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Mercury Pollution and Alimentation Change through the Globalization Process in two Amazon River Communities

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***Keywords*— Overweight, BMI, Waist circumference, Mercurial contamination, riverine populations.**

***Abstract*—** *Background: Excess body weight and metabolic comorbidities represent a risk for the emergence of chronic diseases and premature deaths, a growing phenomenon observed in riverside communities in the Amazon. Methods: The study developed was a descriptive and analytical cohort of the risk factors predisposing to excess body weight in communities of the Tapajós valley region exposed to mercurial contamination. The sample population includes 130 adult individuals from Barreiras and 80 from São Luiz do Tapajós, of both sexes, who agreed to participate in this study. A semi-structured questionnaire was applied to obtain epidemiological and nutritional information, and validated conventional methods were used to evaluate the anthropometric parameters. Results: Total mercury in hair was measured using the atomic absorption spectrometry technique. In both communities, the prevalence of overweight was 60%, and abdominal adiposity among these individuals was higher than in those without overweight. The consumption of fish in the overweight and eutrophic groups in the inhabitants of the community of São Luiz do Tapajós differed, as well as and the average levels of mercury in the hair were higher in those who were overweight. However, this association was not observed in the community of Barreiras, where about approximately 61% of individuals, regardless of body weight, consumed little fish and in turn had low average levels of mercury in their hair. Conclusions: The evidence indicates changes in the eating habits of the studied communities, determining a nutritional imbalance through an increasing body weight gain among individuals, high BMI, and consequently the measurement of abdominal adiposity, which are factors for non-transmissible chronic diseases. Moreover, not only the excessive caloric intake and sedentary lifestyle, but also it is note, that mercurial toxicity must have contributed to affect affecting endocrine homeostasis and the physiology of metabolism; and, therefore, it is essential to seek appropriate interventions to combat public health diseases in communities exposed to mercurial contamination.*

I. INTRODUCTION

The frequency of obesity is one of the multiple components associated with metabolic syndrome. A disorder that can lead to the loss of homeostasis of the body by involving modifications in the metabolism of carbohydrates, lipids, and proteins from food consumption.

Obesity is a major risk factor contributing to the global burden of disease worldwide In Brazil, a study carried out in the Brazilian capitals showed that there was a statistically significant increase in most indicators related to weight gain for both genders, age groups, schooling, and regions from 2006 to 2013, with a growth trend towards both overweight and obesity (Malta *et al*., 2016).

Body overweight is a trait of multifactorial origin, whose group of factors interact with each other, such as in particular the genetic predisposition of individuals to weight gain and environmental aspects, involving inappropriate eating habits, and sedentariness, which are able to modulate gene expression (Caspers *et al*., 2019).

These factors added to the intense urbanization and globalization of food marketing have consequently an increase in consumption of industrialized products and a decrease in "fresh" foods such as fruits, vegetables and legumes (De Souza, 2017), with changes in the food pattern, providing an imbalance by excessive calorie intake. (M.S.2014). The occurrence in a global context of this nutritional transition and its aspects reflect the current nutritional status of the Brazilian population, including changes in the nutritional status of riverine communities in relation to the development of overweight and obesity (Piperata, 2011).

Thus, the various metabolic and lifestyle interactions associated with overweight, and obesity have a socioeconomic impact, as they favor chronic pathologies such as hypertension, heart failure, coronary artery disease, diabetes mellitus, dyslipidemias and premature death (Hall *et al*., 2014). Circumstantially, among these aspects, it is also important to mention a relationship between exposure to heavy metals and the development of obesity (Lubrano *et al*., 2013).

Several revised data suggest that contamination by heavy metals may interfere with mechanisms related to weight gain (Rotter *et al*., 2015), as these elements act as chemical disrupters of the endocrine system and human metabolism (Moon, 2017). Fish is the main source of protein for riverine communities, and it is through the contamination of these fish by the organic form of mercury that human intoxication occurs (Dolbec *et al*., 2000). The consequences of exposure to methylmercury are irreversible, with symptoms associated with neurologic genesis among which changes such as blurred vision, reduced visual field, hearing loss, motility disorder, and in severe cases of exposure can lead to death (Bisinoti & Jardim 2004).

Some reports (Park & Lee, 2017; Eom *et al*., 2014; Qin *et al*.,2010) point to a significant relationship between capillary and blood mercury levels and body mass index (BMI), waist circumference, systolic and diastolic blood pressure, and changes in triglyceride and glucose levels, especially among people diagnosed with metabolic syndrome. On the other hand, the role of Hg in the development of these metabolic diseases is still contradictory and not properly clarified. Therefore, it is of extreme value to public health to understand the impact that this environmental chemical has on the metabolic system, the mechanisms that induce these effects and how they can be mitigated.

In this sense, the objective of this study is to know the influence of risk factors associated with overweight and obesity in riverine residents of the Tapajós-PA region, seeing to relate the nutritional status and its anthropometric parameters to the frequency of consumption of fish and other foods in the riverine communities studied, exposed to mercurial contamination.

II. METHODOLOGY

Design of the study

The study developed was a descriptive and analytical cohort that included the riverside communities of Barreiras and São Luiz do Tapajós in the Tapajós River basin, exposed to mercurial contamination, in the municipality of Itaituba, Belém-Pa.

Casuistic and place of study

The survey evaluated the communities of Barreiras and São Luiz do Tapajós, located on the banks of the Tapajós River basin characterized by a history of chronic exposure to mercury. The samples were collected from June 2014 to November 2017. The target audience included individuals' ≥ 18 years of age, of both sexes, who have resided in the community for more than one year and who have agreed to participate in the study after appropriate guidance and informed consent. This study was approved by the Research Ethics Committee of the Center for Tropical Medicine of the Federal University of Pará (Advice No. 2,749,867).

According to a survey conducted by the Brazilian Institute of Geography and Statistics (IBGE) in 2010, the municipality of Itaituba has an estimated population of 97,343 inhabitants within a territory of 62,041 km², with several communities distributed along the banks of the Tapajós River, inhabited by families that subsist on agriculture, mainly manioc and subsistence fishing.

Barreiras and São Luís do Tapajós are from these community.

Epidemiological and body composition assessment.

A semi-structured questionnaire was applied to collect information regarding the sociodemographic profile (age, gender, income, and education), presence of comorbidities, food survey, lifestyle (smoking, elitism), economic conditions (occupation, income) and health. In the evaluation of the nutritional status for the public, 18 to 60 years was determined by the Body Mass Index body mass index (BMI), the measurement of waist circumference (WC) for adults over 18 years, based on data validated by the World Health Organization (WHO, 1998). While for individuals over 60 years was used old, the cutoff point of BMI for the elderly, was validated by Lipschitz *et al*., 1994. The measurement of waist circumference was obtained using an inelastic tape measure adjusted to the body at the midpoint between the upper iliac crest and the last rib, with the reading made at the end of the normal expiratory movement.

Analysis of diet variety

The dietary history obtained by questioning the participants of the study about the frequency of food consumption in the last three months. The frequency of food consumption was converted into a daily equivalent. These values were assigned: "more than three times/day" = 3; "two to three times/day" = 2; "one times/day" = 1; "five to six times/week" = 0.79 (=[(5+6)/2]/7); "two to four times/week"= 0.43 (=[(2+4)/2]/7); "once/week" = 0.14 (1/7); "once to three times/month" = 0.07 (=[(1+3)/2]/30); "never/when never" = 0. This dietary information was evaluated according to the recommendations of the Food Guide for the Brazilian population (Ministério da Saúde, 2005) and the food pyramid proposed by the Ministry of Health (14) as a parameter for food groups. Based on the studies by Fisberg *et al*.; 2004 and Mota *et al*., 2008 was made, a comparison of dietary variety was made, while the description and scoring of dietary quality was performed through the Healthy Eating Index (IAS).

Healthy eating index (IAS)

IAS has evaluated six different basic components of a healthy diet. The score varied from 0 to 10 for each of these six components, and so the index ranged from 0 to 60 points. Components 1 to 5 evaluate the diet according to the food pyramid portion recommendations for the six main groups: cereals, vegetables, fruits, milk, legumes, and meat. Thus, the maximum score is obtained when 6-11 portions of cereals are consumed; 3-5 portions of vegetables; 2-4 portions of fruits; 2-3 portions of milk and milk products; and 2-3 portions of meat and legumes.

On the other hand, when there is no consumption of these items, i.e., when the consumption is zero, the score obtained is zero. For all these components of IAS, whose consumption is between the minimum (zero) and maximum (ten) cut-off points, the score is proportionally calculated. Moreover, according to the sum of these scores for each of these assessed IAS of components, diets have been classified into three categories: healthy diet (over 48 points), diet requiring improvement (31-48 points) and inadequate diets (under 31 points).

Biological sampling and treatment

Hair samples were collected from each participant, obtained by cutting with stainless steel scissors near the scalp, for analysis of total Hg. After collection, the samples were duly stored and sent to the Laboratory of Human and Environmental Toxicology of the Center for Tropical Medicine (NMT) of the Federal University of Pará (UFPA), to be analyzed by atomic absorption spectrophotometry technique.

In the determination of total mercury, the samples were washed with neutral detergent, and rinsed intensely with deionized water to remove the detergent. Finally, they were washed twice with 3 mL of acetone and dried at room temperature. Then, they were transferred to glass flasks previously washed with 5% potassium permanganate solution and intensely chopped (cuts smaller than 2 mm) using stainless steel scissors.

In the analysis of total Hg concentrations, the combustion method was used, followed by the amalgamation in gold plates using a flameless SP3D atomic absorption spectrometer from Nippon Corporation-Japan. In this method, hair samples are mineralized at 800°C in a closed oven, and the mercury vapor is released and amalgamated on gold plates, washed, and later transferred to a detector with a fixed wavelength of 254.7 mm.

Statistical analysis

The survey data were tabulated using the Microsoft Excel® 2013 program, and thea significance level of 5% (p-value < 0.05) was adopted for statistical tests. Statistical calculations were performed using Bioestat® version 5.0 AYRES,2007.

III. RESULTS

The study included 210 individuals living in two riverside communities of the Tapajós River valley, corresponding to 130 samples from the population of Barreiras (BAR) and 80 samples from the community of São Luiz do Tapajós (SLT). In general, the mean age of the individuals evaluated was 46.04 ± 15.62 years (47.79 ± 16.24 years for Barreiras and 43.28 ± 14.25 years for São

Luiz do Tapajós). A mean BMI of 27.05 ± 4.86 kg/m2 (26.74 ± 4.42 Kg/m2kg/m2 for Barreiras and 27.28 ± 5.18 kg/m2 for São Luiz do Tapajós), with a minimum value of 15 kg/m2 and maximum of 45.08 kg/m2.

In the elderly group (age > 60 years), the observed proportions of overweight for BMI values ≥ 27 Kg/m2kg/m2 oscillated close to 50%, with 47.1% (16/34) for Barreiras and 53.8% (7/13) for São Luiz do Tapajós (figure 1).

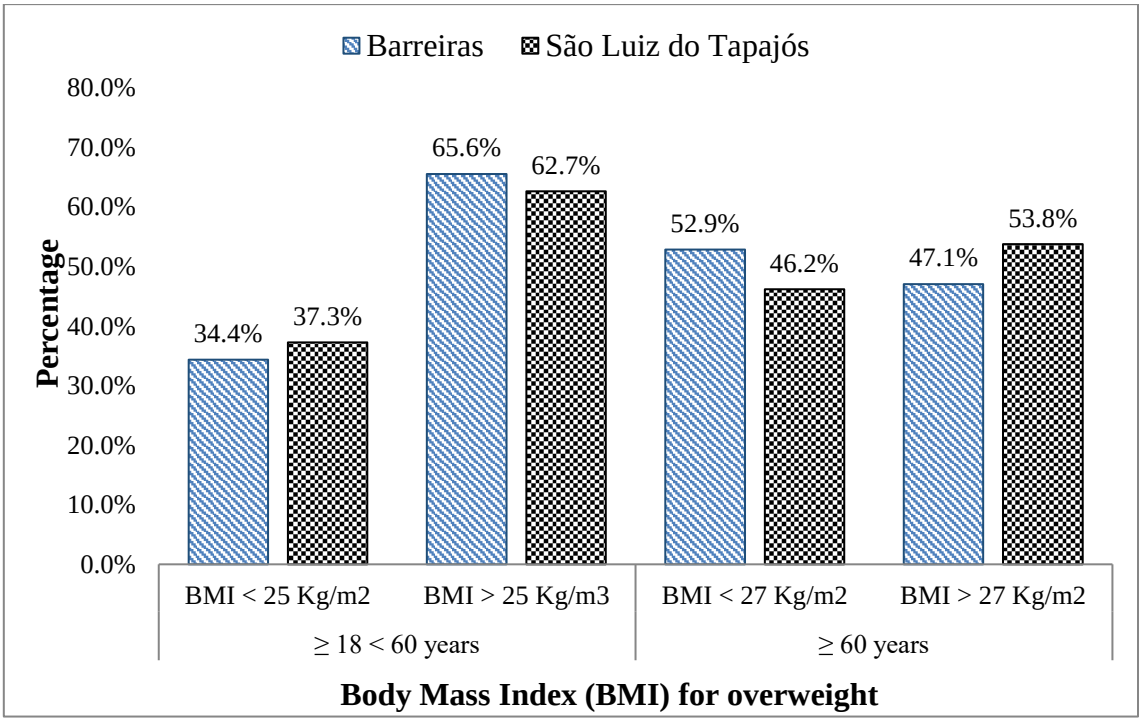

Fig.1. Estimated frequency of BMI values (kg/m²) according to the criteria established for determining overweight in adults and the elderly in the riverside communities of Barreiras and São Luiz do Tapajós in the municipality of Itaituba, Pará, 2014-2018.

In the analysis of the classification of the waist circumference measurement regarding risk for chronic non-transmissible diseases, the highest percentages were observed in the high-risk group (Men > 102 cm: Women > 88 cm), especially in the population of Barreiras, with 41.5% (54/130) of the cases. The proportion of individuals classified with normal waist circumference values (Men < 94 cm; Women < 80 cm) occurred in 37.0% in Barreiras and 31.2% in São Luiz do Tapajós (figure 2).

When the factor, central adiposity, was analyzed, significant differences ($p < 0.001$) were shown as a function of the nutritional status determined by BMI in both communities studied, with individuals with excess weight presenting a greater measure of abdominal circumference than those without excess weight, as shown in Figure 3. The general mean (88.97 cm), in turn, was lower than the mean of those who were overweight in both populations but exceeded that of individuals without overweight. Thus, the displacement of the mean and confidence interval (CI) of those affected by overweight can be clearly seen. In both communities, in the group of individuals with excess body weight, the mean circumference was 93.39 cm in Barreiras and 95.17 cm in SLT, and the lower limits (91.50 cm and 92.36 cm) of the respective IC were greater than the upper limit (90.46 cm) of the general mean IC (88.97 cm). Similarly, in the group of individuals without excess body weight, the mean circumference was 81.45 cm in Barriers and 79.87 cm in TLS, and the upper limits (84.05 cm and 82.36 cm) of the respective IC were lower than the lower limit (87.48 cm) of the general mean IC (88.97 cm). The IC (95%) of the general mean, as expected in the face of the sample size (n=210), was lower (87.48 cm to 90.46 cm), that is, 2.98 cm.

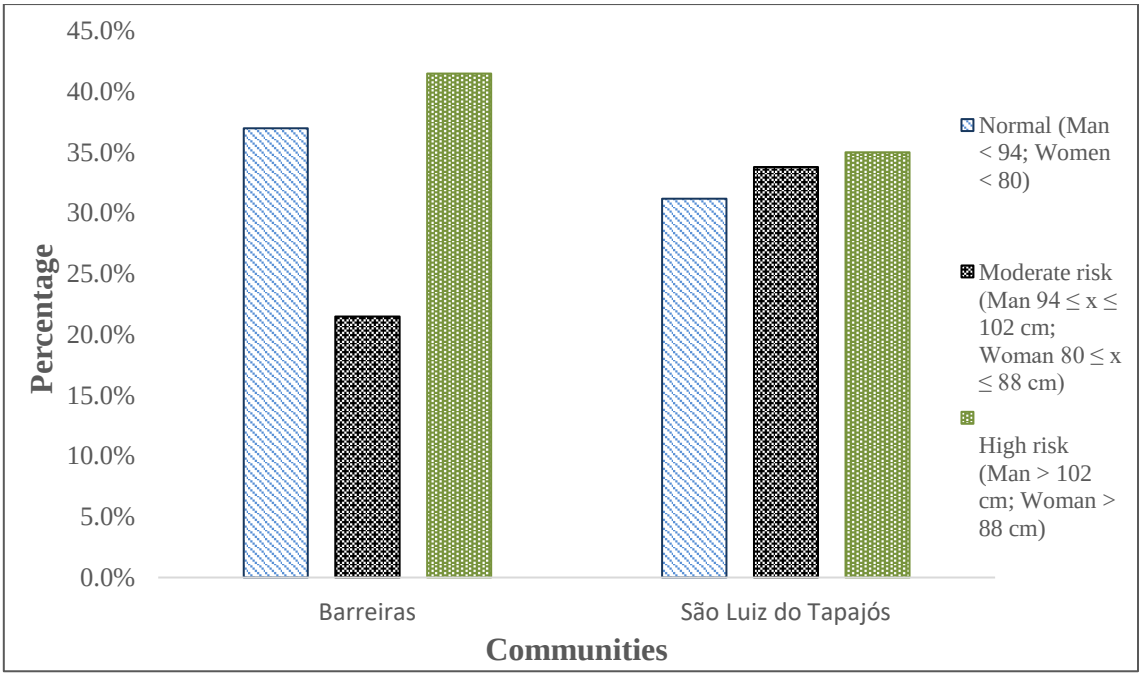

Fig.2. Distribution of risk classification for chronic noncommunicable diseases according to waist circumference (cm) measurements in the riverside populations of Barreiras and São Luiz do Tapajós in the municipality of Itaituba, Pará, 2014-2018.

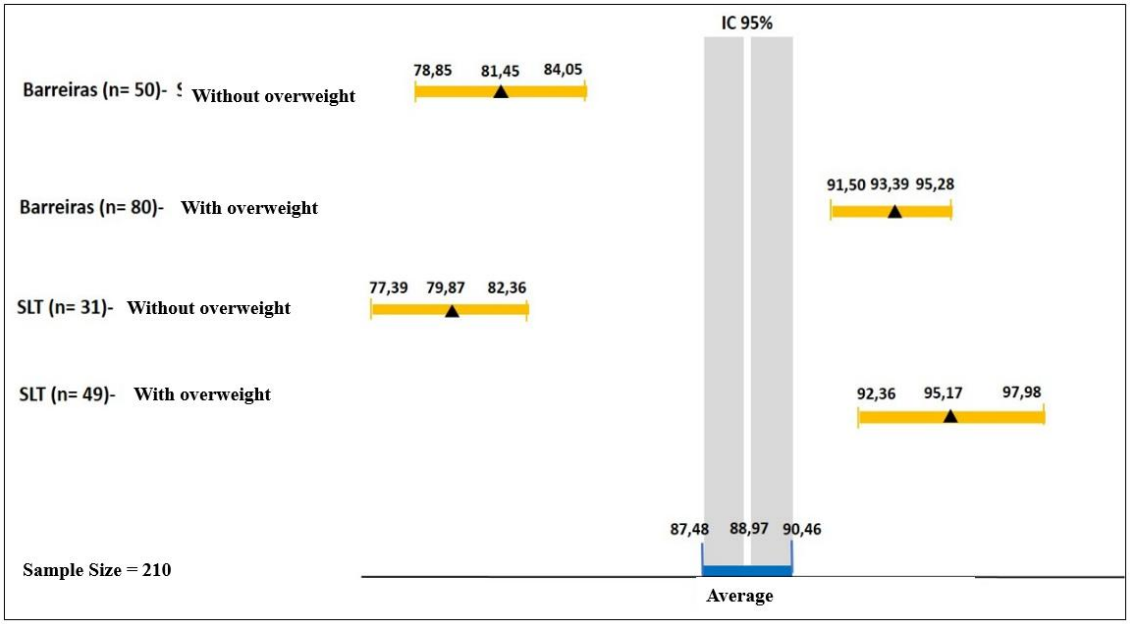

Fig.3- Confidence interval diagram (95%) of the general average waist circumference (cm) considering the presence of overweight in the riverside populations of Barreiras and São Luiz do Tapajós in the municipality of Itaituba, Pará, 2014-2018.

In relation to the nutritional status, with respect to consumption and specific dietary habits present in riparian communities, the distribution relative to the variety of the diet, found that 76.7% of individuals consume 6-10 different types of food per day, reaching a score of 5, which defines an average rating for food variety. Another 22.8% consume ≤ 5 different foods daily, with a score of zero, this food variety being the minimum (Table 01). The findings of the global diet analysis show that the average food variety was 6.3 types per day, reflecting a food pattern that still needs to improve the diversity of foods consumed in these studied communities. Alone, the types of foods estimated

are not enough to express the quality of the diet, since this does not necessarily imply the occurrence of the ingestion of all food groups, nor indeed the excessive consumption or scarcity of foods, whose increased information is relevant to analyze the consumption of nutrients in a healthy diet.

Table 01. Classification of diet quality according to food variety score in the riverside populations of Tapajós, Itaituba, Pará 2014-2018.

Food variety	Population		Variety of aliments	Punctuation
	Barreiras	SLT		
	N (%)	N (%)		
Minimum	31 (23.85)	17 (21.52)	≤ 5 types	0
Average	99 (76.15)	62 (78.48)	6-10 types	5
Adequate	0 (0.00)	1 (1.25)	> 10 types	10

Thus, in this study, in the evaluation of the quality of the diet, IAS was added, which divides foods into groups and portions, allowing comparison of the amount of food ingested with the recommended ideal according to the Brazilian food pyramid. The average of portions and the score acquired for analysis of the healthy eating index are distributed respectively in tables 2 and 3, respectively.

Table 02. Average values of portions consumed by food category as a function of nutritional status in inhabitants of the riverside areas of the Tapajós River, Itaituba, Pará, 2014.

Average portion consumed/ Food group	BAR (Overweight)		SLT (Overweight)	
	[2]No	[3]Yes	[2]No	[3]Yes
Cereals, roots and tubers	5.90	5.46	5.87	6.33
Vegetables	0.93	1.13	0.89	0.74
Leguminous plants	0.91	0.98	1.30	0.92
Fruits	0.42	0.46	0.48	0.46
Milk and dairy products	0.85	0.75	0.79	0.67
Meat	2.18	2.26	2.30	2.38
Fish/meat ratio[1]	1.75	1.64	5.85	8.72

1Including beef, chicken, pork and other wild game, 2No: for BMI > 25 kg/2 for ages > 18 and < 60 years or < 27 kg/m2 for ages > 60 years, 3Yes: for BMI > 25 kg/m2 for ages > 18 and < 60 years or > 27 kg/m2 for ages > 60 years.

Table 03. Average values of scores obtained for the components of food groups in the healthy eating index (IAS) as a function of nutritional status in inhabitants of the riverside areas of Tapajós.

Components of IAS by food group	BAR (Overweight)		SLT (Overweight)	
	[2]No	[3]Yes	[2]No	[3]Yes
Cereals, roots and tubers	11.8	10.92	11.74	12.66
Vegetables	2.32	2.82	2.22	1.85
Leguminous plants[1]	9.10	9.80	13	9.20
Fruit[3]	1.40	1.53	1.60	1.53

Milk and dairy products[3]	2.83	2.50	2.63	2.23
Meat and eggs	21.80	22.60	23.00	23.80
Total Score	49.25	50.17	54.19	51.27
Fish/meat ratio[1]	3.06	3.74	7.39	8.37
Food variety	5.53	6.46	6.97	6.24

1Including beef, chicken, pork and other wild game, **2No**: for BMI > 25 kg/2 for ages > 18 and < 60 years or < 27 kg/m2 for ages > 60 years, **3Yes**: for BMI > 25 kg/m2 for ages > 18 and < 60 years or > 27 kg/m2 for ages > 60 years.

First, the evaluated group of cereals, consisting of foods rich in carbohydrates, was the most consumed, particularly among those individuals with overweight and greater abdominal circumference in the SLT community. The group of vegetables and fruits were less consumed, further reinforcing this relationship between those who were overweight and the reduced intake of natural, fiber-rich foods. The legume group presented an ideal intake of these foods, represented by the consumption of beans, a source of essential amino acids and a typically Brazilian habit. The combination of beans and rice is culturally the most important food base and presented an even higher consumption among those without excess weight in the SLT community. In the group of milk and dairy products, the average consumption was low, essentially due to the higher cost and its low availability and cultural acceptance, and this reduction tends to be slightly accentuated among those who are overweight, which favors the damage to health, such as susceptibility to chronic diseases and osteoporosis. The meat group presented a consumption above the recommended, which is also constituted of foods rich in fats, being with its consumption expressive among the individuals of both communities studied. However, when the fish/meat ratio was evaluated, significant differences were found between the two communities studied, showing the consumption of fish is proportionally at least twice as frequent among individuals of SLT compared to BAR (Table 2).

From the final IAS score of IAS (Table 3), the quality of diet among individuals with or without excess weight in the communities studied can be interpreted as "need for changes". Since the total scores (45<X<72 points) establish that not all food needs were contemplated. This status is due to a priority / reference consumption of the group of cereals, pulses and meat and shortages in the consumption of milk and of fruits and vegetables, coupled with sedentariness.

According to the socio-demographic information of the surveyed subjects, it was observed that there was a higher percentage of women, corresponding to approximately 70% for both communities of São Luiz do Tapajós and Barreiras. Many people with low levels of education (Illiterate/Elementary Schooling) were also observed, corresponding to 75% and 65% of the communities of SLT and BAR, respectively. On the other hand, most of this population earn income equal to or less than one minimum wage, with a distribution of 84% for São Luiz do Tapajós and 53% in Barreiras. In this case, these communities differ, since in SLT, only 16% of individuals have a family income higher than one minimum wage, compared to 47% in BAR. In relation to the type of occupation, the community of SLT differs from BAR (51% vs. 33%), since more than half of the individuals do not have a wage (Table 4).

Table 04. Socio-demographic and epidemiological characteristics of the populations studied according to the presence of excess.

Variables	BAR (n=130)		[a]p-valor	SLT (n=80)		[a]p-valor	Total (n=210)		[a]p-value
	[b]Não n=51 (%)	[b]Sim n=79 (%)		[b]Não n=31 (%)	[b]Sim n=49 (%)		[b]Não n =82 (%)	[b]Sim n= 128	
Sex									
Female	35 (68,6)	56 (70,9)	0,9375	19 (61,3)	39 (79,6)	0,1263	54 (65,9)	95 (74,2)	0,2514
Male	16 (31,4)	23 (29,1)		12 (38,7)	10 (20,4)		28 (34,1)	33 (25,8)	
Age group									
< 60 years	33 (64,7)	63 (79,7)	0,0889	25 (80,6)	42 (85,7)	0,7736	58 (70,7)	105	0,0806
≥ 60 years	18 (35,3)	16 (20,3)		6 (19,4)	7 (14,3)		24 (29,3)	23 (18,0)	
Family income									
≤ 1 minimum wage	27 (52,9)	43 (54,4)	0,9889	26 (83,9)	41 (83,7)	0,7736	53 (64,6)	84 (65,6)	0,9989
> 1 minimum wage	24 (47,1)	36 (45,6)		5 (16,1)	8 (16,3)		29 (35,4)	44 (34,4)	
Comorbidities									
Yes	7 (13,7)	17 (21,5)	0,3752	9 (29,0)	11 (22,4)	0,6910	16 (19,5)	28 (21,9)	0,8129
No	44 (86,3)	62 (78,5)		22 (71,0)	38 (77,6)		66 (80,5)	100	
Fish consumption									
≤ 4 meals per week	35 (68,6)	42 (53,2)	0,1166	19 (64,5)	16 (40,8)	**0,0224**	54 (65,9)	58 (45,3)	**0,0056**
> 4 meals per week	16 (31,4)	37 (46,8)		12 (35,5)	33 (59,2)		28 (34,1)	70 (54,7)	
Fruit Consumption									
≤ 4 meals per week	41 (80,4)	57 (72,2)	0,3918	21 (67,7)	33 (67,3)	0,8350	62 (75,6)	90 (70,3)	0,4969
> 4 meals per week	10 (19,6)	22 (27,8)		10 (32,3)	16 (32,7)		20 (24,4)	38 (29,7)	
Consumption of beans									
≤ 4 meals per week	32 (62,7)	47 (59,5)	0,8518	12 (38,7)	31 (63,2)	0,0554	44 (53,6)	78 (60,9)	0,3683
> 4 meals per week	19 (37,3)	32 (40,5)		19 (61,3)	18 (36,8)		38 (46,4)	50 (39,1)	
Consumption of									
≤ 4 meals per week	40 (78,4)	49 (62,0)	0,0763	23 (74,2)	39 (79,6)	0,7729	63 (76,8)	88 (68,8)	0,2655
> 4 meals per week	11 (21,6)	30 (38,0)		8 (25,8)	10 (20,4)		19 (23,2)	40 (31,2)	
Vegetable									
≤ 4 meals per week	37 (72,5)	46 (58,2)	0,1409	21 (67,7)	34 (69,4)	0,9260	58 (70,7)	80 (62,5)	0,2815
> 4 meals per week	14 (27,5)	33 (41,8)		10 (32,3)	15 (30,6)		24 (29,3)	48 (37,5)	

[a] Chi-square (X)2 test with Yates Correction; b No: for BMI > 25 Kg/2 for ages > 18 and < 60 years or < 27 Kg/m2 for ages > 60 years, Yes: for BMI > 25 Kg/m2 for ages > 18 and < 60 years or > 27 Kg/m2 for ages > 60 years.

The only significant difference in socio-demographic and alimentation standards between the two villages has been the consumption of fish, (in frequency supplemented by cassava meal). All other parameters were at the same level also for the individuals with excess of body weight. In addition, it is relevant to mention that it was reported by personal accounts during the anamnesis that none of the research participants exercised regularly.

During the analysis of the epidemiological aspects of the riverine populations studied, a high frequency of fish consumption was observed, particularly among individuals from the community of São Luiz do Tapajós. It became necessary to re-evaluate these data, regarding the frequency of fish consumption among groups with and without the presence of excess body weight in both communities studied. The difference observed was very significant (t= 2,4205; p= 0.0089) in São Luiz do Tapajós. However, this was not statistically significant (t= 1, 57; p > 0.05) in the Barreiras group.

In addition, considering the data above, it was verified whether there is an association between the levels of mercury detected in these communities in relation to the nutritional status through the BMI parameter. This analysis detected that there is a difference in the average mercury levels between overweight and underweight individuals, only in the population of São Luiz do Tapajós, and the average mercury levels in the overweight group showed higher values than those without overweight. However, in

the community of Barreiras, the mean capillary mercury levels among the analyzed groups did not differ. These findings are shown in figure 4.

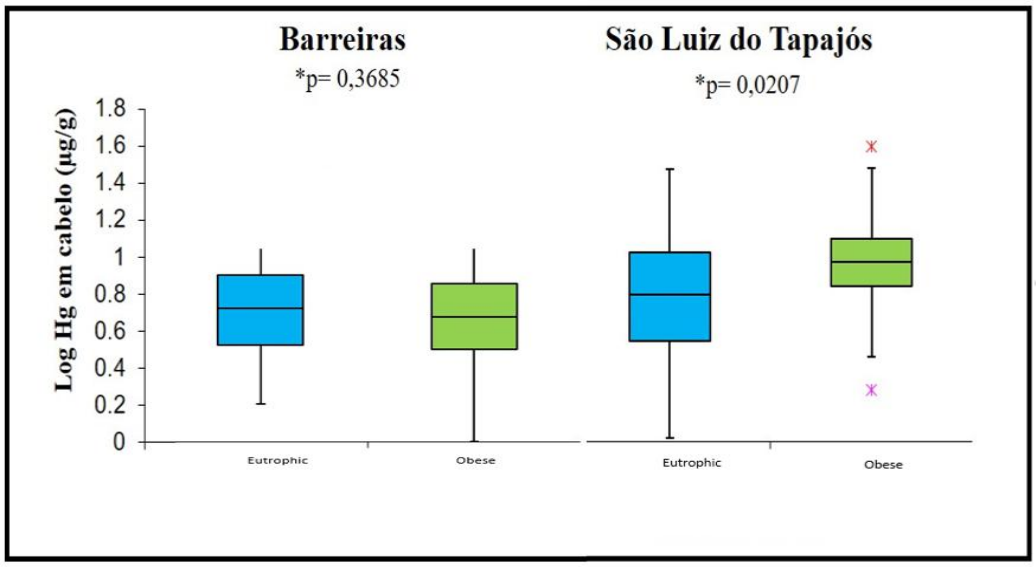

Fig.4 - Box plot graph as a function of the mean values of capillary mercury Log (µg/g) between the groups with and without excess weight in the riverside populations of Barreiras and São Luiz do Tapajós in the municipality of Itaituba, Pará, 2014-2018.

IV. DISCUSSION

The study highlights that the epidemiological scenario is related to the high prevalence of overweight found in the Tapajós riverside communities. The population, Barreiras and São Luiz do Tapajós, in the state of Para, reveal a phenomenon (Popkin *et al*, 1993; Popkin & Bisgrove, 1998) that occurred on a global scale and has been observed in other populations in Brazil. This characterize characterizes an increase in rates of obesity in different social, economic, environmental, lifestyle and health contexts (Malta *et al*., 2015).

The World Health Organization has estimated that approximately 39% of individuals over 18 years of age are overweight in the world worldwide (WHO, 2018). In Brazil, the map defined for overweight by regions, estimates frequencies of 56.08% for the south, 50.45% for the southeast, 48.3% for the center-west, 44.45% for the northeast and 48.3% for the north [1]. In a study developed in riverside communities of the Madeira River, in the state of Rondônia, about approximately 55% of the evaluated population was overweight (Oliveira *et al*., 2013). In this study, the frequency of overweight affected approximately 60% of adult individuals in the riverine populations analyzed in the Tapajós valley, and the prevalence described above is similar for other Brazilian populations.

According to previous studies (Berzas-Nevado, 2010; Bosch *et al*., 2015), the traditional in habitants of the Amazon basin have in fish their main source of protein. The regular in fish. Regular consumption in food may be associated with an increase in caloric of energy, either by the amount or by the method of preparation of this animal protein, or by excessive consumption of other energy sources, such as cassava flour (Oliveira *et al.*, 2010)

From this study, the estimated dietary rates made it possible to determine the quality of the diet, according to the quantity consumed by groups of foods, showing similarities and differences between individuals with and without excess body weight in the communities studied. There is consumption, which satisfies the recommended values in the cereals and legumes. However, consumption is above the ideal of meat, while, the shortage is present in groups of vegetables and fruits, as well as other natural foods rich in fibers, such as whole grains and nuts. Also additionally, milk and derivatives are reduced, which results in a strong reduction in the variety of foods.

This is an increasingly common food pattern among riverine populations, translated by changes in lifestyle based on subsistence economy to another dependent on a market economy, and consequent increase in rates of excess body weight. (Pinheiro *et al*.; 2004)

Therefore, in accordance with these findings, it is necessary to invest in food education in these communities, seeking the identification of food groups at risk or of nutritional benefit, capable of preventing metabolic

disorders, in health promotion. In general, the diet foods and lifestyle (toxic exposure, education, and socioeconomic aspects) are factors that may modify gene expression, affecting metabolic functions (Rist *et al*., 2006)

This diet can be interpreted either by a high concentration of saturated fats coming from the consumption of different types of meat, besides in addition to simple carbohydrates and industrialized products. This occurrence is one of the determinant causal factors for weight gain, which suggests having a relationship with the community of Barreiras. Since the main determinant cause is a nutritional imbalance bound to the excess of total calories consumed, and as an example of the high consumption of fish flour and proteins, probably contaminated with methyl mercury, in São Luiz do Tapajós.

In this study, the evidence revealed some heterogeneity supported by a differentiated reality among the riverine populations studied, although they share several socio-environmental and cultural similarities. It is worth pointing out that the community of Barreiras in relation to the community of São Luiz do Tapajós, has the following peculiarities:

1) A geographical location close to the routes to the most populated urban centers and, therefore, with greater ease of access to these centers, which allows greater availability and variety in the purchase of industrialized products.

2) A reduction in fish consumption, and consequently, its beneficial action on the body.

3) Increased by the intake of an increased rate of saturated fat from other types of meat and industrialized products.

4) Improved family and occupational income, with changes in labor activities of greater intensity to more sedentary behaviors.

In this sense, these environmental conditions structured around this community of Barreiras, seem to have influenced the rate of local overweight in different ways from those observed in the population of São Luiz do Tapajós.

On the other hand, the trend of weight gain among individuals of São Luiz do Tapajós was directly linked to the consumption of fish, supplemented with cassava flour at a higher frequency of four times a week. In the community of São Luiz do Tapajós, weight gain may be associated with increased availability and a high frequency of fish consumption, also reflecting higher average levels of capillary mercury among individuals in the overweight group than among those individuals without overweight. Murrieta *et al*. (2008) also highlights that in riverine populations, fish may not only be the main source of protein but also the most important animal source of energy.

The nutritional status is a multifactorial process, who is, environmental and genetic aspects reflect on the nutritional profile of this community. The contrasts observed inherent to the epidemiological aspects of these communities were provided by the synergism resulting from the heterogeneous nature of lifestyles and the coexistence of socioeconomic differences among individuals from these communities, which has naturally contributed to nutritional imbalances and body weight increase. Thus, these transformations interfere both in the nutritional state as well as and in the health state. In addition, by anthropometric and clinical parameters can likely classify these individuals not only with high BMI, but also with measures of waist circumference, with moderate to high risk for non-transmissible chronic diseases, linked to ages that are more advanced and the appearance of the metabolic syndrome.

Over a long period, genetic predisposition, excessive caloric intake, and sedentary lifestyle were responsible for being the main risk factors in the involvement of excess body weight (Zhang *et al.*, 2009). However, recent research has also pointed out the role of environmental pollutants in the development of overweight has been interrelated with exposure to heavy metals (Moon *et al*., 2014). There is no precise mechanism of how mercury interacts with the parameters associated with overweight. Tinkov *et al*. (2015) support the hypothesis that mercury-induced induces systemic responses such as inflammation, oxidative stress and endoplasmic reticulum stress. These alterations may be determinant for the development of physiological changes in the body, contributing to the manifestation of metabolic disorders, as one of its components, which is overweight.

Thus, some studies indicate the association of high levels of capillary mercury (Skalnaya *et al*., 2014) and mercury in blood (Cho *et al*., 2014) with overweight and obesity, this which trigger one of the starting points to assess the physiological changes caused in the human body by mercurial contamination in the environment. An investigation involving 1853 people in Knhanes in 2010 demonstrated an association between blood mercury versus BMI, as well as waist circumference values (Cho *et al*., 2014).

To some extent, some data in the literature have been reinforced by extensive investigation of 2114 adults without occupational exposure to mercury compounds but who, from the influence of dieting, showed a significant relationship between blood mercury levels and clinical parameters such as BMI, waist circumference, systolic and

diastolic blood pressure, fasting glucose and triglycerides (Eom *et al.*, 2014).

Similarly, Qin *et al.* (2010) reported that the mercury concentration is significantly higher in visceral fat than in subcutaneous fat. Other studies (Brzoska *et al*., 2010; Michalek *et al*., 1996) reported that obesity predisposes people to lower levels of bile secretion, which would harm people with more body fat to eliminate heavy metals, because mercury are lipophilic, people tend to excrete more slowly than those with less body fat.

This fact has been corroborated by the study of Park & Lee (2017), which described individuals with higher concentrations of mercury who also consumed more fish. These authors found that individuals with higher mercury levels were more likely to be male and had higher body mass index, waist circumference and visceral fat tissue, although, according to the authors, the mechanisms of these interrelations are still unclear.

Overall, some studies (Chang *et al.*, 2011; You *et al*., 2011; Skalnaya *et al.*, 2014; Tinkov *et al.*, 2015) have shown an association of between mercury levels in the body and overweight, although there are also gaps in information regarding the interrelationship between mercurial exposure and the pathogenesis of obesity. This leads to insufficient information on the cause-and-effect relationships between mercury and obesity.

In the case of this study, the findings indicated that overweight people in the community of São Luiz do Tapajós are exposing to higher levels of methyl mercury due to a high frequency of fish consumption. This could explain, at least partially, the higher percentage of overweight individuals found among the inhabitants of the community of São Luiz do Tapajós.

While the rates of overweight observed in Barreiras seem to grow similarly to large urban centers and capital cities. This finding was not expected, highlighting the importance of more in-depth studies capable of clarifying the pathogenic mechanisms of overweight. It is necessary to promote a model of attention for appropriate treatment, integrating socioeconomic policies in the sphere of public health.

The main limitations inherent to this study and that supposedly could have influenced the analysis and interpretation of the data are basically the tools applied in the methodology. In this context, it is considered the food indexes selected to estimate and evaluate the quality of the diet, as well as the semi-quantitative type of nutritional questionnaire, which was elaborated to obtain the information of the eating habits of the studied communities. Therefore, additional, and complementary studies are expected, considering the peculiarities and specificities of the diet of the riverine communities, in the scope of basic health care.

V. CONCLUSION

The study demonstrated a high prevalence of excess body weight and consequently increased waist circumference, whose assessment related to abdominal adiposity, presented a moderate to high risk for manifestation of metabolic complications related to chronic non-transmissible diseases.

In relation to the epidemiological and nutritional aspects, a differentiated food pattern was identified in the studied river communities. One is more influenced by the globalization processes that favored changes in the traditional alimentary habits, mainly in relation to a diet with scarcity of natural and fiber-rich foods such as vegetables and fruits and to the preferential consumption of meat, whose ingestion was above the recommended amount in the healthy diet. Therefore, the quality of these diets measured by IAS portrays/enhances a nutritional profile that requires increasing changes favorable to the variety of foods rich in essential nutrients, balanced and appropriate to individual needs, decreasing overweight, in addition to positively influencing the state of health and quality of life. The other food pattern of São Luiz do Tapajós is still more traditional, and there we found, especially among individuals with excess body weight, a greater frequency in the consumption of fish, which in turn showed a positive and significant relationship with mercury levels in hair.

ABBREVIATIONS

PA - State of para

WHO- World Health Organization

BMI- Body mass index

IAS- healthy eating index

NMT- Tropical Medicine Nucleus

UFPA- Federal University of Pará

BAR- population of Barreiras

SLT- population of São Luis do Tapajos

CI- confidence interval

IC- confidence index

HG- Mercury

AVAILABILITY OF DATA AND MATERIALS

Data sets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All participants signed an informed consent letter. We will obtain ethical approval from the Nucleus Tropical Medicine Committee of the Federal University of Para (Advice No. 2,749,867)

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DATA SHARING STATEMENT

No additional data are available.

INFORMED CONSENT STATEMENT

All study participants, or their legal guardians, provided informed written consent prior to study enrollment.

REFERENCES

[1] ABESO. **Mapa da Obesidade**. Disponível em: <http://www.abeso.org.br/atitude-saudável/mapa-obesidade> Access on:10 de janeiro de 2018.

[2] ARBEX, A. K.; ROCHA, D.R.T.W.; AIZENBERG, M.; CIRUZZI, M.S. **Obesity Epidemic in Brazil and Argentina:** A Public Health Concern. Journal of Health Population and Nutrition, v. 32, n. 2, p. 327-334, 2014.

[3] AYRES, M; AYRES JR, M; AYRES, D L & SANTOS A A. **Bioestat 5.0**. Belém: Sociedade Civil Mamirauá. 364p. 2007.

[4] AZEVEDO, F. A. & RAMOS, A. C. **Bibliografia brasileira de mercúrio. Aspectos ambientais e toxicológicos.** Bol. Téc. CEPED, v. 8, n. 1, p. 7 – 13.1993.

[5] AZEVEDO, F. A.; NASCIMENTO, E. S.; CHASIN, A. **(Caderno de Meio Ambiente) Aspectos Atualizados dos Riscos Toxicológicos do Mercúrio**. TECBAHIA R. Baiana Tecnol., v. 16, n. 3, p.87 a 104.2001

[6] BASTOS, W. R. **Métodos de digestão utilizando microondas para determinação automatizada de Hg em amostras ambientais e humanas: implantação de laboratórios e avaliação da qualidade analítica.** Dissertação apresentada à Universidade Federal do Rio de Janeiro. pp 118. Rio de Janeiro.1997.

[7] BERLIN, M. Mercury. In: Friberg, L., Nordberg, G. F., Vouk, V. (eds) **Handbook on the toxicology of metals,** 2nd ed., p. 345-387. New York. Elsevier Science Publishers BV, 1986

[8] BISINOTI, M. C. & JARDIM, W. F. **O comportamento do metilmercúrio (MetilHg) no ambiente**. Quim. Nova, Vol. 27, No. 4, p593-600.2004**.**

[9] BOSCH, A. C., O'Neill, B., Sigge, G. O., Kerwath, S. E., & Hoffman, L. C. (2015). **Heavy metals in marine fish meat and consumer health: a review.** Journal of the Science of Food and Agriculture, 96(1), 32–48. doi:10.1002/jsfa.7360

[10] BRZÓSKA MM, Majewska K, Kupraszewicz E. 2010. **Effects of low, moderate, and relatively high chronic exposure to cadmium on long bones susceptibility to fractures in male rats.** Environ Toxicol Pharmacol. 2010 29(3):235-245.

[11] CASPERS M, Blocquiaux S, Charlier R, Lefevre J, De Bock K, Thomis M. **Metabolic fitness in relation to genetic variation and leukocyte DNA methylation.** Physiol Genomics. 2019 Jan 1;51(1):12-26. doi: 10.1152/physiolgenomics.00077.2018. Epub 2018 Dec 7. PMID: 30526334.

[12] CHANG JW, Chen HL, Su HJ, Liao PC, Guo HR, Lee CC. **Simultaneous exposure of non-diabetics to high levels of dioxins and mercury increases their risk of insulin resistance.** J Hazard Mater. 2011 doi: 10.1016/j.jhazmat.2010.09.084.

[13] CHO, S.; JACOBS, D.R.; PARK, K. **Population correlates of circulating mercury levels in Korean adults: the Korea National Health and Nutrition Examination Sircvey** IV. BMC Public Health, v. 14, p. 527, 2014.

[14] COSTA, LUCIANO T.; DAMAS, GIANE B.; BERTOLDO, BRUNO**. Mercúrio: da antiguidade aos dias atuais**. Revista Virtual de Química, v. 6, n. 4, p. 1010-1020, 2014.

[15] DE SOUZA, ELTON BICALHO. **Transição nutricional no Brasil: análise dos principais fatores**. Cadernos UniFOA, v. 5, n. 13, p. 49-53, 2017.

[16] DEPARTAMENTO DE ATENÇÃO BÁSICA. secretaria de atenção à saúde. ministério da saúde. **Guia alimentar para a população brasileira**. 2014.

[17] DOLBEC, J. et al. **Methylmercury exposure affects motor performance of a riverine population of the Tapajos River, Brazilian Amazon**. International Archives of Occupational and Environmental Health, v. 73, n. 3, p. 195-203, 2000.

[18] EOM SY, Choi SH, Ahn SJ, Kim DK, Kim DW, Lim JA, Choi BS, Shin HJ, Yun SW, Yoon HJ, Kim YM, Hong YS, Yun YW, Sohn SJ, Kim H, Park KS, Pyo HS, Kim H, Oh SY, Kim J, Lee SA, Ha M, Kwon HJ, Park JD. **Reference levels of blood mercury and association with metabolic syndrome in Korean adults.** Int Arch Occup Environ Health. 2014; doi: 10.1007/s00420-013-0891-8.

[19] HALL, M.E.; CARMO, J.M; SILVA, A.A.; JUNCOS, L.A.; WANG, Z.; HALL, J.E. **Obesity, hypertension, and chronic kidney disease.** International Journal of Nephrology and Renovascular Disease, v. 7, p. 75-88, 2014.

[20] HAMADA M. **Neurotoxicity of methylmercury, Minamata and the Amazon**. In: Yasui M., Strong, M. J.,

Ota, K. K., Verity, M. A. (eds.) Mineral and Neurotoxicology, p. 177-187. New York, U.S.A.: CRC Press, 1997.

[21] HASLAM, D. W.; JAMES, W. P. T. **Obesity.** Lancet, v. 366, n. 9492, p. 1197-1209, 2005.

[22] INSTITUTO BRASILEIRO DE GEOGRAFIA et al. BGE, **Indicadores de desenvolvimento sustentável: Brasil 2010**.

[23] KANG, D.; LEE, K. **The relationships between blood Mercury concentration and body composition measures using 2010 Korean National Health and Nutrition Examination Survey**. The Korean Journal of Obesity, v. 22, n.4, p.237–242, 2013.

[24] LACERDA, L. D.; SALOMONS, W. **Mercúrio na Amazônia: uma bomba química? Série Tecnologia Ambiental.** Rio de janeiro: CETEM/ CNPq, p. 78, 1992.

[25] LIPSCHITZ, DA. **Screening for nutritional status in the elderly**.Vol. 21, n.1, 1994

[26] LUBRANO, Carla; Genovesi, Giuseppe; Specchia, Palma; Costantini, Daniela; Mariani, Stefania; Petrangeli, Elisa; Lenzi, Andrea; Gnessi, Lucio (2013). **Obesity and Metabolic Comorbidities: Environmental Diseases.** Oxidative Medicine and Cellular Longevity, 2013, 1–9. doi:10.1155/2013/640673

[27] MALTA, D. C.; SANTOS, M.A.S.; ANDRADE, S.S.C.A; OLIVEIRA, T.P; STOPA, S.R; OLIVEIRA, M.M; JAIME, P. **Tendência temporal dos indicadores de excesso de peso.** Ciência & Saúde Coletiva, v. 21, n. 4, p.1061-1069, 2016.

[28] MICARONI, R. C. D. C. M., BUENO, M. I. M. S., & JARDIM, W. D. F. **Compostos de mercúrio. Revisão de métodos de determinação, tratamento e descarte**. Química Nova, 2000.

[29] MICHALEK, Joel & Pirkle, J & Caudill, Samuel & Tripathi, Ram & Patterson, D & Needham, L. (1996). **Pharmacokinetics of TCDD in veterans of Operation Ranch Hand: 10-year follow-up.** Journal of toxicology and environmental health. 1996; doi:209-20. 10.1080/009841096161744.

[30] MOON, S. **Association between blood mercury level and visceral adiposity in adults.** Diabetes and Metabolism Journal, v. 41, p.96-98, 2017.

[31] MURRIETA, R. S. S.; BAKRI, M. S.; ADAMS, C.; OLIVEIRA, P. S. D. S.; STRUMPF, R. **Consumo alimentar e ecologia de populações ribeirinhas em dois ecossistemas amazônicos: um estudo comparativo.** Revista de Nutrição, v.21, p.123-133, 2008.

[32] NEVADO, J.J. Berzas, R.C. Rodríguez Martín-Doimeadios, F.J. Guzmán Bernardo, M. Jiménez Moreno, A.M. Herculano, J.L.M. do Nascimento, M.E. Crespo-López. **Mercury in the Tapajós River basin, Brazilian Amazon: A review**. Environment International, Volume 36, Issue 6, 2010.

[33] OLIVEIRA, R. C.; DÓREA, J. G.; BERNARDI, J. V.; BASTOS, W. R.; ALMEIDA, R.; MANZATTO, Â. G. **Fish consumption by traditional subsistence villagers of the Rio Madeira (Amazon): impact on hair mercury**. Annals of human biology, v. 37, n.5, p. 629-642, 2010.

[34] PARK, S.; LEE, B.K. **Body fat percentage and hemoglobin levels are related to blood lead, cadmium, and mercury concentrations in a Korean Adult population (KNHANES 2008-2010).** Biological Trace Element Research, v. 15, n. 3, p. 315-323, 2013.

[35] PHILIPPI, S. T., LATTERZA, A. R., CRUZ, A. T. R., & RIBEIRO, L. C. **Pirâmide alimentar adaptada: guia para escolha dos alimentos Adapted food pyramid: a guide for a right food choice**. Rev. Nutr, *12*(1), 65-80, 1999.

[36] PINHEIRO, ANELISE RIZZOLO DE OLIVEIRA; FREITAS, SÉRGIO FERNANDO TORRES DE; CORSO, ARLETE CATARINA TITTONI. **Uma abordagem epidemiológica da obesidade. 2004.**

[37] PIPERATA, BARBARA A; SPENCE, JENNIFER E; DA-GLORIA, PEDRO; HUBBE, MARK. **The nutrition transition in Amazonia: rapid economic change and its impact on growth and development in Ribeirinhos**. American journal of physical anthropology, v. 146, n. 1, p. 1-13, 2011.

[38] POPKIN, BARRY M. **Urbanization, lifestyle changes and the nutritional transition.** World Development, v. 27, n. 11, p. 1905-1916, 1999.

[39] QIN, Yan-Yan & Zhang, Chan & Zhang, Jin & Cao, Yucheng & Wu, Sheng-Chun & Wong, Chris & Wong, Ming. **Plasma mercury levels in Hong Kong residents: In relation to fish consumption.** The Science of the total environment. 2013; doi:463. 10.1016/j.scitotenv.2013.04.049.

[40] RASMUSSEN, P. E. **Current methods of estimating atmospheric Mercury fluxes in remote areas**. The environmental Science, V. 28, p.2233-2241,1994.

[41] RIST, M. J., Wenzel, U., & Daniel, H. **Nutrition, and food science genomic.** Trends in Biotechnology. 2004; doi: 10.1016/j.tibtech.

[42] ROTTER, I.; KOSIK-BOGACKA.; DOLEGOWSKA, B.; SANFRANOW, K.; LUBKOWSKA, A.; LASZCZYNSKA, M. **Relationship between the Concentrations of Heavy Metals and Bioelements in Aging Men with Metabolic Syndrome.** International Journal of Environmental Research and Public Health, v. 12, n. 4, p. 3944-3961, 2015.

[43] SKALNAYA, MARGARITA G; TINKOV, ALEXEY A; DEMIDOV, VASILY A; SEREBRYANSKY, EUGENY P; NIKONOROV, ALEXDR A. **Hair toxic element content in adult men and women in relation to body mass index.** Biological trace element reaserch. v. 161, n. 1, p. 13 – 19, 2014.

[44] TINKOV, AA, AJSUVAKOVA, OP, SKALNAYA, MG, POPOVA, EV, SINITSKII, IA, NEMERESHINA, & SKALNY, AV. **Mercury and metabolic syndrome: a review of experimental and clinical observations.** Biometals, 28 (2), 231-254, 2015.

[45] YOU CH, Kim BG, Kim JM, et al. **Relationship between blood mercury concentration and waist-to-hip ratio in elderly Korean individuals living in coastal areas.** J Prev Med Public Health. 2011; doi:10.3961/jpmph.2011.44.5.218

[46] ZHANG, X.; Shu, X. O.; Gao, Y. T.; Yang, G.; Li, H.; Zheng, W. **General and Abdominal Adiposity and Risk of Stroke in Chinese Women**. Stroke. 2009. doi:10.1161/strokeaha.108.539692.2009