Association of active behavior, body mass index, blood pressure and inflammatory cytokine in adolescents

Associação do comportamento ativo, índice de massa corporal, pressão arterial e citocinas inflamatórias em adolescentes

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Abstract

Introduction: Physical inactivity is associated with obesity, chronic inflammation and the occurrence of chronic non-communicable diseases. **Objective:** To investigate the association of active behavior, body mass index (BMI), diastolic blood pressure (DBP) with serum levels of inflammatory interleukins in adolescents. **Methods:** Cross-sectional population-based study of adolescents from public schools in São Luís, Maranhão. A theoretical model was built, based on Structural Equation Modeling, to explore the effects of the latent variable "active behavior" adjusted for socioeconomic status and gender, with effects on BMI, DBP and inflammatory load. **Results:** Active behavior was associated with lower DBP values (standardized coefficient (SC) = -0.146; p = 0.029), while higher BMI was associated with higher DBP values (SC = 0.177; p < 0.001). For the highest values of active behavior there was a higher inflammatory load (SC = 0.442; p < 0.001); and a higher BMI was associated with a higher inflammatory burden (SC = 0.145; p = 0.025). Female gender had a higher inflammatory burden (SC = 0.282; p < 0.001). There was an indirect effect for females on lower inflammatory load values via reduction in active behavior (SC = -0.155; p < 0.001). **Conclusion:** Active behavior reduces blood pressure levels in adolescents; while the increase in inflammatory cytokines induced by active behavior may be involved in their anti-inflammatory response for disease prevention.

Keywords: Adolescent. Inflammation. Physical exertion. Statistical models.

Resumo

Introdução: A inatividade física está associada à obesidade, inflamação crônica e ocorrência de doenças crônicas não trans-missíveis. **Objetivo:** Investigar a associação do comportamento ativo, índice de massa corporal (IMC) e pressão arterial diastólica (PAD) com os níveis séricos de interleucinas inflamatórias em adolescentes. **Métodos:** Estudo transversal de base populacional de adolescentes da rede pública de São Luís, Maranhão. Construiu-se um modelo teórico, baseado na Modelagem com Equações Estruturais, para explorar os efeitos da variável latente "comportamento ativo" ajustada para a situação socioeconômica e sexo com efeitos no IMC, PAD e carga inflamatória. **Resultados:** O comportamento ativo foi associado aos menores valores de PAD (coeficiente padronizado (CP) = -0,146; p = 0,029), enquanto o maior IMC foi associado a maiores valores de PAD (CP = 0,177; p < 0,001). Para os maiores valores do comportamento ativo houve maior carga inflamatória (CP = 0,442; p < 0,001) e o maior IMC foi associado à maior carga inflamatória (CP = 0,145; p = 0,025). Sexo feminino teve maior carga inflamatória (CP = 0,282; p < 0,001). Houve um efeito indireto para o sexo feminino nos menores valores de carga inflamatória via redução do comportamento ativo (CP = -0,155; p < 0,001). **Conclusão:** O comportamento ativo reduz os níveis pressóricos em adolescentes, enquanto o aumento das citocinas inflamatórias induzidas pelo comportamento ativo pode estar envolvido na sua resposta anti-inflamatória para a prevenção de doenças.

Palavras-chave: Adolescentes. Inflamação. Esforço físico. Modelos estatísticos.

Introduction

The substantial increase in the prevalence of physical inactivity is associated with obesity, chronic inflammation and global mortality from chronic non-communicable diseases.[1,2] Considering that physical inactivity is a modifiable risk factor, it is recommended to use active behaviors and/or physical activity (PA) with a view to reducing the risk of heart disease, stroke, diabetes, breast and colon cancer,[2] since there is evidence of the anti-inflammatory and antioxidant effects of physical exercise (PE), involving the immune system, muscle and adipose tissue.[3,4]

Excess adipose tissue is associated with the secretion and release of pro-inflammatory cytokines,[5,6] with the increase in their serum levels and the development of low-intensity chronic inflammation. On the other hand, adopting active behavior contributes to the reduction of adipose mass with or without weight loss,[4] modulates inflammatory and anti-inflammatory cytokines (myokines)[3,5,7] and, consequently, prevents diseases. Among the cytokines there are pro-inflammatory interleukins 1ß, IL-6, IL-8 and TNFα, which are involved with metabolic alterations such as insulin resistance, atheogenesis, dyslipidemia, favoring increased cardio-vascular risk.[7]

The benefits of active behavior for the prevention or adjuvant treatment of diseases depend on its type, intensity and duration.[8,9] Both PA and PE are associated with muscle contraction and energy expenditure. However, by definition, PA refers to any body movement involving skeletal muscles in different activities, whether domestic, occupational, active displacements, physical education, among others, while PE, the resulting muscle work, aims to optimize the individual's performance to meet their daily activity demands,[1] both being elements of active behavior.

On PA in adolescents, there is evidence of gains in cardiorespiratory conditioning associated with decreased inflammatory and adiposity markers.[4,10] A study (n = 1089) demonstrated that overweight and obese adolescents have higher inflammatory scores than eutrophic ones, and increased levels of PA decreased inflammation and visceral adiposity.[11] Another study found that regardless of diet, active behavior was associated with reduced plasma levels of inflammatory markers in obese adolescents.[12]

Measuring the active behavior of adolescents is a challenge in choosing the most appropriate method.[13] In the complexity of understanding its effects, it is relevant to explore the direct and indirect effects of the adoption of a non-sedentary life in inflammatory markers, because studies on this theme in adolescents have emerged.[10-12] Therefore, this study aimed to investigate the association of active behavior, body mass index (BMI) and blood pressure with serum levels of inflammatory cytokines.

Methods

This is a cross-sectional study conducted from January 2014 to June 2016, in the municipality of São Luís, Maranhão. The sample consisted of adolescents enrolled in the state public school system in São Luís.

This is a complex random sample, done in three stages:

1) Primary sampling unit - identification of all public high schools in the urban area (n = 52) and randomization to select a sample of 13 schools;

2) Secondary sampling unit - represented by the classes, previously selected in three levels of students of the 1st, 2nd and 3rd year, totaling 39 classes. Students aged 17 and 18 of both sexes (n = 2030) were considered eligible for the study;

3) Tertiary sampling unit - represented by eligible and randomized students from the school attendance list. Those who used orthodontic apparatus (n = 52) and pregnant women (n = 3) were not included in the study, because these criteria could interfere in the oral health evaluation parameters of the matrix research,[14] whose sample was common to this study. Other non-inclusion criteria: physical limitation (n = 0), those who refused to participate in the study (n = 109) and infrequency (n = 62). Epi-Info software, version 6.0, was used for the sample calculation. A sample of 400 adolescents was estimated, which would have 80% power to detect prevalence ratios (PR), with a significance level of 0.05 for outcomes of interest. The final sample was 405 adolescents.

Data collection was performed by a trained team and information on the sociodemographic variables of the adolescent and the mother, the guardian required as a companion, were collected in the classroom through a printed questionnaire. Anthropometric measurements were performed by nutritionists according to standardized techniques.[15] A portable Tanita® scale, with accuracy of 100 grams and capacity of 150 kg, measured body weight. In the height measurement, a portable stadiometer (Alturexata®) was used, with an accuracy of 1.0 cm. BMI was obtained using the equation BMI = weight (kg) /height^2 (m), and adolescents were categorized as: eutrophic (< 25 kg/m^2), overweight (≥ 25 and < 30 g/m^2) and obese (> 30 kg/m^2).[16]

Diastolic blood pressure (DBP) was measured in the left arm, with a Microlife digital device (MedLevensohn/batch: 1214000001 MS Record: 10222460055), duly calibrated, following the standardized techniques.[17,18] Two measurements were performed with an interval of 5 minutes, obtaining the mean DBP.

Blood collection was performed by a nursing technician. Blood serum aliquots were stored in freezing for further reading of inflammatory markers: IL-1β, IL-6 and IL-8 (pg/mL), TNF-α (pg/mL), and c-reactive protein (CRP) (pg/mL). Serum concentrations of inflammatory markers were determined according to the manufac-turer's instructions: Milliplex® MAP kits Human Cytokine/Chemokine Magnetic Bead Panel-Immunology Multiplex Assay (HCYTOMAG-60K), with LuminexTM xMAP technology (EMD Millipore Corporation, Germany).

To measure PA, the Physical Activity Questionnaire for Adolescents (PAQA) was used, elaborated from an adaptation of the Self-Administered Physical Activity Checklist (SAPAC),[19] estimating in the last seven days the adolescent's PA according to frequency (number of days/week), duration (minutes/day) and intensity (in metabolic equivalent-Met).[20] The students reported the type of PE practiced at school or outside school, for at least ten minutes, and PA in other domains.[19] For the active behavior reported by students who did not appear in the compendium of PA,[20] Mets of similar activities were used. By convention, 1 Met was considered as resting metabolic rate.[21]

The energy expenditure was determined by calculating the product of time (min/day), spent in each activity/day by the corresponding Met, adapted from the International Physical Activity Questionnaire (IPAQ).[21] The products resulting from all activities practiced were added, obtaining the final value in "Mets min/day".

PA was classified as moderate to vigorous (MVPA), according to each sports modality (≥ 3 Mets),[21] and total (total PA), corresponding to the sum of the Mets of the MVPA and the PA in other domains (displacements, domestic and occupational activities). According to the World Health Organization (WHO), "active" adolescents have a minimum of 60 min/day of MVPA, which corresponds to a minimum energy expenditure of 240 Mets min/day.[1]

For the objective measurement of active behavior, a Flitzclip® pedometer was used, fixed around the hip (above the iliac crests), through an elastic belt, for seven consecutive days,[22] twelve hours a day, including Saturday, Sunday and holiday, with the recommendation of removing it before bed, bathing or any aquatic activity. The use for ≥ 4 days was considered for the calculation, including at least one atypical day (Saturday, Sunday and holiday), for a time ≥ 8 h/day and the weighted average was calculated.[22] In case of non-compliance with the minimum monitoring period (days/h), the test was requested to be repeated.

The latent variables in this study,[23] selected based on the literature,[2-5,7-11,24-26] were:

- Family socioeconomic status (FSS), formed by observable variables: maternal education (0 to 4; 5 to 8; 9 to 11; and 12 or more years of study); family

income (< 1; 1 to < 3; 3 to < 5; and ≥ 5 minimum wages (MW) = R$879.99). According to the Brazil Economic Classification Criterion,[24] FSS was considered as upper social class (A and B), middle (C) and low (D and E).

- Active behavior: the latent variable of PA (Mets min/day), formed by MVPA, total PA and number of steps/day, which were then categorized into tertiles.

- Inflammatory load: formed by IL-1β, IL-6 and IL-8 and categorized into tertile. Among the cytokines collected, CRP and TNF-α did not present significant convergent factorial load for the construct.

Proposed theoretical model

The theoretical model aimed to evaluate the association between active behavior and inflammatory load in adolescents (Figure 1), through direct or indirect pathways. The FSS was considered a distal determinant,

causing effects on inflammatory load (outcome) and other variables of the model: active behavior, BMI, DBP. As a hypothesis, it is thought that active behavior is inversely associated with BMI and the variable sex, explaining the "active behavior" and the "inflammatory load" (Figure 1).

Modeling with structural equations

Structural equation modeling (SEM) was used as a statistical procedure to test the hypotheses about the relationships between latent and observable variables, as well as to reduce measurement errors (bias-free) in statistical estimation[23] eand to present the maximum likelihood estimate to deal with absent data.[27] For the analysis of latent variables, the standardized and significant factor loadings were adopted as assumptions.
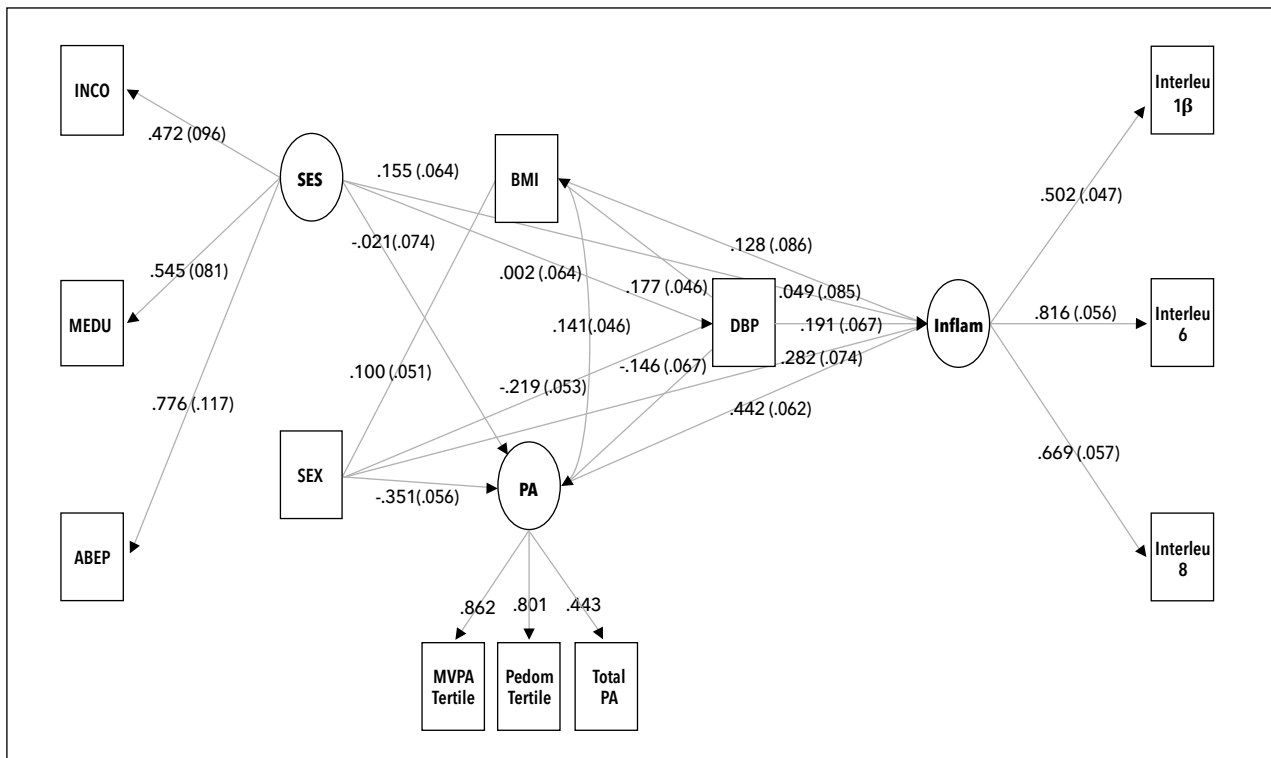
Figure 1 - Proposed theoretical model of latent variables: socioeconomic status (SES) and physical activity (PA) associated with the outcome inflammatory load (Inflam) of adolescents.

Note: INCO = family income; MEDU = mother´s education; ABEP = Brazilian Association of Research Companies categorized (high, medium, low social class); BMI = body mass index; MVPA = moderate to vigorous physical activity; Pedom = pedometer; DBP = diastolic blood pressure; Interleu = interleukin.

The model adjustment was tested according to the criteria: a) p > 0.05 in the chi-square test (X^2); b) for root mean square error of approximation, p < 0.05 and the upper limit of the 90% confidence interval < 0.08; c) Comparative Fit Index and Tucker-Lewis Index > 0.95; d) values < 1 for weighted root mean square residual.[23] The estimator "root of weighted mean quadratic residue and adjusted variance" (weighted least squares means and variance adjusted) and theta parameterization were used to control residual variances.[28] The change indexes (modindex) command was adopted for suggestions for changes in the latent variable.[29] The analyses were conducted by the Mplus software version 7.0. Standardization coefficients were estimated for direct, indirect and total effects of observable and latent variables in the outcome, considering p < 0.05 for a significant effect. Stata 14 software was used to determine the frequency, mean, standard deviation and tertile of the variables.

This study was approved by the Ethics Committee of the Federal University of Maranhão (CAAE 12498713. 8.0000.5087). All participants and their guardians signed an informed consent form.

Results

According to the sociodemographic characteristics of the mother and adolescents, it was observed that 18.5% studied four years or less and 40.9% had a family income of 1 to < 3 minimum wages. Of the 405 adolescents, 44.4% were male, 13.6% were obese and/ or overweight, and 5.6% had DBP > 80 mmHg (Table 1).

For the latent variable "active behavior", the mean of the indicators was 962.1 Mets min/day for MVPA, 1601.9 Mets min/day for total PA and 8701.9 steps/ day. With the exception of the number of steps/day, the other variables were above the WHO'S minimum recommendations (Table 1). In this study, the prevalence of active adolescents was 94.7%, referring to the sum of MVPA and PA.

The assumption increased serum levels of interleukins in the 3rd tertile was greater than 100% compared to the values of the 1st tertile, especially for IL-6, which ranged from 0.19 - 0.86 (1st tertile) to 1.66 – 84.39 (3rd tertile), suggesting a strong inflammatory load in adolescents of the 3rd tertile (Table 2).

Table 1 - Sociodemographic characteristics of the mother and adolescents, body mass index, diastolic blood pressure, interleukins and adolescent physical activity

Variable	n = 405	%
Mother´s education (years)		
0 - 4	75	18.5
5 - 8	92	22.7
9 - 11	163	40.2
12 or more	22	5.4
Missing data	53	13.0
Family income (MW)		
< 1	40	9.8
1 - < 3	166	40.9
3 - < 5	40	9.8
≥ 5	20	4.9
Missing data	139	34.3
Sex		
Male	180	44.4
Female	225	55.5
BMI (kg/m²)		
Eutrophy	350	86.0
Overweight	37	9.1
Obesity	18	4.5
DBP (mmHg)		
≤ 80	382	94.3
> 80	23	5.6
Interleukins (IL)		
IL-1β	355	1.0 ± 0.9
Missing data IL-1β	50	
IL-6	353	2.1 ± 5.3
Missing data IL-6	52	
IL-8	279	58.7 ± 104.2
Missing data IL-8	126	
Physical activity (PA)		
Moderate to vigorous AF (Mets)	405	962.1 ± 1059.1
Total PA (Mets)	405	1601.9 ± 1176.6
Pedometer (n. of steps/day)	181	8701.9 ± 3349.4
Missing data pedometer	23	-

Note: MW = minimum wage; BMI = body, max index; DBP = diastolic blood pressure. The variables were presented in percentage (%), except for the indicators of physical activity and interleukins, which were shown as mean and standard deviation (±).

Table 2 - Indicators that make up the latent variable "inflammatory load" (interleukin 1β, 6 and 8) and "active behavior" (MVPA, total PA and pedometer) in adolescents

Variable	n	%
Interleukin 1β (pg/mL)		
1st tertile (0.24 - 0.68)	119	29.3
2nd tertile (0.69 - 1.06)	148	36.5
3rd tertile (1.07 - 10.31)	89	21.9
Missing data	49	12.1
Interleukin 6 (pg/mL)		
1st tertile (0.19 – 0.86)	117	28.8
2nd tertile (0.87 – 1.65)	125	30.8
3rd tertile (1.66 – 84.39)	111	27.4
Missing data	52	12.8
Interleukin 8 (pg/mL)		
1st tertile (0.11 – 15.80)	93	22.9
2nd tertile (15.90 – 45.43)	94	23.2
3rd tertile (46.00 – 894.43)	92	22.7
Missing data	126	31.1
MVPA (Mets min/day)		
1st tertile (20.00 – 469.00)	133	32.8
2nd tertile (470.00 – 1053.66)	133	32.8
3rd tertile (1054.00 – 5238.00)	133	32.8
Missing data	6	6.0
Total PA (Mets min/day)		
1st tertile (80.00 – 1038.00)	135	33.3
2nd tertile (1039.00 –1782.00)	135	33.3
3rd tertile (1783.00 – 6424.00)	134	33.0
Missing data	1	0.2
Pedometer (number of steps/day)		
1st tertile (1662.20 – 7492.50)	53	13.0
2nd tertile (7493.00 – 10069.20)	53	13.0
3rd tertile (10079.00 – 17431.20)	52	12.8
Missing data	23	5.6

Note: MVPA = moderate to vigorous physical activity; PA = physical activity.

The model presented a good fit for the interpretation of SEM analyses with good constructs, whose factorial loads of the indicators of latent variables had a convergent and significant correlation ($p < 0.001$) (Table 3).

Active behavior was associated with BMI with the standardized coefficient (SC = 0.141; $p = 0.002$), and the highest BMI was associated with the highest values of inflammatory load (IL = 0.145; $p = 0.025$). Higher Mets

values of active behavior presented higher inflammatory load (IL = 0.442; $p < 0.001$), and lower DBP values (IL = -0.146; $p = 0.029$), as shown in Table 4. Regarding gender, girls had lower values for active behavior (AB = -0.351; $p < 0.001$), and higher inflammatory load values (SC = 0.282; $p < 0.001$). There was an indirect effect for girls in the lowest inflammatory load values, via the reduction of active behavior (AB = -0.155; $p < 0.001$). SES was associated with BMI (SC = 0.155; $p = 0.016$), sex with BMI (female borderline association) and BMI was associated with DBP (CP = 0.177; $p < 0.001$) (Table 4).

Table 3 - Modeling fit index with structural equations for association of "active behavior" and "inflammatory burden" in adolescents

Index	Parameter	Theorem model
X^{2*}	-	49,428
Degrees of liberty	-	42
p-value X^2	> 0.05	0.200
RMSEA 90% CI	< 0.08	0.000 - 0.042
p-value	< 0.05	0.021
CFI	> 0.95	0.994
TLI	> 0.95	0.991
WRMR	< 1.00	0.618

Note: *Chi-square test. RMSEA = Root mean square error of approximation; CI = confidence interval; CFI = Comparative Fit Index; TLI = Tucker Lewis Index; WRMR = weighted root mean residual.

Discussion

An association of active behavior with inflammatory load was found, suggesting that the highest Mets of PA in adolescents contribute to inflammation. These findings corroborate other studies.[30-33]

Forti et al.,[9] in a study with healthy young people, found that acute PA increased levels of inflammatory cytokines, while chronic PA decreased IL-6 levels and increased the production of anti-inflammatory cytokines.

Other studies have shown that cardiorespiratory fitness was indirectly associated with inflammatory cytokines in adolescents,[10,11] suggesting that maintaining active behavior (through PA) increases cardiorespiratory fitness and decreases the level of inflammatory markers.

Table 4 - Associations and total, direct and indirect effects of socioeconomic status, sex, "active behavior", body mass index (BMI) and diastolic blood pressure (DBP) on "inflammatory load" in adolescent

Variables	Outcomes	β*	p-value	Effects	β▪	p-value
Socioeconomic status	BMI	0.155	0.016	-	-	-
Sex	Active	-0.351	< 0.001	-	-	-
	BMI	0.100	0.052	-	-	-
	DPB	-0.219	< 0.001	-	-	-
	Inflammation	0.282	< 0.001	Direct Indirect/Active	0.282 -0.155	< 0.001 < 0.001
Active behavior	Inflammation	0.442	< 0.001	Total Direct	0.429 0.442	< 0.001 < 0.001
	DBP	-0.146	0.029	-	-	-
	BMI	0.141	0.002	-	-	-
BMI	Inflammation	0.128	0.050	Total Direct	0.145 0.128	0.025 0.050
	DBP	0.177	< 0.001	-	-	

Note: *Standardized factor loading of the association; β▪ Standardized factor loading of the effect.

There is evidence that acute MVPA contributes to the anti-inflammatory effect of chronic PA,[5] because it is involved in increased production of IL-6 secreted by muscle and modulation of the production of inflammation-inhibiting proteins.[6,9] The present study corroborates this idea, because the female gender, when it was less active, had an indirect effect for the lower values of inflammatory load; possibly, the lower Mets of PA do not alter the serum levels of inflammatory interleukins sufficient to trigger or activate the trigger of the production of anti-inflammatory cytokines. Moreover, active behavior and inflammatory load were associated with sex, suggesting that females had a higher chance for high inflammatory load and males were more active. It is believed that the increase in PA may be a protective factor for females, due to the possibility of reduction of adipose tissue[6] and immunological modulation.[5,6,32] This interpretation was marked according to the output of the statistical program used.

It should be noted that blood samples were collected thirty minutes after the teenager's arrival in the classroom, without the control of abstinence from PA in the previous 24 hours. In addition, it should not be ruled out the increase in the practice of PA (in the various domains) of adolescents, including the active displacement from home to school and vice versa, voluntarily, motivated by the research. Going to school walking or cycling is an acute daily physical stimulus, which involves an inflammatory response of myokines and simultaneously favors the anti-inflammatory effect of chronic PA, with health benefits.[3-5,8,12]

The active behavior associated with inflammatory load is possibly aroused by the acute response of PA of adolescents, either on the previous day or minutes before blood collection.[31] It is believed that the result found is largely due to the action of IL-6, because by excluding it from the group of indicator variables of the construct (inflammatory load), the same result was not obtained. During the exercise, muscle contraction occurs and high production of inflammatory cytokines such as IL-6 occurs, which with a different function from IL-6 derived from adipose tissue stimulates the synthesis of anti-inflammatory cytokines such as IL-10, the IL-1β antagonist receptor (IL-1ra), capable of inhibiting the inflammatory intracellular response of IL-1, as well as inhibiting the pro-inflammatory production of TNF-α.[32,33]

Additionally, the indirect effect in females for the lowest inflammatory load values, via reduction of PA, suggests a higher risk of inflammation, whether induced by increased adipose tissue or by lower induction of anti-inflammatory cytokines via muscle contraction.[5,6,31,32]

BMI was associated with inflammatory load and 13.6% of adolescents were overweight and obese. The recommendation of active behavior favors the prevention of cardiovascular risk factors, since the increase in adipose tissue is involved in the process of

production and release of pro-inflammatory cytokines.[6,7] This result corroborates a longitudinal study with 843 adolescents,[26] that demonstrated the association of BMI with inflammatory markers. Agostinis-Sobrinho et al.[10] showed the association of higher BMI values, low PA levels and high score of inflammatory markers.

In this study, high BMI was associated with higher DBP values. The increase in BMI in adolescents was associated with low rates of active behavior and, consequently, lower stimulation of nitric oxide production and higher risk of dyslipidemia and arterial hypertension.[26]

Family SES was associated with higher BMI values. This is one of the aspects related to the process of nutritional transition experienced by Brazilian society in the last three decades, due to the reduction in the prevalence of malnutrition and increased obesity, which involves social factors such as the growth of multi-processed food industries and, consequently, higher consumption of fast foods, regardless of social strata.[33] A study conducted with adolescents from urban and rural areas also found a direct association between SES and BMI. [25]

The adoption of active behavior by adolescents, however, is encountered with some obstacles. In public schools, physical education as a compulsory discipline in high school is not practiced regularly, either due to the lack of teacher, appropriate place, among others. In addition, leisure sports and active outdoor commuting are often discouraged by public insecurity in urban centers.

As strengths of this study, we highlight the use of statistical analysis based on a theoretical model conducted by modeling with structural equations, with the formation of latent variables and the possibility of evaluating the possible total, direct and indirect effects of constructs on the outcome, minimizing the measurement error and estimating the maximum likelihood for the missing data. In addition, the evaluation of the PA of the adolescents was performed in their different domains, by subjective and objective measures.

Regarding the limitations of the study, one can attribute: the design of the study (cross-sectional), which prevents the establishing temporality in the associations found, as well as the cause-effect relationship, although the statistic adopted aims at an analysis of the direct and indirect effects between the variables. Another limitation was the lack of criteria to control biological collection (abstinence from PA).

Regarding the limitations of the study, one can attribute: the design of the study (cross-sectional), which prevents the establishing temporality in the associations found, as well as the relationship of cause and effect, although in this way, chronic (regular) and acute (non-regular) PA as components of active behavior, present anti-inflammatory effects from their involvement with immunological modulation, favoring organic homeostasis and disease prevention. Investigating anthropometric, cardiometabolic and inflammatory markers in adolescence is of paramount importance, as changes in these biomarkers can be perpetuated for adulthood and are associated with risk factors for chronic noncommunicable diseases (NCDs).

Conclusion

This research did not aim to finalize the discussions about the theme addressed, seeking to present new contributions through the methodology of structural equations. Understanding these and other variables related to inflammation and active behavior is fundamentally necessary to provoke new discussions and research in the scientific environment.

Active behavior contributed to the reduction of blood pressure levels in adolescents, while the increase in inflammatory cytokines induced by active behavior was involved in the anti-inflammatory response for disease prevention.

Acknowledgments

Authors' contribution

RSBM, CDSC, CCCR, AJMC participated in the structuring of the research project, methodological design, data collection, writing of the results and revision of the manuscript. VMSS supported the revision of the manuscript and final writing.

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