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Ultra-processed foods, changes in blood pressure and incidence of hypertension: the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil)

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Abstract

Objective: To estimate changes in blood pressure and the incidence of hypertension associated with consumption of ultra-processed foods (UPF) by Brazilian civil servants at a 4-year follow-up.

Design: Longitudinal analysis of the ELSA-Brasil with non-hypertensive individuals at baseline. We applied the FFQ at the baseline and categorised energy intake by degree of processing, using the NOVA classification. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured at baseline (2008–2010) and again at first follow-up (2012–2014). Incidence of arterial hypertension was defined as SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or antihypertensive medication during the previous 2 weeks. A mixed-effect linear regression model and mixed-effect logistic regression model were used to estimate associations between UPF consumption and, respectively, changes in blood pressure and incidence of hypertension.

Setting: Brazil.

Participants: Civil servants of Brazilian public academic institutions in six cities (*n* 8754), aged 35–74 years at baseline (2008–2010).

Results: UPF consumption contributed 25·2 % (SD = 9·6) of total energies consumed. After adjustment, participants with high UPF consumption presented a 23 % greater risk of developing hypertension (OR = 1·23, 95 % CI 1·06, 1·44) than those with low UPF consumption. We did not find association between UPF consumption and changes in blood pressure over time.

Conclusions: The higher the UPF consumption, the higher the risk of hypertension in adults. Reducing UPF consumption is thus important to promote health and prevent hypertension.

Keywords
Ultra-processed food
Blood pressure
Hypertension
Cardiovascular diseases

In recent decades, diets began to shift towards increased consumption of ultra-processed foods (UPF) and reduced natural or minimally processed foods[1]. At the same time, the burden of CVD and mortality related to unhealthy eating habits is high and increasing worldwide[2].

Consumption of UPF used to be limited to high-income countries, but such diets have now extended to middle- and low-income countries[1]. These products' attractiveness goes beyond longer shelf life; their predominance in food choices has been guaranteed by high palatability, practicality and convenience[3].

UPF are rich in Na, simple sugars, saturated and *trans*-fats, higher energy density and poor in micronutrients[3]. That composition – particularly the high proportion of Na, saturated fats and low K, Ca and Mg – is a risk factor for arterial hypertension. World prevalence of arterial hypertension is about 22 %[4], but there are also non-dietary factors associated with this disease, such as smoking,

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drinking, physical inactivity, genetic factors and ageing[5]. In addition to these foods' nutritional characteristics, the processing itself – particularly the use of additives, such as emulsifiers, and plasticisers such as bisphenol A and phthalates – has been identified as responsible for adverse cardiometabolic events in animal and *in vitro* studies[6].

Cross-sectional[7] and longitudinal[8] studies have established a relationship between increased consumption of UPF and obesity. Also, nutritional status plays a recognised role in chronic non-communicable diseases, and obesity can be an important route to developing hypertension and other adverse health outcomes[9].

There is growing evidence of an association between UPF consumption and adverse health outcomes such as cancer[10] and mortality[11] in adults. Findings regarding arterial hypertension and blood pressure levels are limited and less consistent. Three studies were identified, as follows. Lavigne-Robichaud *et al.*[12] analysed UPF consumption cross-sectionally among 811 indigenous individuals over 18 years old, in northern Quebec, Canada, and found no significant association between UPF consumption and the presence of hypertension. In the second study, with 14 790 individuals in Spain, Mendonça *et al.*[13] found a 21 % incidence of arterial hypertension during a mean of 9·1 years of follow-up among those whose UPF consumption was higher. Finally, Smaira *et al.*[14], in a recent cross-sectional study with fifty-six postmenopausal women with rheumatoid arthritis, found no association between UPF consumption and blood pressure.

Although UPF have received attention in recent decades, there is still insufficient and inconsistent evidence to prove their blood pressure effects. For this reason, studies, especially prospective ones, are necessary to extend knowledge of this relationship. Accordingly, the aim here was to estimate changes in blood pressure measurements and the incidence of hypertension associated with UPF consumption in adults from the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil) at a 4-year follow-up.

Methods

Study population

The current study is part of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil), a multi-site cohort intended to contribute substantial information about the development and progression of chronic clinical diseases, particularly CVD and diabetes[15]. The baseline (2008–2010) comprised 15 105 participants from 35 to 74 years old from among civil servants in six Brazilian cities: Salvador, Vitória, Belo Horizonte, Porto Alegre, São Paulo and Rio de Janeiro[16].

Participants answered a structured questionnaire addressing health and lifestyle, and socio-economic and working conditions for the baseline evaluation. Clinical and laboratory measures were also taken according to pre-established protocols. Candidates for ELSA-Brasil were excluded if they had severe communication or cognitive disorders, were current or recent (< 4 months before the first interview) pregnancy or were retired and living outside the metropolitan area containing the respective study site. Data collection procedures were repeated at follow-up between 2012 and 2014[16].

For the analysis of the two outcomes, the current study excluded participants who were absent from the first follow-up (1091) or who reported bariatric surgery (ninety-six) or had an implausible total food intake (116), that is, <2510 or >25 104 kJ/d (<600 or >6000 kcal/d) or reported reduced salt intake in the previous 6 months (175). For incidence analysis, we also excluded hypertensive individuals at the beginning of the study (4872). Arterial hypertension was defined as systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg or antihypertensive medication in the previous 2 weeks. The use of medications was confirmed from the prescription and the question: '*Were any of the medications you took in the past two weeks for hypertension (high blood pressure)?*'[16]. The resulting study population was composed of 8754 individuals. For the analysis of changes in blood pressure levels over time, we excluded participants who used antihypertensive medication at the beginning of the study and the first follow-up visit (*n* 5455). For the current analysis, the final sample was composed of 8171 participants.

Exposure

UPF consumption was assessed using a 114-item FFQ at baseline. The FFQ presented satisfactory reliability for all nutrients and reasonable relative validity for energy, macronutrients, Ca, K and vitamins E and C. The intraclass correlation coefficients varied between 0·55 and 0·83 for protein and vitamin E in the reproducibility analysis, respectively. In the validation analysis, they varied between 0·20 and 0·72 for Se and Ca, respectively. The description and validation of this questionnaire were detailed in another paper[17]. The amount (g/d) of each food item was calculated by multiplying the number of portions by the portion weight and the consumption frequency weight (3 for >3 times/d, 2 for 2–3 times/d, 1 for 1 time/d, 0·8 for 5–6 times/week, 0·4 for 2–4 times/week, 0·1 for 1 time/week, 0·07 for 1–3 times/month and 0 for never/rarely). Thus, daily food intake was calculated from the frequency of daily consumption frequency. Nutritional composition and energy value were estimated using the Nutrition Data System for Research software (University of Minnesota).

UPF were classified by the current food classification, NOVA(3), which considers the extent and purpose of food processing. This process resulted from an extensive discussion of experts that included all ELSA centres to argue regional eating habits. Some foods were doubtful as to

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the extent and purpose of processing, so we made some adaptations. For example, in the FFQ administered in the current study, bread, white bread, pita bread and toasted bread were considered a single food item. However, according to the classification proposed by Monteiro *et al.*[3], bread is classified as processed food, whereas the other bread types are classified as UPF. Thus, we estimated the energy contribution of bread separately from that of other bread types, using the bread energetic contribution reported in the food records of the QFA ELSA-Brasil validation process, namely 21·5 %[17], and incorporated its energies into the energetic contribution of processed foods. Similarly, we incorporated the energies of other bread types into UPF.

The description of the UPF in ELSA-Brasil has been published elsewhere[18]. UPF energy consumption was obtained by adding the energy of all UPF. The percentage contribution of UPF to total daily energy intake was calculated and categorised in tertiles as low (0·1–20·5 %), medium (20·6–28·8 %) or high (28·9–73·8 %).

Outcome

SBP and DBP were measured, after 5 min of rest, using an oscillometer (Omron HEM 705CPINT) in a quiet room at controlled temperature (20–24°C). Measurements were taken from participants with an empty bladder and after overnight fast. Three consecutive measurements were taken on the left arm, at intervals of 1 min. The last two measurements' mean was considered to be their casual blood pressure (mmHg)[19]. These measurements were taken at baseline (2008–2010) and again at the first follow-up (2012–2014).

The incidence of arterial hypertension was defined as SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication in the previous 2 weeks[16], checked at the first follow-up visit and who did not present this condition at baseline.

Covariables

The covariables were sex (male or female), age (in years), self-declared colour or race (white, brown and black), education (elementary school, high school and higher/graduate education), smoking (never smoked, former smoker and smoker), alcohol consumption (none, moderate, excessive: >210 g/week for men and >140 g/week for women) and antihypertensive drug use (yes/no).

Total daily energy intake (kJ/d) was obtained through the FFQ. Na consumption (g/d) was estimated using Na excretion in a 12-h urine sample at baseline[20]. Most of the more reliable predictions of Na consumption as a referred population's general habit have been based on 24-h urine collections. Thus, the 24-h Na excretion was calculated as the 12-h excretion divided by 0·47, as proposed by Mill *et al.*[21] The 12-h urinary Na excretion was used to adjust the regressions, and the 24-h urinary Na excretion was used for descriptive purposes and salt consumption estimation assuming that all Na was consumed in sodium chloride.

Physical activity (PA) was assessed using the leisure domain of the long form International Physical Activity Questionnaire and classified as: (a) low (those who do not exercise and who did not meet the criteria to be included into the other categories); (b) moderate (three or more days of high-intensity activity during at least 20 min each day; or five or more days of moderate-intensity activity and/or walking during 30 min/d; or five or more days of any combination between walking, moderate or intensity activity, reaching a minimum of 600 MET-min/week) and (c) high (high-intensity activity during 3 d a week, reaching a minimum of 1500 MET-min/week; or 7 d of any combination between walking, and moderate or high-intensity activity, reaching a minimum of total PA of 3000 MET-min/week)[22].

The covariables used in the sensitivity analyses were saturated fat consumption (g/d), obtained through the FFQ; self-reported diabetes (no/yes); and nutritional status, assessed through the BMI calculated as body weight divided by height squared (kg/m^2).

Statistical analyses

Population characteristics were described using frequencies, means or medians, and a difference in UPF consumption was evaluated using the χ^2 test, ANOVA F test and Kruskal–Wallis test, respectively. The association between UPF consumption and blood pressure changes was estimated using mixed-effect regression models. SBP and DBP changes were obtained by mixed-effect linear regression, and incidence of arterial hypertension was calculated using mixed-effect logistic regression. The mixed effects model is suitable for longitudinal analyses because it describes changes in the temporal trend considering the correlation between repeated measures in the same individual and between individuals within clusters[23]. For this reason, we have included a random effect for the study site, assuming that participants at the same study site are correlated with each other as a cluster, especially regarding regional eating habits. In this modelling, the average response is given by combining the effects on individuals with the population effects (fixed effect) and each individual has its intercept and its inclination. The individual effect expresses that unique characteristic of an individual in particular. The population effect is one that is shared by everyone. This model is also able to accommodate unbalanced data and both time-invariant and time-dependent measures[23].

The mixed effects model was adjusted for several potential confounders defined a priori. We identified potential confounders and mediators based on previous causal knowledge of the existing literature and simple analyses, as recommended to perform multivariate analyses.

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Crude models (model 1), models adjusted for age, sex, self-declared colour or race, education, time since baseline (model 2), and models adjusted for PA, smoking, alcohol, Na consumption (12-h urinary Na excretion) and total daily energy intake (model 3) were obtained. We also analyse model 4 adding the BMI to test the nutritional status hypothesis acting as a mediator.

The variables age, education, smoking, alcohol consumption, PA and self-report of diabetes and BMI were considered time-dependent, that is, both the baseline measure (2008–2010) and the first follow-up visit (2012–2014) were used. Sex and colour or self-declared race were considered invariable and, therefore, only the baseline data were used. UPF consumption, total daily energy intake, Na intake and saturated fat intake were assessed only at the baseline (2008–2010).

The interaction terms between UPF consumption, and sex and age were not statistically significant. Quality of fit was assessed using the Akaike information criterion. The two-tailed tests assumed 5 % significance, and the results were presented as β and OR with a 95 % CI. The analyses were performed using R software, version 3.4.3.

Sensitivity analyses were conducted by re-estimating the regression models that showed significant associations as follows: (i) adjusted for saturated fat intake (g/d); (ii) adjusted for self-reported diabetes and (iii) excluding 369 participants with self-reported diabetes at baseline (n 8385). The analysis for diabetes was performed due to the possibility of a different dietary pattern with restrictions caused by the disease.

Results

The participants' median age at the beginning of the study was 49·0 years. The mean follow-up time was 3·9 years (SD = 0·42, ranging from 2·6 to 6 years). Mean percentage energy from UPF was 25·2 %, ranging from 14·5 % for low UPF consumption to 35·4 % for high consumption. Participants with high UPF consumption were younger, women, colour self-declared as white, with higher education, had never smoked, consumed no alcohol, had a higher intake of saturated fats and were not diabetic (self-reported). There were no statistically significant differences in PA, Na intake, energy intake and BMI observed between the UPF consumption groups. Mean SBP and DBP increased over time and varied slightly with UPF consumption (Table 1).

Table 1 Population characteristics by consumption of ultra-processed foods – ELSA-Brasil, baseline (2008–2010), n 8754

	Overall	Ultra-processed food (UPF) consumption			
	% or mean or median	Low consumption	Medium consumption	High consumption	*P*
SBP at baseline (mmHg; mean)	114·1	115·6	114	112·9	<0·001
DBP at baseline (mmHg; mean)	72·4	78·2	72·4	72·1	0·004
Sex (%)					<0·001
Male	42	35	34	31	
Female	58	27	34	40	
Age (years; median)	49·0	51·0	49·0	47·0	<0·001
Colour or race (%)					<0·001
White	58	26	33	41	
Brown	28	36	35	29	
Black	13	37	35	29	
Education (%)					<0·001
Elementary school	9	46	31	23	
High school	33	33	35	32	
Higher/postgraduate education	59	26	34	40	
Physical activity (%)					0·074
Low	76	29	34	36	
Moderate	16	33	32	35	
High	8	30	34	36	
Smoking (%)					<0·001
Never smoked	60	29	34	38	
Former smoker	27	32	35	33	
Smoker	13	34	33	33	
Alcohol consumption (%)					<0·001
None	52	28	33	39	
Moderate	42	31	35	34	
Excessive	6	43	35	22	
Self-reported diabetes (%)					<0·001
No	96	29	34	37	
Yes	4	48	30	22	
BMI (kg/m²; median)	25·5	25·3	25·5	25·5	0·402
Na intake (g/d; mean)*	4·6	5·2	4·4	4·2	0·137
Saturated fat intake (g/d; median)	27·9	25·4	27·8	30·0	<0·001
Energy from UPF (%;mean)	25	15	24	35	<0·001
Total energy intake (kJ/d; median)	10 212·7	10 149·7	10 178·1	10 298·9	0·073

*Na intake measured by 12-h urine sample estimated for 24 h.

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At 4-year follow-up, 1312 incident cases of hypertension were identified. Model 3 was considered the final model. Estimates for the association between UPF consumption and changes in SBP and DBP were non-significant after adjustment for covariables. However, when we included BMI in model 4, we found a weak but statistically significant association in the analysis of SBP. In the same period, a higher risk of arterial hypertension (OR = 1·23, 95 % CI 1·06, 1·44) was observed in the high UPF consumption group than in the low consumption group (model 3). However, when we included BMI (model 4), this association was no longer significant (Table 2). The sensitivity analyses showed no changes in the estimates (Table 3).

Discussion

In our study, we found an association between high UPF consumption and the incidence of hypertension in 4 years of follow-up. However, by including the mediator (BMI), the association loses significance, reinforcing our hypothesis that BMI would be a mediator in the causal path between food consumption and hypertension. We did not find an association between UPF consumption and blood pressure changes over time in the final model (model 3). The weak but significant association observed in model 4 in the SBP analyses possibly corresponds to the mediated (or indirect) effect between UPF consumption and changes in the SBP, that is, the important reduction in the estimate

Table 2 Changes in SBP and DBP, and incidence of arterial hypertension, at 4-year follow-up, by ultra-processed food consumption – ELSA-Brasil

	Ultra-processed food (UPF) consumption					
		Medium consumption		High consumption		
	Low consumption	*β*	95 % CI	*β*	95 % CI	AIC
Changes in systolic blood pressure (SBP)†						
Model 1‡	0 (ref)	**−2·31**	**−3·03, −1·60**	**−4·05**	**−4·77, −3·34**	127 303·1
Model 2§	0 (ref)	−0·31	−0·96, 0·35	−0·37	−1·05, 0·30	119 614·0
Model 3‖	0 (ref)	−0·40	−1·07, 0·27	−0·54	−1·23, 0·15	114 688·9
Model 4¶	0 (ref)	−0·58	−1·24, 0·07	**−0·86**	**−1·54, −0·18**	114 075·6
Changes in diastolic blood pressure (DBP)†						
Model 1‡	0 (ref)	−0·77	−1·24, −0·30	**−1·48**	**−1·95, −1·01**	114 437·9
Model 2§	0 (ref)	0·13	−0·33, 0·59	0·19	−0·28, 0·66	108 201·1
Model 3‖	0 (ref)	0·06	−0·40, 0·53	0·08	−0·39, 0·56	103 718·4
Model 4¶	0 (ref)	−0·13	−0·58, 0·31	−0·25	−0·71, 0·20	102 439·9
Incidence of hypertension**		OR	95 % CI	OR	95 % CI	
Model 1‡	1 (ref)	0·87	0·76, 1·00	**0·81**	**0·70, 0·93**	9316·9
Model 2§	1 (ref)	1·07	0·92, 1·24	**1·20**	**1·04, 1·40**	8418·8
Model 3‖	1 (ref)	1·08	0·93, 1·25	**1·23**	**1·06, 1·44**	8185·4
Model 4¶	1 (ref)	1·05	0·91, 1·23	1·17	1·00, 1·37	7914·2

Bold values indicate statistical significance.
*As time-dependent covariables.
†Participants who used antihypertensive medication were excluded from the baseline and the first follow-up visit (*n* 8171).
‡Model 1: UPF consumption + SBP/DBP/hypertension* (crude model).
§Model 2: model 1+ age* + sex + colour or race + education*+time since baseline.
‖Model 3: model 2 + physical activity* + smoking* + alcohol consumption* + Na intake measured by 12-h urine sample + total daily energy intake.
¶Model 4: model 3 + BMI.
**Hypertensive participants at baseline were excluded (*n* 8754).

Table 3 Sensitivity analysis with adjustment variables – ELSA-Brasil, *n* 8754†

	Ultra-processed food (UPF) consumption				
		Medium consumption		High consumption	
Adjustments	Low consumption	OR	95 % CI	OR	95 % CI
Incidence of hypertension‡					
Additionally adjusted for saturated fat intake	1 (ref)	1·08	0·93, 1·26	**1·25**	**1·07, 1·47**
Additionally adjusted for self-reported diabetes*	1 (ref)	1·09	0·94, 1·27	**1·27**	**1·08, 1·48**
Excluding self-reported diabetes	1 (ref)	1·09	0·93, 1·28	**1·27**	**1·08, 1·49**

Bold values indicate statistical significance.
*As time-dependent covariables.
†Model: UPF consumption + SBP/DBP/hypertension* + age* + sex + colour or race + education*+ time since baseline + physical activity* + smoking* + alcohol consumption* + Na intake measured by 12-h urine sample + total daily energy intake + saturated fat intake or self-reported diabetes * or excluding self-reported diabetes at baseline.
‡Hypertensive participants at baseline were excluded (*n* 8754).

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observed in model 4 in relation to model 1 indicates that BMI mediates a large part of the effect of UPF consumption on SBP.

Compared with the low consumption group, the risk of hypertension was 23 % higher (95 % CI 1·06, 1·44) in the high UPF consumption group. These results are consistent with those of Mendonça *et al.*[13], the only other study to analyse this relationship using NOVA, as far as we know.

To our knowledge, no studies have used NOVA prospectively to investigate changes in blood pressure levels as an outcome, and those that have investigated the association between UPF and hypertension, besides Mendonça *et al.*[13], were cross-sectional[12,14] or considered a different age population[24]. Some authors have examined UPF' impact on incidence of hypertension, but using a single isolated UPF as proxy for the group, which is a limitation. In these studies, sweetened beverages are the predominant UPF, as in meta-analyses by Xi *et al.*[25] and Jayalath *et al.*[26], which showed an incidence of hypertension of 8 % (relative risk = 1·08; 95 % CI 1·04, 1·12) and 12 % (hazard ratio = 1·12; 95 % CI 1·06, 1·17), respectively, in the highest consumption group.

Equivalent results were found in large, well-known cohort studies, such as the Framingham Heart Study[27], the Coronary Artery Risk Development in Young Adults[28] and the *Seguimiento Universidad de Navarra* cohort study[27]. These studies found risk of hypertension for those with high consumption of sweetened drinks, to be 18 % (OR = 1·18; 95 % CI 0·96, 1·44), with borderline significance ($P = 0·10$); 6 % (relative risk = 1·06; 95 % CI 1·01, 1·12); and 60 % (OR = 1·60; 95 % CI 1·30, 2·10), respectively.

Lajous *et al.*[29] also used isolated UPF. They followed 44 616 French women 15 years to investigate the blood pressure effects of consuming ultra-processed meats. Their results showed that those who consumed more ultra-processed meat were at higher risk of hypertension than those who consumed less (hazard ratio = 1·17; 95 % CI 1·09, 1·26).

The analysis shows a risk of hypertension of varying magnitude associated with the consumption of UPF, whether by NOVA group or in isolation, and this fact cannot be ignored.

Obesity has a significant role in the development of hypertension, and it is associated with important regulators of blood pressure levels[5]. It is estimated that each one-unit reduction in BMI leads to 7 % fewer cases of hypertension[9]. Studies with the ELSA population showed an association between UPF consumption and obesity[7,30]. Asfaw[31] showed that, in the Guatemalan population, a 10 % increase in total household food expenditure on UPF led to a 4·25 % increase in the BMI of family members over 10 years of age.

We chose not to use the nutritional status as a covariate in the final model (model 3). The role of BMI is to mediate, not confound and the adjustment is inappropriate for non-confounders[32]. The inclusion of a mediator covariate in the adjustment set may produce a bias in the effect estimate[33]. A study with the ELSA population that investigated an association between the consumption of UPF and serum C-reactive protein levels also observed this loss of association when they performed BMI adjustments and also chose not to consider this model as final because nutritional status was a mediating variable[34].

In Brazil, the 2008–2009 Household Budget Survey (HBS) showed that UPF contribute 20·4 % of total energy[35]; this value is lower to that of our cohort (25·2 %) and in other countries such as the USA, United Kingdom and Canada. In those countries, UPF contribute about 60 %[36–38]. Considering that national surveys, such as the HBS, include younger populations than ours, UPF consumption in ELSA-Brasil is considered higher than expected; it transcends the generation effect observed in the general population. This happens because the food industry expanded in the emerging countries during the 1980s, affecting younger individuals more strongly today[1].

UPF's high Na content is one of the main problems related to industrial food processing, and reduced consumption of this micronutrient is associated with a decrease in blood pressure. Accordingly, lower dietary salt is recommended not just for hypertensives but for the overall population. Meanwhile, a measure recommended for the general population is to restrict dietary salt. Although the World Health Organization[4] recommends that Na consumption be limited to 2 g/d, we observed higher than recommended average consumption in the ELSA-Brasil population (4·6 g/d of Na, equivalent to 11·5 g/d of salt intake).

The consumption of Na and free sugars in Brazil is high, around the 3·7 g/d and 15·4 % of total energy intake, respectively[39,40]. Therefore, voluntary agreements were created to reduce these ingredients' content added to the UPF, reformulating their nutritional composition[41]. There is also legislation to limit *trans*-fat until eliminated in 2023[42]. However, these measures cause less conflict with the private commercial sector than other regulatory actions, such as regulating purchases and advertising used in tobacco control. At the same time, they are not useful in solving malnutrition problems because these products remain UPF since the 'reduced' density of Na, sugar or fat is still far higher than the recommended levels[43].

However, the problems related to industrial food processing go beyond the unfavourable nutritional composition. There are neoformed compounds such as acrolein and acrylamide and several artificial additives such as emulsifiers, flavour enhancers and sweeteners involved in the manufacture of UPF that have shown deleterious health effects[44–46]. In addition, environmental issues are also involved. Substances that act as endocrine disruptors used as packaging plasticisers in ultra-processing, such as bisphenol and phthalates, can permeate the entire food

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chain due to the improper disposal of products, atmospheric deposition and the transfer made by rains, configuring a widespread dissemination[47,48].

Given these facts listed here, it is not correct to attribute industrial food processing harms only to the nutritional composition of these products. Likewise, it is not enough to reduce harmful nutrients from the UPF to avoid adverse health effects.

The current study has added to the evidence produced by related longitudinal studies. No study was found to have assessed SBP and DBP changes related to UPF consumption over time. Its large sample population was drawn from diverse socio-economic backgrounds. A valid estimation of Na consumption was obtained using a gold standard method, superior to food consumption data. Statistical analysis was performed that considers correlation among repeated measures over time. The follow-up time was sufficient to observe a statistically significant association between UPF and arterial hypertension incidence. It was also possible to use time-dependent variables as covariates, which is not the case in most of the published studies.

One limitation is that food consumption was not measured at first follow-up (2012–2014). However, the period between baseline and follow-up was relatively short. There are believed to have been no major changes in the ELSA-Brasil diet that may have impacted results. Another limitation was the use of FFQ because it provides a measure of the usual food intake and lacks precision when it comes to categorising each food listed in the FFQ. Besides, the validated FFQ developed by ELSA-Brasil is not specifically intended for the study of UPF consumption. The FFQ comprises a pre-established fixed list of foods and checks the frequency of consumption of these items. Therefore, there may be UPF not included in the FFQ.

The use of the ELSA-Brasil's FFQ to categorise foods according to the NOVA classification was a challenge. For example, 'bread' was not easily placed in the UPF category because there were several types of bread in a single item in the FFQ. We had to adapt the loaves to discriminate them as UPF more appropriately. But we did it based on a validation study in a subsample of our population to obtain more accurate information. Consumption measurement methods that use the extension and purpose of processing in its design are necessary to improve the assessment of UPF consumption and overcome the limitations of existing instruments. Experimental studies also need to be carried out to investigate the association between UPF consumption and hypertension, just as it was done to study weight gain[49].

Finally, in our population there may be a selection bias called the bias of the 'healthy worker' because the individuals who work generally have a better health profile than the general population, which could lead to underestimated results.

Conclusion

In conclusion, high UPF consumption was associated with an increased risk of developing hypertension in adults. Public policies aimed at reducing UPF consumption may contribute to minimising the incidence of hypertension.

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