Percentage of energy contribution according to the degree of industrial food processing and associated factors in adolescents (EVA-JF study, Brazil)

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Abstract

Objective: To evaluate energetic contribution according to the degree of industrial food processing and its association with sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics in adolescents.
Design: Cross-sectional study (Adolescent Lifestyle Study). Food consumption was assessed using 24-h dietary recalls, with foods classified by degree of industrial progressing. The usual diet was estimated using the Multiple Source Method. In a linear regression model, the energy percentage (E %) was associated with sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics, after adjustment for sex and age.
Setting: Juiz de Fora, Brazil.
Participants: Eight hundred and four adolescents, of both sexes, 14–19 years of age, enrolled in public schools.
Results: The E % of unprocessed or minimally processed foods corresponded to 43·1 %, processed foods to 11·0 % and the ultraprocessed foods to 45·9 %. E % of unprocessed foods was associated with socio-economic stratum (adjusted $\beta = -0.093$; $P = 0.032$), neck circumference (adjusted $\beta = 0.017$; $P = 0.049$), screen time (adjusted $\beta = -0.247$; $P = 0.036$) and HDL-cholesterol (adjusted $\beta = -0.156$; $P = 0.003$). E % of ultraprocessed foods was associated with socio-economic stratum (adjusted $\beta = 0.118$; $P = 0.011$), screen time (adjusted $\beta = 0.375$; $P = 0.003$), BMI (adjusted $\beta = -0.029$; $P = 0.025$), neck circumference (adjusted $\beta = -0.017$; $P = 0.028$) and HDL-cholesterol (adjusted $\beta = 0.150$; $P = 0.002$).
Conclusions: There was a high E % of ultraprocessed foods in the diet of the adolescents. Actions are needed to raise the awareness of adopting healthy eating habits.

In the latest decades, changes have been observed in the world food economy that have reflected changes in the population's eating patterns[1,2]. Such changes verified in the adult population[3,4] are also already demonstrated in the young population, in which there is a substitution of foods and culinary preparations based on unprocessed or minimally processed foods by ready or precooked products for consumption, such as ultraprocessed food[5–7].

In the NOVA food classification system, items are grouped according to the nature, purpose and degree of industrial processing, comprising four groups: unprocessed or minimally processed foods (e.g. rice, meat, fruits and vegetables), processed culinary ingredients (e.g. salt, sugar, and oils and fat), processed foods (e.g. bread and cheese) and ultraprocessed foods (e.g. soft drinks, ready frozen food and candies), the latter being rich in sugars, fats, Na, and low in fibre, micronutrients and proteins[8].

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Adolescence is a phase characterised by several biopsychosocial and behavioural changes, thus becoming a period in which adolescents may be more vulnerable to the presence of risky behaviours which have health implications, such as the emergence of non-communicable diseases[9,10].

Studies conducted with adolescents have shown that ultraprocessed food consumption was associated with family income and parents' education level[6,11,12]; physical inactivity[13]; sedentary behaviour, especially in individuals with high screen time[14]; culminating in excess of weight[15–18], metabolic[19] and blood pressure alterations[20]. Although diseases appear mainly in adulthood, their precursors can still be present during childhood and adolescence[21,22].

Considering the ongoing increase in the energy percentage (E %) of the diet from ultraprocessed foods[1–3,23] and its implications for health[18,24], this study contributes to the existing literature, showing the association with sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics, in contrast to other studies that work with these variables separately[11,14,20,25–27]. This study is relevant because it contributes effective strategies for promoting healthy eating habits in adolescence and is also important because it deals with the different realities of the Brazilian population, since Brazil is a country with continental dimensions.

Thus, the aim of this study was to evaluate the energetic contribution according to the degree of industrial food processing and its association with sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics in Brazilian adolescents.

Methods

Data source, population and sampling

This is a cross-sectional study based on data from the Adolescent Lifestyle Study (Portuguese acronym EVA-JF Study), a representative survey of adolescents from public schools in Juiz de Fora, Minas Gerais, Brazil.

The study included adolescents, aged 14–19 years, of both sexes, regularly enrolled in schools located in the urban area of the municipality. The sample calculation (n 790) was performed based on the number of students enrolled in basic education in the years 2018 and 2019, referring to the morning classes of the 9th grade of elementary school and 1st, 2nd and 3rd year of high school, according to the Brazilian educational system, and the prevalence of obesity among adolescents of 8·0 %[10,28,29], accuracy around 2·0 % of prevalence, SE of 1·0 %, CI of 95 % and subject loss of 20 %. The participants were 835 adolescents. Considering the lack of information about food consumption data, the final sample consisted of 804 adolescents.

The selection of participants was carried out at random, stratified and proportional by administrative regions, schools, school years, classes and sex. Data collection was carried out by a team trained at the educational institutions themselves, in the morning, from May 2018 to May 2019. Further details on the sampling, selection of participants and methodology can be obtained in Neves et al.[30].

Food consumption and classification

Food consumption data were obtained by applying two 24-h dietary recalls, with an interval of approximately 1 week, on alternate weekdays. Both recalls were applied in person by trained researchers using the multiple-pass method[31]. A food photo manual containing examples of portion sizes, serving utensils and household measures was used, helping to estimate the quantities consumed, as well as providing more accurate information on food consumption[32].

Energy intake (kcal) was estimated using a table of food consumption[33] and nutritional labels, when necessary, with foods classified according to the extent and purpose of industrial processing, according to the NOVA food classification system, proposed by Monteiro et al.[34,35]. Foods were divided into three groups: (a) unprocessed or minimally processed foods, culinary ingredients and preparations based on these foods (e.g. rice, beans, fruits, milk, salt and oils); (b) processed foods (e.g. breads and processed cheeses) and (c) ultraprocessed foods (e.g. soft drinks, salted crackers, filled cookies, sweeties, frozen foods). Culinary ingredients were clustered with unprocessed or minimally processed foods, since they are rarely used in isolation, but generally used in culinary preparations. In addition, all reported culinary preparations had their respective foods listed and later classified into the groups to which they belonged. Supplement 1 presents the main foods and/or food groups consumed by adolescents in the study.

Subsequently, the usual diet was estimated using the Multiple Source Method version 1.0.1 (German Department of Epidemiology of the Potsdam-Rehbrücke Institute of Human Nutrition, Germany), which can estimate the usual intake of each individual by means of adjustment based on 24-h dietary recalls, attenuating the intra-individual variance. The outcome variable was described using the energy percentage (E %) of each food group.

Sociodemographic and anthropometric variables

Information about age, sex, skin colour and educational level of the legal guardians was obtained through interviews using structured questionnaires. The socio-economic status was verified using the Brazilian Criterion of Economic Classification[36], defining the economic classes at A1, A2, B1, B2, C1, C2, D and E, in decreasing order of purchasing power.

For anthropometric analysis, weight and body fat were measured using a bipolar bioelectrical impedance scale

(Tanita Ironman®, model BC-553, Tanita Corp.), with participants standing upright in the centre of platform, barefoot and wearing light clothing[37]. Height was determined using a portable stadiometer (Alturexata®), with participants with their backs to the marker, in an upright position, barefoot and with their feet joined at the ankles[37]. The BMI-for-age was defined by the Z-score, according to the WHO[38] criteria. Neck circumference was measured using an inelastic tape (Sanny®, American Medical Ltda), in the middle cervical spine and the mid-anterior region, perpendicular to the longitudinal axis, at the level below the laryngeal prominence[39]. Waist circumference was measured midway between the lowest rib and the iliac crest with inelastic tape[40,41].

Biochemical, clinical and behavioural variables

For the evaluation of biochemical parameters, blood samples were collected after fasting for 8–12 h to measure total cholesterol, cholesterol associated with HDL, cholesterol associated with LDL and TAG, using the reference values of the Brazilian Society of Cardiology[42,43] by age group, and fasting blood glucose, classified according to the criteria established by the American Diabetes Association[44], also according to age.

Blood pressure levels were measured using a digital oscillometric device (Omron® 705-IT, Omron Healthcare Inc.) with an adjustable cuff for the perimeter of the arm. The values of systolic blood pressure and diastolic blood pressure were classified by percentiles according to sex, age and height, according to the recommendations of the Brazilian Society of Cardiology[45], and for those between 18 and 19 years of age, the classifications recommended for adults were used[46].

The practice of physical activity in the last 12 months was assessed using a questionnaire, in which the type of exercise, frequency and time spent in a regular week were reported[47,48]. Participants who reported practicing ≥420 min/week were classified as physically active[49]. Furthermore, information was obtained regarding screen time (watching movies, soap operas, playing video games, and using a smartphone, tablet or computer); the information was obtained using the cut-off point of the American Academy of Pediatrics[50], which recommends 2 h as the maximum daily limit.

Statistical analysis

For statistical analysis, the normality of continuous variables was initially verified using the Kolmogorov–Smirnov test. The sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics of the sample were described using measures of central tendency (mean and SD). For quantitative variables, absolute and relative frequencies (percentages and absolute numbers) were used.

An analysis was performed using linear regression models adjusted between the E % from the consumption of each food group, according to NOVA, and the

sociodemographic, anthropometric, biochemical, clinical and behavioural variables. The level of education of the legal guardians was described by years of study, and screen time and regular physical activity using the daily average (in minutes), including weekdays and weekends. For the analysis of the association between sociodemographic and behavioural variables, the E % from the consumption of each food group was used as the dependent variable, whereas the analysis with anthropometric, biochemical and clinical variables, the E % from the consumption of each food group was used as an independent variable. Subsequently, the analyses were adjusted for sex, age and skin colour. For all analyses, a 95 % CI and a 5 % significance level were taken into account. The data were analysed using the Statistical Package for the Social Sciences (SPSS) version 20.0 statistical software.

Results

Population characteristics

The sample consisted of 804 adolescents with a mean age of 16·1 ± 1·2 years. Females comprised 57·7 % (n 462) of the evaluated students. Regarding skin colour, 62·4 % (n 497) declared themselves as black or brown and 46·9 % (n 377) presented low income (including classes C1, C2, D–E) from the Brazilian Criterion of Economic Classification. Regarding maternal schooling, 75·2 % (n 548) of the students reported that their mothers had more than 8 years of education.

Most of the sample showed normal weight (70·0 %, n 561) and normal blood pressure levels (84·4 %, n 677). The practice of regular physical activity in the last 12 months was reported by 55·3 % (n 445); however, only 16·5 % (n 133) engaged in exercise for ≥420 min/week. Regarding sedentary behaviour, 91·8 % (n 738) of the adolescents had a daily screen time of more than 2 h. Table 1 shows the sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics of the sample.

Distribution of total energy by food group

The average energetic intake of the sample was 8949·95 ± 2005·39 kJ. Regarding the degree of industrial processing, the mean E % of the contribution of unprocessed or minimally processed foods and preparations based on these foods was 43·1 % (95 % CI 42·4, 43·8), of processed foods 11·0 % (95 % CI 10·7, 11·3) and 45·9 % (95 % CI 45·1, 46·7) for ultraprocessed foods.

Associations of sociodemographic and behavioural variables with food consumption

In linear regression models (Table 2), when comparing the E % of contribution with sociodemographic and behavioural characteristics, a negative association was observed between the classification score of the socio-economic

Table 1 Sociodemographic, anthropometric, biochemical, clinical and behavioural characteristics, EVA-JF study, Brazil, 2018–2019

Variables	n	Mean	SD
Sociodemographic			
Age (years)	804	16·1	1·2
Years of study of a male parent/legal guardian	612	10·4	3·7
Years of study of a female parent/legal guardian	719	10·7	3·6
Anthropometrics			
Weight (kg)	802	61·7	13·0
Height (cm)	803	166·3	8·8
BMI for age (kg/m²)	802	22·2	4·2
Neck circumference (cm)	803	33·6	3·2
Waist circumference (cm)	803	73·5	9·6
Body fat (%)	803	21·5	9·6
Biochemical and clinical			
Total cholesterol (mg/dl)	800	157·5	33·2
HDL-cholesterol (mg/dl)	800	71·8	15·9
LDL-cholesterol (mg/dl)	800	71·4	28·5
TAG (mg/dl)	800	71·7	30·2
Fasting glucose (mg/dl)	800	84·7	7·3
SBP (mmHg)	802	107·9	12·7
DBP (mmHg)	802	68·7	7·4
Behavioural			
Screen time* (h/d)	804	6·3	3·1
Physical activity† (min/d)	445	339·8	266·2

SBP, systolic blood pressure; DBP, diastolic blood pressure.
*Daily exposure time considering activities such as watching movies, soap operas, series, playing video games, and using smartphones, tablets or computers for other purposes.
†Regular practice of sports or physical exercise at home, on the street, at a square, park, club, gym or sports school considering the last 12 months.

stratum and unprocessed foods after adjustment for sex and skin colour (adjusted $\beta = -0.093$; $P = 0.032$) and positive with ultraprocessed foods, with and without adjustments (crude $\beta = 0.089$; $P = 0.047$; adjusted $\beta = 0.118$; $P = 0.011$), as well as screen time with all food groups, unprocessed or minimally processed foods, culinary ingredients and preparations based on these foods (crude $\beta = -0.233$; $P = 0.047$; adjusted $\beta = -0.247$; $P = 0.036$), processed foods (crude $\beta = -0.114$; $P = 0.025$; adjusted $\beta = -0.128$; $P = 0.011$) and ultraprocessed foods (crude $\beta = 0.347$; $P = 0.006$; adjusted $\beta = 0.375$; $P = 0.003$).

Associations of anthropometric, biochemical and clinical variables with food consumption

Regarding anthropometric characteristics (Table 3), a negative association was observed between BMI and consumption of ultraprocessed foods after adjustment for sex and age (adjusted $\beta = -0.029$; $P = 0.025$). Furthermore, there was a positive association between the neck circumference and the group of unprocessed or minimally processed foods, remaining significant after adjustment for sex and age (crude $\beta = 0.023$; $P = 0.034$; adjusted $\beta = 0.017$; $P = 0.049$), and a negative association with the consumption of ultraprocessed foods, in both models (crude $\beta = -0.031$; $P = 0.002$; adjusted $\beta = -0.017$; $P = 0.028$). No association was found with the other anthropometric variables.

Regarding biochemical and clinical characteristics (Table 4), there was an inverse association between total cholesterol and unprocessed or minimally processed foods (crude $\beta = -0.262$; $P = 0.019$) and a positive one with ultraprocessed foods (crude $\beta = 0.228$; $P = 0.029$). However, after adjustments, they did not remain significant. An association was also observed in the same directions between the HDL-cholesterol fraction with the same food groups, with and without adjustments, for unprocessed foods (crude $\beta = -0.178$; $P = 0.001$; adjusted $\beta = -0.156$; $P = 0.003$) and ultraprocessed foods (crude $\beta = 0.175$; $P = 0.000$; adjusted $\beta = 0.150$; $P = 0.002$).

Discussion

The results of the present study showed a high E % of contribution from ultraprocessed foods. Furthermore, an association was observed between food consumption, according to the degree of industrial processing, and socio-economic stratum, screen time, BMI, neck circumference and serum HDL-cholesterol levels.

The E % from ultraprocessed foods found in this study was similar to the one observed by D'ávila and Kirsten[12], in a Brazilian municipality, representing 49·2 % of the total daily energy value. Similarly, in another study conducted with adolescents in the Northeast of Brazil, a high E % of contribution from this group of foods (46·2 %)[26] was also demonstrated. Therefore, a high intake of ultraprocessed foods is observed in this age group.

When evaluating the association between food consumption and sociodemographic characteristics, an inverse association was found between the socio-economic stratum and unprocessed foods, demonstrating a higher consumption of these foods among those with less purchasing power. In contrast, a positive association was found with the consumption of ultraprocessed foods, with a higher E % of contribution of foods belonging to this group among those with a higher socio-economic stratum. A similar pattern was observed in a study conducted with Brazilian[6] and Chilean[51] adolescents; young individuals living in urban areas and with higher income had a higher intake of ultraprocessed foods, although inverse associations were also found[12].

Several factors can influence food choices, such as physiological, behavioural, social and economic, among others. Unlike what we find in relation to income, there was no association between food consumption and education level of parents or guardians. Sociodemographic factors such as higher income and education allow better access to information and a more varied diet; however, this condition is not always related to adequate food choices[6,52]. According to data from the Household Budget Survey (POF 2017–2018), carried out in Brazil, the total energetic intake of ultraprocessed foods in the diet

Table 2 Linear regression models, association of food consumption according to degree of industrial processing and sociodemographic and behavioural characteristics, EVA-JF study, Brazil, 2018–2019

	Unprocessed foods*				Processed foods				Ultraprocessed foods			
	Crude β	95 % CI	Adjusted β	95 % CI	Crude β	95 % CI	Adjusted β	95 % CI	Crude β	95 % CI	Adjusted β	95 % CI
Age (years)†	−0·451	−1·06, 0·16	−0·469	−1·08, 0·14	0·178	−0·08, 0·44	0·161	−0·01, 0·42	0·273	−0·38, 0·93	0·308	−0·34, 0·96
Socio-economic stratum (score)‡,§	−0·074	−0·16, 0·01	−0·093	−0·18, −0·01	−0·016	−0·05, 0·02	−0·025	−0·06, 0·01	0·089	0·00, 0·18	0·118	0·03, 0·21
Mother education level (years of study)‖,§	−0·075	−0·29, 0·14	−0·116	−0·33, 0·10	−0·027	−0·12, 0·07	−0·045	−0·14, 0·05	0·102	−0·12, 0·33	0·161	−0·07, 0·39
Father education level (years of study)¶,§	−0·071	−0·29, 0·15	−0·103	−0·32, 0·12	−0·033	−0·13, 0·07	−0·040	−0·14, 0·06	0·104	−0·13, 0·34	0·143	−0·09, 0·38
Physical activity (min)**,††	0·000	−0·00, 0·00	−0·001	−0·00, 0·00	0·001	−0·00, 0·00	−0·000	−0·00, 0·00	−0·001	−0·00, 0·00	−0·001	−0·00, 0·00
Screen time (h)‡‡,††	−0·233	−0·46, −0·00	−0·247	−0·48, −0·02	−0·114	−0·21, −0·01	−0·128	−0·23, −0·03	0·347	0·10, 0·59	0·375	0·13, 0·62

*Or minimally processed, culinary ingredients and preparations based on these foods.
†Adjusted for sex.
‡Score obtained from the Brazilian Criterion of Economic Classification (BCEC).
§Adjusted for sex and skin colour.
‖Or female legal guardian.
¶Or male legal guardian.
**Time spent on sports or physical activities in a typical week.
††Adjusted for sex and age.
‡‡Daily exposure time considering activities such as watching movies, soap operas, television shows, playing video games, and using smartphone, tablet or computer for other purposes.

Degree of processing and associated factors

Table 3 Linear regression models, association of food consumption according to degree of industrial processing and anthropometric characteristics, EVA-JF study, Brazil, 2018–2019

		Weight (kg)		Height (cm)		BMI (kg/m^2)		Body fat (%)		Neck circumference (cm)		Waist circumference (cm)	
		β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI
Unprocessed foods*	Crude β	0.043	−0.04, 0.13	−0.008	−0.07, 0.05	0.016	−0.01, 0.04	0.005	−0.06, 0.07	0.023	0.00, 0.04	0.027	−0.04, 0.09
	Adjusted β†	0.038	−0.04, 0.12	−0.034	−0.08, 0.01	0.022	−0.01, 0.05	0.036	−0.01, 0.09	0.017	0.00, 0.03	0.029	−0.03, 0.09
Processed foods	Crude β	0.221	0.02, 0.42	0.086	−0.05, 0.22	0.059	−0.01, 0.12	−0.079	−0.23, 0.07	0.068	0.02, 0.12	0.140	−0.01, 0.29
	Adjusted β†	0.121	−0.07, 0.31	−0.062	−0.16, 0.04	0.061	−0.00, 0.13	0.076	−0.04, 0.19	0.018	−0.02, 0.06	0.093	−0.05, 0.24
Ultraprocessed foods	Crude β	−0.072	−0.15, 0.01	−0.007	−0.06, 0.05	−0.024	−0.05, 0.00	0.008	−0.05, 0.07	−0.031	−0.05, −0.01	−0.046	−0.11, 0.01
	Adjusted β†	−0.053	−0.13, 0.02	0.040	−0.00, 0.08	−0.029	−0.05, −0.00	−0.044	−0.09, 0.00	−0.017	−0.03, −0.00	−0.040	−0.10, 0.02

*Or minimally processed, culinary ingredients and preparations based on these foods.
†Adjusted for sex and age.

Table 4 Linear regression models, association of food consumption according to degree of industrial processing and biochemical and clinical characteristics, EVA-JF study, Brazil, 2018–2019

		TC (mg/dl)		LDL-cholesterol (mg/dl)		HDL-cholesterol (mg/dl)		TAG (mg/dl)		Fasting glucose (mg/dl)		SBP (mmHg)		DBP (mmHg)	
		β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI	β	95 % CI
Unprocessed foods*	Crude β	−0.262	−0.48, −0.04	−0.079	−0.27, 0.11	−0.178	−0.28, −0.07	−0.026	−0.23, 0.17	−0.009	−0.06, 0.04	0.064	−0.02, 0.15	−0.018	−0.07, 0.03
	Adjusted β†	−0.206	−0.42, 0.01	−0.048	−0.23, 0.14	−0.156	−0.26, −0.06	−0.008	−0.21, 0.19	−0.019	−0.07, 0.03	0.046	−0.03, 0.12	−0.012	−0.06, 0.04
Processed foods	Crude β	−0.008	−0.52, 0.50	0.150	−0.29, 0.59	−0.131	−0.38, 0.11	−0.134	−0.60, 0.33	0.048	−0.06, 0.16	0.210	0.02, 0.40	0.064	−0.05, 0.18
	Adjusted β†	0.140	−0.36, 0.64	0.251	−0.18, 0.69	−0.086	−0.33, 0.16	−0.127	−0.59, 0.34	0.014	−0.10, 0.12	0.063	−0.11, 0.24	0.067	−0.05, 0.18
Ultraprocessed foods	Crude β	0.228	0.02, 0.43	0.044	−0.13, 0.22	0.175	0.08, 0.27	0.044	−0.14, 0.23	0.000	−0.05, 0.05	−0.089	−0.17, −0.01	0.005	−0.04, 0.05
	Adjusted β†	0.157	−0.04, 0.36	0.022	−0.17, 0.18	0.150	0.06, 0.25	0.027	−0.16, 0.21	0.014	−0.03, 0.06	−0.050	−0.12, 0.02	−0.000	−0.05, 0.05

TC, total cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure.
*Or minimally processed, culinary ingredients and preparations based on these foods.
†Adjusted for sex and age.

tended to increase with the increase in income, that is, families that had higher incomes, purchased twice the amount of ultraprocessed food compared to families with lower incomes (24·7 % of total energies *v.* 12·5 %, respectively)[23].

Sociocultural changes over the years have shown a decrease in the time spent on food preparation and the consequent increase in consumption of ultraprocessed foods. Some studies point out the lack of time due to work, family and other daily tasks as factors for such changes[53,54]. The present study investigates the food consumption of adolescents and potential negative influences on their consumption. Despite having autonomy over their own food choices, aspects related to family issues, such as the acquisition of food at home, the work situation of parents or guardians, the availability of time for preparing meals, among others, should be considered[55].

The daily exposure time to screens was also associated with the degree of industrial food processing, showing an inverse correlation with the consumption of unprocessed or minimally processed foods and processed foods, and a positive correlation with the consumption of ultraprocessed foods. Data from the latest National Adolescent School-based Health Survey, carried out in 2009 and 2015, showed high prevalence of sedentary behaviour (79·5 % and 68·1 %, respectively) among the evaluated students, with the latter showing that the higher the number of hours in front of screens, the higher the prevalence of daily consumption of ultraprocessed foods ($P < 0·001$)[14,56]. This behaviour can be attributed to the greater practicality of consuming ultraprocessed foods, since they do not require preparation time and can be consumed while watching television, using tablets and playing video games. Furthermore, these means of communication are vehicles for advertisements and advertising campaigns that tend to favour inappropriate food consumption[57,58].

Regarding anthropometric variables, only BMI and neck circumference were associated with food consumption by degree of industrial processing. There was a relationship between increase of unprocessed food consumption and the increase in these anthropometric parameters, and inverse relation with ultraprocessed food consumption. Although no association was found with weight and waist circumference, the same pattern of consumption can be observed. This inverse relationship of anthropometric parameters with ultraprocessed foods may have occurred due to the fact that the majority of the sample had appropriate weight. Unlike other studies that find inverse associations[17,59], the higher consumption of unprocessed foods and less processed foods in the present study can be attributed to a possible change in eating behaviour due to the presence of overweight in these individuals, called reverse causality. However, due to the characteristic of the design of the present study, it will not be possible to confirm this relationship.

Associations with biochemical parameters were also found in this study. There was a negative correlation for unprocessed or minimally processed foods and preparations based on these foods with total cholesterol, and a positive correlation with ultraprocessed foods, so that the serum levels decreased as the percentage of contribution of the first group increased and were directly proportional to the ultraprocessed foods. Corroborating our findings, other studies have also found positive associations[60,61]. However, after adjustments for sex and age, they did not remain significant.

The same pattern was also observed with the HDL-cholesterol fraction, showing associations with and without adjustments according to the degree of industrial processing. However, the results of this study differ from those found in other studies, in which the consumption of unprocessed foods favours the increase of HDL-cholesterol levels, while the consumption of ultraprocessed foods favours its reduction, the latter being a risk factor for the development of CVD in adulthood[60,62,63]. Only one study carried out in India, with women over 35 years old, also found a positive association between dietary pattern composed of saturated, hydrogenated fats, sweet condiments, fish and refined grains and serum levels of HDL-cholesterol[64]. The authors relate the finding to the greater presence of fats and lower carbohydrate content in this pattern, which may have favoured the increase in HDL-cholesterol.

In our sample, 97 % of adolescents presented adequate HDL-cholesterol levels and high mean values, different from other studies, where lower prevalence of adequate HDL-cholesterol levels was observed, such as in the Study of Cardiovascular Risks in Adolescents (ERICA), in 53·2 % of the sample[65] and in the study carried out by Martins *et al.*[27], in which 47·7 % of those evaluated had adequate serum HDL-cholesterol levels. A possible explanation for the association we found is that with an increase in the consumption of ultraprocessed foods, there is an increase in serum HDL-cholesterol levels, to a level similar to adolescents with lower consumption of ultraprocessed foods.

Another finding that draws attention in the study was the negative association between systolic blood pressure and consumption of ultraprocessed foods. However, after adjusting the model, it did not remain significant. Other studies carried out with children and adolescents show that the Western pattern, with the presence of processed foods, ready-made foods, sugary drinks, as they have high amounts of Na and energies from simple fats and carbohydrates, and low in proteins and fibres, favour the elevations in blood pressure levels[66,67]. As it is a chronic change, changes in blood pressure levels may not yet exist in our population.

The study has some limitations. The use of only two 24-h recalls, both performed on weekdays, may not represent the individuals' usual intake. However, the inclusion of a third recall was not possible and to minimise this existing

intrapersonal variation, correction was then used, using the Multiple Source Method. Another limitation is that the sample is only representative of adolescents from public schools, which impedes generalising the results to Brazilian adolescents from private schools of the same age group. The cross-sectional study design may not be a limitation, since it does not allow inferences about causality; however, it helps in generating hypotheses about the causes of health problems. The study was carried out with a poorly studied population and with a representative sample and sought to analyse the relationship between the consumption of food according to its processing and several variables, which can contribute in the implementation of preventive interventions and the promotion of healthy habits in adolescence.

Conclusions

The present study found that in the diet of adolescents in Brazilian public schools, the E % contribution of ultraprocessed foods is high. Moreover, associations were found between socio-economic stratum, screen time, BMI, neck circumference and serum HDL-cholesterol levels and food consumption according to the degree of industrial food processing. Therefore, the importance is highlighted for food and nutrition education activities in the school environment to guide appropriate food choices, together with effective public policies that promote actions and interventions that make this age group aware of adopting healthy lifestyle habits, such as engaging in regular physical activity and reducing screen time. In addition, changes in food labels, making them clearer and more understandable to the population, as well as the implementation of strict inspection policies on ultraprocessed foods, are necessary and urgent measures.

Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S1368980021000100

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