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Metabolic and hepatic alterations; eating habits and physical activity in Ecuadorian adolescents

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Abstract: Metabolic and hepatic alterations; eating habits and physical activity in Ecuadorian adolescents. Introduction. Metabolic and hepatic alterations in adolescents may be associated with inappropriate eating habits and sedentary lifestyles, requiring effective intervention actions. **Objective.** To determine the association between metabolic and hepatic alterations with eating habits and physical activity (PA) levels in adolescents from Punín, Ecuador. **Materials and methods.** An analytical cross-sectional observational study was conducted on 100 adolescents from Punín, aged 10-19 years, between October 2023 and March 2024. Data on diet, physical activity (PA), and socioeconomic status were collected through surveys, and body mass index (BMI) and biochemical parameters were measured. The statistical association analysis was performed using the chi-square test with a significance level of 0.05, utilizing SPSS Statistics 26. **Results.** 80% of adolescents presented metabolic or hepatic alterations, with imbalances in glucose, insulin, lipids, and transaminases, such as aspartate aminotransferase (AST) and alanine aminotransferase (ALT). BMI indicated a high proportion of overweight and obesity. Alterations were associated with sedentary lifestyles and unbalanced diets. The consumption of fish, dairy, eggs, and nuts showed no significant association with the alterations (p>0.05), while the consumption of fruits, vegetables, and legumes was associated with a lower risk of developing them (p<0.001). Differences in metabolic parameters between diet and PA groups were significant (p<0.05). **Conclusions:** In Punín, most adolescents exhibited metabolic and hepatic alterations, associated to poor eating habits and low PA levels, highlighting the need for effective interventions. **Arch Latinoam Nutr 2024; 74(4): 267-276.**

Keywords: NAFLD, dyslipidemias, hyperglycemia, insulin resistance, transaminases, adolescents.

Resumen: Alteraciones metabólicas y hepáticas; hábitos alimentarios y actividad física en adolescentes ecuatorianos. Introducción. Las alteraciones metabólicas y hepáticas en adolescentes pueden asociarse a hábitos de alimentación inapropiados y estilos de vida sedentarios, lo que requiere intervenciones eficaces. **Objetivo.** Determinar la asociación entre alteraciones metabólicas y hepáticas con hábitos alimentarios y niveles de actividad física (AF) en adolescentes de Punín, Ecuador. **Materiales y métodos.** Estudio observacional analítico de corte transversal realizado en 100 adolescentes de Punín, de 10-19 años de edad, entre octubre de 2023 y marzo de 2024. Se recopilaron datos sobre dieta, AF y estado socioeconómico mediante encuestas, y se midieron el índice de masa corporal (IMC) y parámetros bioquímicos. El análisis estadístico de asociación se efectuó con la prueba de chi cuadrado y un nivel de significancia de 0,05, utilizando SPSS Statistics 26. **Resultados.** El 80% de los adolescentes presentaron alteraciones metabólicas o hepáticas, con desequilibrios en los niveles de glucosa, insulina, lípidos y transaminasas, como aspartato aminotransferasa (AST) y alanino aminotransferasa (ALT). IMC indicó una alta proporción de sobrepeso y obesidad. Las alteraciones estuvieron asociadas a estilos de vida sedentarios y dietas desequilibradas. El consumo de pescado, lácteos, huevos y frutos secos no mostró asociación significativa con las alteraciones (p>0.05), y el consumo de frutas, verduras y legumbres se asoció a un menor riesgo de desarrollarlas (p<0.001). Las diferencias en parámetros metabólicos entre grupos de dieta y AF sí fueron significativas (p<0.05). **Conclusiones.** En Punín, la mayoría de los adolescentes presentó alteraciones metabólicas y hepáticas, asociadas a hábitos alimentarios inadecuados y bajos niveles de AF, lo que subraya la necesidad de intervenciones eficaces. **Arch Latinoam Nutr 2024; 74(4): 267-276.**

Palabras clave: EHGNA, dislipidemias, hiperglucemia, resistencia a la insulina, transaminasas, adolescentes.

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Introduction

Adolescence is a fundamental stage in human development, characterized by rapid physical, emotional and social changes (1). Adolescence is divided into three stages: early adolescence (10-13 years), where bodily transformations occur due to the development of sex hormones; middle adolescence (14-16 years), focused on psychological changes and the construction of the identity; and late adolescence (17-21 years), where adolescents feel more comfortable with their body and their identity is more defined (2). During these periods, humans require diets high in macronutrients and energy to obtain adequate muscle, bone and brain development, and in this way avoid long-term consequences such as delayed sexual maturation, osteoporosis, obesity, and growth deficiency (3,4).This is why eating habits and PA level play a crucial role in the present and future health of these individuals.

The metabolic alterations are characterized by the presence of both lipidic and non-lipidic risk factors related to the metabolism, including abdominal obesity, dyslipidemias, high blood pressure and insulin resistance (5–7). These factors are directly related to the acquisition of coronary diseases, atherosclerosis and type II diabetes mellitus (DM2) (8).

On the other hand, hepatic alterations, evidenced by elevated ALT and AST levels, are indicative of hepatocellular damage and may be associated with non-alcoholic fatty liver disease (NAFLD), characterized by fat accumulation in hepatocytes in the absence of significant inflammation and by including a subtype known as non-alcoholic steatohepatitis (NASH), a more severe variant characterized by inflammation, cellular degeneration, and occasionally fibrosis, which can progress to hepatic cirrhosis or hepatocellular carcinoma if not intervened in time (9–12). However, this remains a suspicion since the elevation of these transaminases is not a specific indicator, as some patients with this disease have shown normal values of these enzymes (13)

Once the above has been mentioned, it is of utmost importance to highlight that the excessive consumption of ultra-processed products (UPP) and the lack of adequate PA are key factors that negatively affect the functioning of the metabolic and hepatic systems in adolescents (14–16). UPP are made from ingredients derived from processed or synthesized food substances, such as oils, sugars, hydrogenated fats, and modified starches. These products are designed to be easy to consume, with a long shelf life, good taste, and minimal preparation. They are typically high in sugars, fats, and salt, but low in essential nutrients like fiber and vitamins (17). Frequent consumption of UPP is linked to the disruption of lipid regulation mechanisms and liver functions, promoting fat accumulation in the liver and increased body fat (18). Low PA, in turn, reduces the body's ability to maintain proper balance, increasing the risk of dysfunction in both systems (19). In contrast, regular PA, complemented with a balanced diet, acts as an effective therapeutic strategy to restore overall body balance. This combination contributes not only to the normalization of liver enzyme levels but also to the improvement of metabolic processes and body weight control (20,21). Regular physical exercise helps prevent fat accumulation, improves its distribution, and regulates lipid and glucose levels, promoting homeostasis (22). Therefore, this approach reduces the risk of long-term alterations and contributes to the overall well-being of the adolescent population.

It is important to note that adolescents from the parish of Punín, located in the canton of Riobamba, province of Chimborazo, Ecuador, are more vulnerable to the previously mentioned alterations due to increasing sedentary lifestyles, relatively low socioeconomic levels, and a food culture that promotes unhealthy habits. Additionally, the limited availability of healthcare services in the area, resulting from the scarcity of healthcare centers and medical professionals, restricts timely access to preventive, diagnostic, and therapeutic care. This situation increases the risk that adolescents do not receive appropriate management of their health conditions, which could enhance the development of metabolic and hepatic diseases.

The present study focused on analyzing the association between eating habits, PA levels, and metabolic and hepatic alterations in adolescents from the Punín parish. Using a rigorous methodology and an integrated approach, valuable data were collected that will contribute to the design of effective interventions aimed at improving health in this population. The findings of this research not only hold academic significance but also provide practical insights for promoting the well-being of adolescents, both in the studied community and in other areas. This work seeks to inspire future research and actions that can help reduce the prevalence of these conditions, supporting healthy development among adolescents in diverse regions.

Materials and methods

For the present study, an analytical observational cross-sectional design was used. Data collection took place from October 2023 to March 2024, with prior approval from the ethics committee: Code: io03-ceish-espoch-2023 (Ethics Committee for Human Research of the Escuela Superior Politécnica de Chimborazo - CEISH-ESPOCH). A mixed-methods approach, both qualitative and quantitative, was implemented to determine the association between metabolic and hepatic alterations with eating habits and PA levels in adolescents from the Punín parish. The study population consisted of a sample of 100 adolescents, selected through non-probabilistic convenience sampling, who met the following inclusion criteria.

- Adolescents aged 10 to 19 years.
- Adolescents residing in the Punín parish.
- Adolescent children of parents who sign the informed consent.
- Adolescents who sign the informed consent.
- Adolescents of both sexes.

Adolescents were excluded from the study based on the following criteria.

- Adolescents who do not meet the established age.
- Adolescents who do not reside in the Punín parish.
- Adolescent children of parents who do not sign the informed consent.
- Adolescents who do not sign the informed consent.
- Adolescents undergoing medical treatment.

Surveys were conducted to obtain detailed information about the sociodemographic context, dietary preferences and practices, as well as the frequency of PA performed by each participant. Food consumption frequencies (simple carbohydrates, fruits, vegetables, legumes, fish, dairy, eggs, nuts, meats and derivatives, and fats and sugars) were categorized as frequent (1-2 times per week) or very frequent (3-4 times per week) based on food pyramid groups. PA levels were classified as low (less than once a week), moderate (2-3 times a week), and high (6-7 times a week), according to World Health Organization (WHO) guidelines (23). Socioeconomic and educational levels were collected through a structured survey. Socioeconomic level was categorized into three groups: low (monthly income less than one minimum wage), medium (monthly income between 1 and 3 minimum wages), and high (monthly income above 3 minimum wages), while educational level was based on completing secondary and/or primary education.

Ethics Committee for Research on Human Beings

Code: io03-ceish-espoch-2023, approved on October 15, 2023 (Ethics committee for human research of the Escuela Superior Politécnica de Chimborazo) (CEISH-ESPOCH).

BMI

The BMI of everyone was calculated using the formula:

$$BMI = \frac{(Weight\ (Kg))}{(Height^2\ (m))}$$

Using the collected data, the prevalence of the following categories was established: underweight, normal weight, overweight, and obesity (24). Table 1 shows the cut-off points for different BMI categories for the adolescent population (10 to 19 years), which is based on the use of percentiles.

Table 1. BMI cut-off points and percentiles for adolescents aged 10 to 19 years.

BMI (Adolescents 10-19 years old)	Percentile (Adolescents 10-19 years old)
Underweight: Less than 18.5	Underweight: 3rd percentile to less than the 15th percentile,
Normal (Healthy) Weight: Between 18.5 and 24.9	Normal (Healthy) Weight: 15th percentile to less than the 85th percentile,
Overweight: Between 25.0 and 29.9	Overweight: 85th percentile to less than the 97th percentile,
Obesity: Between 30.0 and 34.9	Obesity: Equal to or greater than the 97th percentile,

Analytical findings

Glucose, total cholesterol, triglycerides (TG), high-density lipoprotein (HDL), AST, and ALT were analyzed by UV-visible spectrophotometry with the Humalyzer Primus REF18200 spectrophotometer. Low-density lipoprotein (LDL) was indirectly calculated using Friedwald's formula: LDL = (Total cholesterol - HDL - TG/5), where TG/5 is equal to very low-density lipoprotein (VLDL) (25). For the determination of insulin, an enzyme-linked immunosorbent assay (ELISA) was performed with the Elisys Duo equipment. The normal cut-off values for all these parameters are shown in Table 2.

The HOMA index was calculated to determine possible insulin resistance using the formula: HOMA-IR = fasting serum glucose (mg/dL) x fasting insulin (µIU/mL) / 405. A value below 2.5 was considered normal, while a value above this was interpreted as suspected insulin resistance (26,27). The AST/ALT ratio was calculated, considering that a value lower than 1.5 may be indicative of suspected NAFLD (28).

Statistical data treatment

The association between metabolic and hepatic alterations, including hyperglycemia, hypoglycemia, hypercholesterolemia, hypertriglyceridemia, altered levels of HDL, LDL, and VLDL, hyperinsulinemia, suspected insulin resistance, mixed dyslipidemia, and suspected NAFLD, with factors such as food consumption frequency and PA levels, was evaluated using the Chi-squared test, a non-parametric statistical analysis. Analyses were performed using SPSS Statistics 26, with a statistical significance level of 0.05. The Chi-squared test yielded the p-value, which helped determine whether to accept or reject the null hypothesis. A p-value less than 0.05 indicates statistical significance, leading to the rejection of the null hypothesis, while a *p*-value greater than 0.05 indicates non-significance, leading to the acceptance of the null hypothesis (29).

Table 2. Cut-off points for biochemical parameters.

Biochemical Parameters	Normal Cut-off Points	References
Insuline	5 - 25 uU/mL	(49)
Glucose	70-100 mg/dL	(50)
Tg	<150 mg/dL	(51)
Total Cholesterol	<170 mg/dL	(51)
HDL	Male: >40 mg/dL Female: >50 mg/dL	(51)
LDL	<100 mg/dL	(51)
VLDL	2 - 30 mg/dL	(51)
AST	Male: ≤ 37 U/L Female: ≤ 31 U/L	(52)
ALT	Male: ≤ 42 U/L Female: ≤ 32 U/L	(53)

Results

Table 3 describes the sociodemographic characteristics of the adolescent sample from Punín. Among the various parameters considered, it is evident that most of the individuals are in the age range of 10-16 years, which is a critical stage during which hormonal changes can influence metabolic and liver health.

Table 3. Sociodemographic characteristics.

Category		Frequency	Percentage (%)
Age in years	10-13	48	48
	14-16	39	39
	17-19	13	13
Gender	Male	40	40
	Female	60	60
Socioeconomic level	Low	65	65
	Medium	35	35
	High	0	0
Education level	Primary	26	26
	Secundary	74	74

Table 4. Body Mass Index

		BMI			
		Underweight	Normal	Overweight	Obesity
Age range	10-13	1	42	4	2
	14-16	1	34	4	0
	17-19	0	9	3	0
Total	100	2	85	11	2
Total percentage (%)	100	2	85	11	2

Regarding gender, the study was conducted with a 2:3 ratio of males to females. Additionally, the socioeconomic status of most adolescents is low, followed by a medium level. It is worth noting that there were no adolescents with a high socioeconomic level.

Table 4 shows the BMI of the study population. It can be highlighted that the majority of the adolescents are at a normal weight, and only 2% have a weight below the healthy average. Additionally, it was determined that 11% of the population is overweight, while 2% is obese.

Table 5 shows the metabolic and hepatic alterations in the adolescent population of Punín. Of the 100 individuals evaluated, 80% presented at least one metabolic or hepatic alteration. Among the most common conditions were hypertriglyceridemia and hyperinsulinemia, which affected a significant proportion. A high frequency of alterations in cholesterol and glucose levels was also observed, such as hypercholesterolemia and hypoglycemia. Additionally, some participants showed signs of mixed dyslipidemia and alterations in HDL, LDL and VLDL. A significant number were suspected of having insulin resistance and NAFLD.

Table 6 shows the frequency of food consumption based on the food pyramid,

Table 5. Hepatic and metabolic alterations present in the adolescent population of Punín.

		Frequency	Percentage (%)
Metabolic and hepatic alterations present in the adolescent population of Punín	Hyperglycemia	2	2
	Hypoglycemia	8	8
	Hypercholesterolemia	11	11
	Hypertriglyceridemia	54	54
	High Altered LDLc	9	9
	Low altered HDLc	26	26
	High Altered VLDLc	21	21
	Hyperinsulinemia	48	48
	Suspected of having insulin resistance	16	16
	Insulin resistance	18	18
	Mixed Dyslipidemia	8	8
	Suspicion of NAFLD	10	10

Table 6. Frequency of Food Consumption based on the food pyramid

		Adolescents that present alterations		
		N°	Percentage (%)	*p*-value
Frequency consumption of simple carbohydrates	FREQUENT (1-2 times a week)	23	28.7	0.006
	VERY FREQUENT (3-4 times a week)	57	71.3	
Frequency consumption of fruits, vegetables and legumes	FREQUENT (1-2 times a week)	46	57.5	<0.001
	VERY FREQUENT (3-4 times a week)	34	42.5	
Frequency consumption of fish, dairy, eggs and nuts	FREQUENT (1-2 times a week)	75	93.8	0.251
	VERY FREQUENT (3-4 times a week)	5	6.3	
Frequency consumption of meats and derivatives	FREQUENT (1-2 times a week)	22	27.5	0.032
	VERY FREQUENT (3-4 times a week)	58	72.5	
Frequency consumption of fats and sugars	FREQUENT (1-2 times a week)	23	27.7	0.026
	VERY FREQUENT (3-4 times a week)	57	71.0	

considering only 80% out of 100 adolescents who presented at least one metabolic or hepatic alteration. The consumption of simple carbohydrates ranged from frequent to very frequent and is significantly associated with the presence of alterations in metabolic and hepatic processes ($p < 0.05$). In the case of fruits, vegetables, and legumes, their intake was also frequent to very frequent, showing a strong association with a lower risk of developing alterations ($p < 0.005$). On the other hand, the consumption of fish, dairy, eggs, and nuts was mostly frequent, but did not show a significant association with the observed alterations ($p > 0.05$). The high consumption of meats and derivatives, as well as fats and sugars, showed significant associations with metabolic and hepatic disorders ($p < 0.05$), allowing for the rejection of the null hypothesis in both cases.

Table 7 presents the AF levels of 80% of the adolescents, out of a total of 100 evaluated, who presented at least one metabolic or hepatic alteration. In this sample, a sedentary lifestyle predominates, as the majority do not engage in PA at least once a week. Although the percentages of individuals performing moderate and high PA are equivalent, both remain at low levels. There is sufficient statistical evidence ($p < 0.05$) to reject the null hypothesis. Thus, the level of PA is significantly associated with the metabolic and hepatic alterations present in the adolescents.

Table 7. Levels of the participants' physical activity

		Adolescents that present alterations		*p*-value
		Frequency	Percentage of PA (%)	
Levels of PA	LOW (less than 1 time a week)	68	85	0.013
	MODERATE (2-3 times a week)	6	7.5	
	HIGH (6-7 times a week)	6	7.5	

Discussion

This study highlights how sociodemographic and behavioral factors influence the metabolic and liver health of adolescents in Punín. Most participants are in a critical age range, between 10 and 16 years, where hormonal changes significantly impact their health. The male-to-female ratio allows for an adequate assessment of health pattern differences between sexes, which is essential for understanding how these factors affect each gender in a differentiated way (30,31).

The absence of adolescents from a high socioeconomic level limits the interpretation of how this variable could influence access to health services and a healthy diet. Without comparative data from higher socioeconomic classes, it is difficult to establish a direct relationship between economic status and the prevalence of metabolic and hepatic alterations. The lack of diversity in the sample limits the ability to generalize the findings regarding the relationship between socioeconomic status and health in this population.

Limited access to educational resources on nutrition in the primary and secondary schools of this rural community could influence the prevalence of observed metabolic and liver alterations (32). The lack of nutritional education contributes to inadequate eating habits, contributing to these conditions. This underscores the need for nutritional education programs to improve knowledge and practice of healthy eating among adolescents.

The analysis of BMI reveals that, although most adolescents maintain a healthy weight, a considerable percentage exhibit overweight and obesity, associated with the frequent consumption UPP (33). This dietary pattern not only generates negative short-term effects, such as metabolic alterations, but also increases the risk of developing chronic diseases like DM2, hypertension, and cardiovascular diseases in the future (34–36).

The analysis of the diet of adolescents in Punín shows that, although there is occasional consumption of healthy foods such as fruits, vegetables, legumes, fish, dairy, eggs, and nuts, their intake is not frequent enough to counteract the adverse effects of an imbalanced diet. This dietary pattern, characterized by high consumption of simple carbohydrates, meats and derivatives, and high intake of fats and sugars, is closely linked to metabolic and hepatic alterations (37,38). In particular, excessive consumption of saturated fats and sugars may be related to increased levels of TG and LDL, risk factors for the development of chronic diseases such as hypertension, metabolic syndrome, and dyslipidemia (39). Additionally, this dietary pattern favors the onset of liver disorders such as NAFLD and hepatic fibrosis, highlighting the urgent need to modify eating habits in this population to prevent irreversible damage to metabolic and liver health in the long term (38).

The sedentary lifestyle prevalent among adolescents in Punín has significant repercussions on the onset of these alterations. Physical inactivity promotes the accumulation of visceral and hepatic fat, leading to disruptions in lipid and glucose metabolism, exacerbating insulin resistance, fostering dyslipidemias, and increasing the risk of developing liver diseases (37). Moreover, excess weight profoundly impacts adolescents' self-esteem and emotional well-being, intensifying sedentary behaviors and perpetuating unhealthy lifestyle habits. This emotional impact, combined with inactivity, creates a vicious cycle that hinders the adoption of healthier practices essential for improving metabolic and liver conditions (40).

The high prevalence of metabolic and hepatic alterations in the adolescent population of Punín is associated with a considerable risk for the development of chronic non-communicable diseases. The most prevalent conditions, such as hypertriglyceridemia and hyperinsulinemia, may be associated with dysfunctions in lipid metabolism and glucose regulation, which could be linked to a diet high in simple carbohydrates and saturated fats, as well as insufficient PA—factors associated with metabolic syndrome (41,42). The presence of hypercholesterolemia and hypoglycemia suggests alterations in lipid and glucose homeostasis, which are associated with an increased risk of developing cardiovascular diseases, DM2, and other metabolic pathologies (43). Mixed dyslipidemia is commonly associated with an increased cardiovascular risk, as these lipid disorders promote the formation of atherosclerotic plaques, which are linked to arterial diseases, such as coronary artery disease and stroke (44). Additionally, the high prevalence of suspected insulin resistance and NAFLD highlights the relationship between glucose metabolism and liver damage, conditions that are associated with diets rich in saturated fats and refined sugars, and a sedentary lifestyle (45–48).

The data presented in this study provide a comprehensive view of how sociodemographic factors, eating habits, and PA levels influence the metabolic and liver health of adolescents in Punín. Interventions aimed at improving nutritional education and increasing PA could be essential to address the health disparities observed in this population. Implementing educational and health promotion programs that take these factors into account can significantly contribute to the long-term health improvement of adolescents in Punín. Longitudinal studies are recommended to evaluate the long-term impact of these interventions, aiming to reduce the prevalence of metabolic and liver alterations in this community.

Study limitations

The size of the sample, limited to 100 adolescents, could affect the result's generalizability since a larger sample could offer more representative data.

Data collection through dietary and PA surveys is subject to memory and social desirability biases, as participants may not remember their habits precisely or respond in a socially acceptable manner.

The study used a cross-sectional design, which means that the data was collected at a single point in time. This type of design doesn't allow causal relationships to be established, only associations. Longitudinal studies would be necessary to determine the causality between the studied factors and the metabolic and hepatic alterations.

Conclusions

Metabolic and hepatic alterations in adolescents from Punín are significantly associated with inadequate eating habits and insufficient levels of PA. A sedentary lifestyle, along with a high consumption of simple carbohydrates, fats, sugars, meats, and their derivatives, contrasts with the limited intake of healthy foods. This highlights the need to implement nutritional education strategies and promote PA tailored to this population to prevent and reduce these alterations.

Conflicts of Interest

The authors declare no conflict of interest.

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