m), medium (927.47 m), and high (1143.72 m) CRF. The same was found for muscular strength, at low (1.14 m), medium (1.46 m), and high (1.77 m) LLS points. Additionally, adolescents who reached more than 1164.81 m and 1.99 m in the CRF and muscular strength tests, respectively, were protected from high BMI. Therefore, CRF and muscle strength seem to be important components for BMI of children and adolescents who have obese mothers (Fig. 2).

Discussion

The main findings of the present study indicate that lower levels of CRF and muscular strength in children and lower levels of CRF in adolescents, as well as with higher BMI in children and adolescents, were associated with their mother's obesity. Moreover, to the best of the author's knowledge, this

Table 1 Participant's characteristics

Characteristics	SE (mean)		
	Total (n = 1842)	Children (n = 928)	Adolescents (n = 914)
Age (years)	0.063 (11.41)	0.047 (9.14)	0.050 (13.72)
Height (m)	0.003 (1.50)	0.003 (1.39)	0.003 (1.61)*
Weight (kg)	0.358 (47.05)	0.373 (37.68)	0.427 (56.60)*
BMI (kg/m ²)	0.095 (20.35)	0.125 (19.08)	0.132 (21.65)*
CRF (m)	4.580 (879.46)	5.344 (832.90)	7.143 (926.95)*
LLS (m)	0.007 (1.32)	0.007 (1.19)	0.010 (1.46)*
		n (%)	
Mother's obesity			
Yes	148 (8.0)	69 (7.4)	79 (8.6)
No	1694 (92.0)	859 (92.6)	835 (91.4)
Maturational stage			
Prepubertal	396 (21.7)	377 (41.6)	19 (2.1)*
Initial development	438 (24.0)	313 (34.5)	125 (13.6)*
Continuous maturation (stages III and IV)	831 (45.6)	195 (21.5)	636 (69.4)*
Matured	157 (8.6)	21 (2.3)	136 (14.8)*
Sex			
Boys	798 (42.7)	409 (43.4)	389 (42.1)
Girls	1069 (57.3)	533 (56.6)	536 (57.9)
Socioeconomic status			
A	75 (4.0)	30 (3.2)	45 (4.9)*
B1	127 (6.8)	56 (5.9)	71 (7.7)
B2	487 (26.1)	240 (25.5)	247 (26.7)
C1	559 (29.9)	284 (30.1)	275 (29.7)*
C2	468 (25.1)	257 (27.3)	211 (22.8)
D-E	152 (8.1)	76 (8.1)	76 (8.2)

BMI body mass index, *CRF* cardiorespiratory fitness, *LLS* lower limb strength, *SE* standard error

*Significant independent *t* test for differences between means for children and adolescents ($p < 0.05$). Standard error of the mean (in parentheses) is quoted for each characteristic (continuum variables)

is the first study to investigate CRF and muscular strength as moderators in the relationship between children's BMI and their mother's obesity, which suggests that children and adolescents with high CRF and LLS levels are protected against elevated BMI, even taking into considering their mother's obesity.

Our results are in line with a recent meta-analysis, which indicated a 264% increase in the chances of the child being obese when the mother has the same profile [10]. In this same perspective, Golab et al. [19] sought to identify whether complications during pregnancy would influence the children's obesity, regardless of maternal adiposity. They concluded that the strategies should focus on reducing the mother's BMI, since a direct relationship between complications and the children's adiposity status is unlikely. Besides, a study followed a group of parents, mothers, and children to verify the association between fat of children and their parental BMI, and showed an association only between the condition of the child and the condition of the mother [8].

The current findings showing the association between children's physical fitness and their mother's obesity are also in agreement with the literature. Cadenas-Sanchez et al. [7] presented a negative association between offspring's muscular strength and maternal BMI. Lower levels of CRF in children and adolescents were associated with overweight/obese parents, compared with normal weight parents [11]. When analyzing prenatal conditions, Mintjens et al. [20] and Tikanmäki et al. [21] showed that reduced CRF in children and adolescents was associated with maternal prepregnancy overweight/obesity.

Our findings have also shown that physical fitness components are associated with children's and adolescent's BMI. Fairchild et al. [22] found that children with the highest BMI have the lowest CRF. Moreover, those children who were of normal weight, but had a high percentage of fat, had lower CRF levels. The same was found in a study that looked at Mexican, Kenyan, and Canadian children [23]. Concerning muscle fitness, a study carried out with Colombian children showed that those with high levels of this component had a

Table 2 Linear association between children’s physical fitness and body mass index with mother’s obesity

	Children (n = 928)			Adolescents (n = 914)		
	β	CI (95%)	p	β	CI (95%)	p
Cardiorespiratory fitness						
Mother’s obesity						
Yes	-64.064	(-103.535, -24.594)	0.001	-93.110	(-135.297, -50.923)	<0.001
No	1			1		
Muscular strength						
Mother’s obesity						
Yes	-0.059	(-0.114, -0.004)	0.035	-0.029	(-0.089, 0.031)	0.339
No	1			1		
Body mass index						
Mother’s obesity						
Yes	2.822	(1.880, 3.763)	<0.001	3.268	(2.359, 4.177)	<0.001
No	1			1		
CRF	-0.008	(-0.009, -0.006)	<0.001	-0.005	(-0.006, -0.004)	<0.001
LLS	-3.562	(-4.676, -2.449)	<0.001	-2.319	(-3.321, -1.316)	<0.001

All analyses were adjusted for socioeconomic status, sex, and sexual maturation
 CRF cardiorespiratory fitness, LLS lower limb strength

better state of physical health, including lower BMI [24]. Another similar study that investigated a two-decade trend showed that muscle fitness was inversely associated with the BMI of Czech children [25]. This might be explained considering that physical exercise practice is able to improve physical fitness and consequently influence children’s BMI [26].

We go further in order to understand the moderating role of physical fitness of the children/adolescent. Indeed, our data have indicated that CRF and muscular strength are moderators

of the association between BMI of children and their mother’s obesity. In addition, our data provided the level of CRF and LLS needed so that the association no longer existed. That is, children who reached more than 945.66 m and 1.31 m in the CRF and muscle strength tests, respectively, were protected from high BMI. The same was observed for adolescents, the ones who reached more than 1164.81 m and 1.99 m in the CRF and muscle strength tests, respectively, were protected from high BMI.

Table 3 Moderation of CRF and LLS in the linear relationship between BMI of children/adolescents and their mother’s obesity

	Body mass index					
	Children (n = 928)			Adolescents (n = 914)		
	β	CI (95%)	p	β	CI (95%)	p
Cardiorespiratory fitness						
CRF	-0.001	(-0.006, 0.004)	0.696	0.0008	(-0.003, 0.005)	0.740
Mother’s obesity						
Yes	6.874	(3.144, 10.603)	<0.001	6.927	(3.447, 10.406)	<0.001
No	1			1		
CRF × mother’s obesity	-0.006	(-0.010, -0.001)	0.011	-0.004	(-0.0086, -0.0008)	0.018
Lower limb strength						
LLS	5.931	(1.391, 10.470)	0.010	1.037	(-2.063, 4.137)	0.511
Mothers obesity						
Yes	12.249	(7.437, 17.061)	<0.001	7.560	(3.549, 11.571)	<0.001
No	1			1		
LLS × mother’s obesity	-8.415	(-12.526, -4.304)	0.001	-2.958	(-5.615, -0.300)	0.029

All analyses were adjusted for socioeconomic status, sex, and sexual maturation
 BMI body mass index, CRF cardiorespiratory fitness, LLS lower limb strength

Fig. 1 Children's cardiorespiratory fitness (a) and muscular strength (b) of children in the relationship between BMI of children and their mother's obesity. CRF cardiorespiratory fitness, LLS lower limb strength. All analyses were adjusted for sex, sexual maturation and socioeconomic status

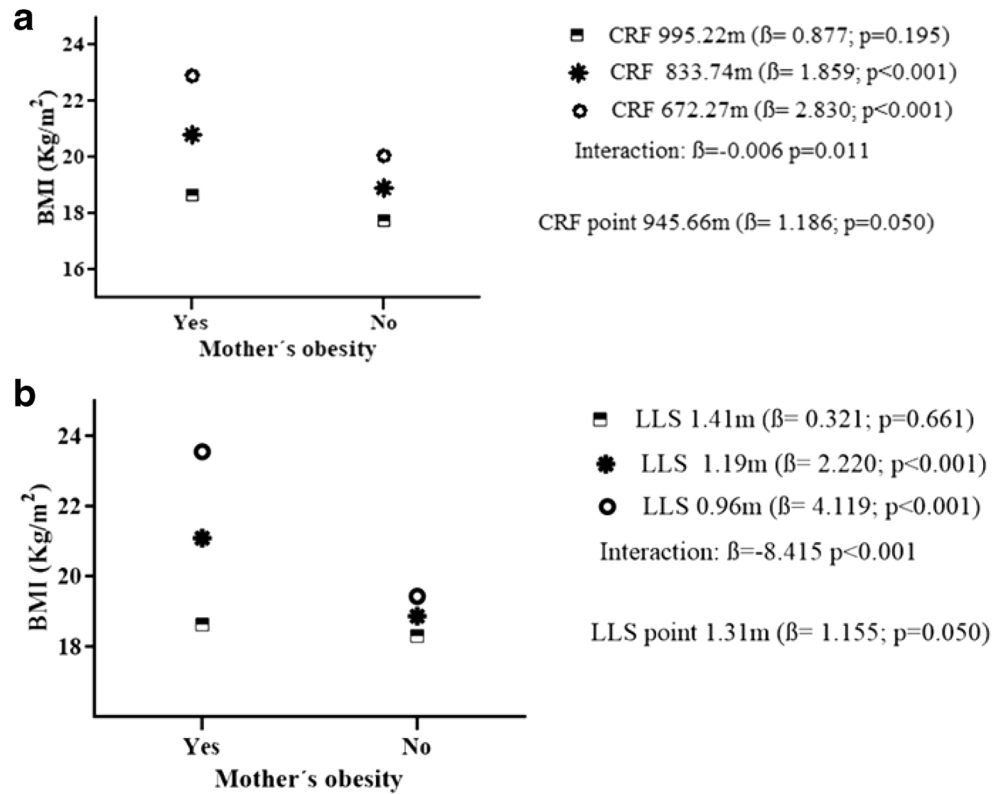
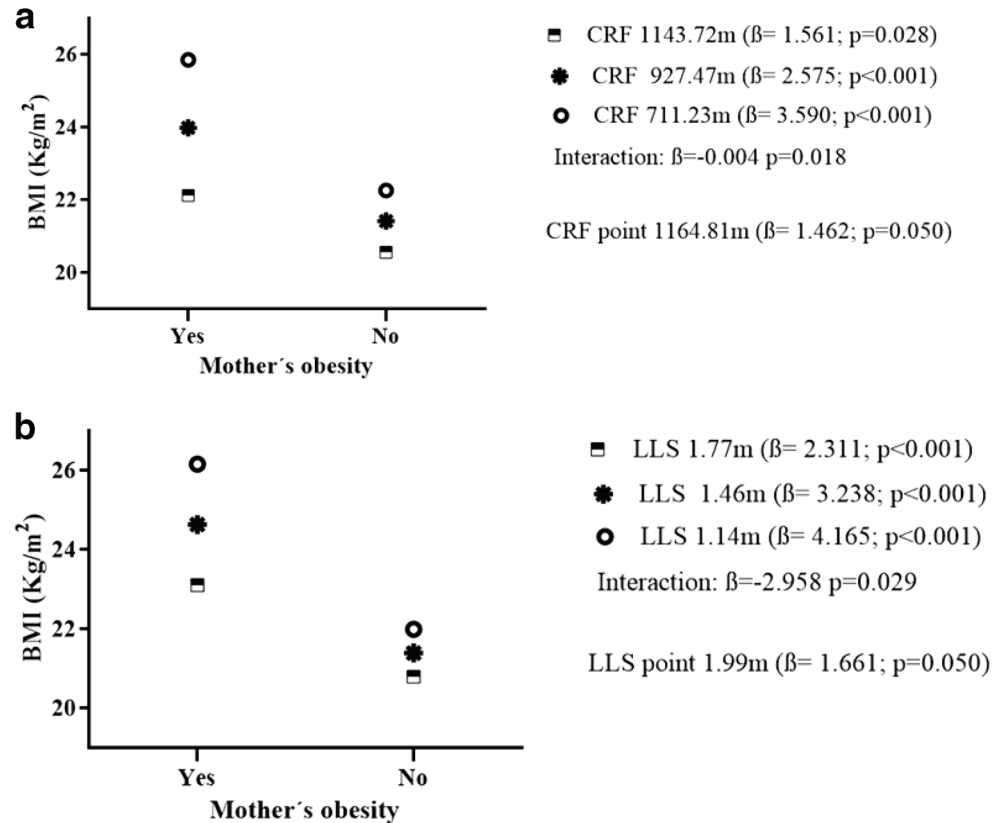


Fig. 2 Results of Johnson-Newman technique applied to adolescent's cardiorespiratory fitness (a) and muscular strength (b) in the relationship between BMI and their mother's obesity. CRF cardiorespiratory fitness, LLS lower limb strength. All analyses were adjusted for sex, sexual maturation and socioeconomic status



We highlight the relevance of these findings, since according to our knowledge, there are no studies investigating the moderator role of physical fitness on the described associations. Additionally, we have established a cutoff for CRF and LLS, considering specific age groups (children and adolescents), that can be used as a target for intervention programs aiming to improve these physical fitness components. Indeed, while maternal overweight/obesity is a nonmodifiable risk factor for children obesity, physical fitness is an important health indicator [27] that can be enhanced by regular and moderate-vigorous physical activity [26] and is also associated with a healthy profile, including higher probability physical activity practice, lower sedentary behavior, and appropriate sleep patterns [28]. Another strategy to increase physical activity level leading to a reduction in weight gain is by promoting active video games, which can provide an experience of enjoyment and socialization, being well accepted, especially in children [29].

This study has several limitations. First, the cross-sectional design precludes definitive causal attributions. Second, unknown confounders could have been a source of bias, like physical activity and diet. Finally, the perception of the mother's obesity was self-reported, which could underestimate the obesity status. Our study also has several strengths, such as the relatively large sample assessed, investigating the moderating role of physical fitness in the relationship between BMI of children and their mother's obesity, and being one of the first using this approach including the novel perspective of determining the moderation point.

In conclusion, CRF and muscle strength in children and CRF in adolescents is associated with the mother's obesity. Children's BMI was also positively associated with their mother's obesity. In addition, CRF and muscular strength are moderators in this relationship between BMI and mother's obesity. Therefore, increasing physical fitness is an important strategy to prevent excess weight in offspring of obese mothers. Such information is key for parents, teachers, physical educationalists and those working with youth.

Authors' contributions C.B. have made substantial contributions to the conception, analysis, and interpretation of data and drafted the work; C.F.F. have made substantial contributions to the conception, analysis, and interpretation of data and drafted the work; A.F.D. contributed to the interpretation of data and drafted the work; A.R.G. substantially reviewed the work; C.M.L.M. substantially reviewed the work; J.D.P.R. contributed to the design of the work; C.P.R. contributed to the design of the work and substantially reviewed the work; R.K. substantially reviewed the work. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the Human Research Ethics Committee of the University of Santa Cruz do Sul (UNISC) under certificate number 1.498.305. Also, was performed in accordance with the ethical standards of the Declaration of Helsinki.

Informed consent Informed consent was obtained from all individual participants included in the study.

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