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ベトナム児童の遊離糖摂取量と肥満・メタボリックシンドロームの関係

RELATIONSHIP BETWEEN FREE SUGAR INTAKES AND OBESITY/METABOLIC SYNDROME IN VIETNAMESE JUNIOR HIGH SCHOOL STUDENTS

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SUMMARY IN ENGLISH

Background: In Vietnam, childhood obesity and metabolic syndrome are rapidly increasing. Increased sugar intake is thought to be the cause of these. However, there is no sugar composition table in Vietnam, making it impossible to calculate the intake. In recent years, isomerized sugar made from starch has been increasingly used because it is rich in fructose, delicious, and inexpensive. The World Health Organization (WHO) recommends reducing sugar intake to less than 10% of total energy, and in the future to less than 5%. Therefore, this study aimed to clarify the glucose, sucrose, lactose, and fructose content of Vietnamese snacks and drinks with high sugar content.

Objective: To create a free sugar composition table for Vietnamese foods and drinking water and to clarify the relationship between sugar intake of children and obesity and metabolic syndrome.

Method: Two studies were conducted. In Study 1, we created a sugar composition table for Vietnamese foods and drinking water. In Study 2, we conducted a dietary survey among junior high school students, along with height, weight, and blood biochemistry tests, to clarify the relationship between free sugar intake and obesity and metabolic syndrome.

Study 1: Create a free sugar composition table for commercially available foods that are thought to contain a lot of sugar. 57 foods from supermarkets and 18 products manufactured in retail stores were collected. Glucose, sucrose, lactose, and fructose were analyzed by HPLC.

Study 2: In Hanoi and its suburbs, 172 students (80 obese children and 92 normal children) out of 2,911 junior high school students were surveyed. Height and weight were measured, a 24-hour dietary recall survey for three days was conducted, and blood biochemistry analysis was performed to determine metabolic syndrome using the International Diabetes Federation pediatric criteria. The relationship between sugar intake and metabolic syndrome in obese and normal children was examined using odds ratios (OR).

Results:

Study 1: The free sugars (g/100g) of foods high in free sugars were 30.2 for cream biscuits, 34.6 for chocolate cake, 25.7 for ice cream, 13.4 for energy drinks, 9.8 for cola, 15.1 for fruit tea, 11.1 for fruit juice milk, and 14.5 for peach tea.

Study 2: The proportion of obese children was 33.6%, of which 12.5% had metabolic syndrome. The OR of free sugar intake exceeding 10% of the WHO recommended value and obesity was 0.7, there was no statistically significant. Energy intake in obese children high than normal children, with statistically significant difference. Among sugars, there was a significant difference in glucose and fructose intake between children with metabolic syndrome and normal children.

Conclusion: Free sugar intake of Vietnamese junior high school was about 25g/day and not a cause of obesity. Obesity and isomerized sugar were suggested as factors of metabolic syndrome.

要旨

背景：ベトナムでは小児の肥満が急増し、メタボリックシンドロームも増えている。それらの原因として糖類摂取量の増加が考えられる。しかし、ベトナムには糖類成分表がなく、摂取量の計算ができない。近年は、デンプンから作った異性化糖はフルクトースが多く、美味しく、値段も安いことから利用が増えている。世界保健機関（WHO）は、糖類の摂取量を総エネルギーの 10%未満、将来は 5%未満まで減らすことを推奨している。そこで、本研究では、糖類含有量の高いベトナムのお菓子・飲み物類のグルコース、スクロース、ラクトース、フルクトース含有量を明らかにせんとした。

目的：ベトナムの食品・飲料水の糖類成分表を作成し、児童の砂糖摂取量が肥満およびメタボリックシンドロームの関係を明らかにすること。

方法：二つの研究を実施した。研究 1 ではベトナムの食品・飲料水の糖類成分表の作成、研究 2 では中学生の食事調査および身長体重と血液生化学検査から、糖類摂取量と肥満やメタボリックシンドロームの関係を明らかにせんとした。

研究 1：糖類が多く含まれていると考えられる市販食品の砂糖成分表を作成する。スーパーマーケットの 57 の食品と小売店で製造された 18 の製品を収集した。 HPLC で、グルコース、スクロース、ラクトース、フルクトースを分析した。

研究 2：ハノイとその郊外で、2911 名の中学生から賛同の得られた 172 名（肥満児 80 名、正常児 92 名）を対象に、身長と体重の測定、3 日間の 24 時間思い出し法食事調査、血液生化学的分析を行い国際糖尿病連合（IDF）の小児用の数値でメタボリックシンドロームを判定した。肥満児と正常児の糖類摂取量とメタボリックシンドロームの関係をオッズ比（OR）で調べた。

結果：

研究 1：遊離糖を多く含む食品の遊離糖は（g/100 g）、クリームビスケット 30.2 、チョコレートケーキ 34.6、アイスクリーム 25.7、エナジードリンク 13.4、コーラ 9.8 、フルーツティー 15.1、フルーツジュースミルク 11.1、ピーチティー14.5 などであった。

研究 2：肥満児童の割合は 33.6%で、そのうちメタボリックシンドロームの割合は 12.5%であった。WHO 推奨値の 10%を超える砂糖摂取量と肥満者とのオッズ比（OR）は 0.7 で、統計的有意さは無かった。肥満児のエネルギー摂取量は正常児より高く、統計的に有意な差がある。糖類のうち、グルコースとフルクトース摂取量は、メタボリックシンドローム児と正常児の間で有意差があった。

結論：ベトナムの中学生の遊離糖は 1 日約 25g、肥満の原因ではなかった。肥満および異性化糖はメタボリックシンドロームの原因になることが示唆された。

INTRODUCTION

Childhood obesity has become one of the critical public health challenges globally with implications for future burdens of non-communicable diseases.

Over 30 years, the number of school-aged children and adolescents living with obesity has increased more than 5-fold, from 31 million in 1990 to 160 million in 2022 (1). In Vietnam, childhood obesity has been on a dramatic rise and has become a big problem in public health, especially in urban centers. Two decades ago, overweight was scarcely observed in Vietnamese children; undernutrition was the dominant issue. But recent surveys and studies document a dramatic uptick in childhood overweight and obesity prevalence over the last 10–15 years. There was a double increase in the prevalence of overweight and obesity in children and adolescents from 8.5% to 19% between 2010 and 2020. Meanwhile, the prevalence of overweight and obesity in big cities among 5-19-year-olds in 2010 was 15.4%, and increased to 26.8% in 2020 (2).

Childhood obesity impacts both physical and psychological health. Obesity is linked to a higher risk of various non-communicable diseases, including cardiovascular diseases, some types of cancer and type 2 diabetes (3). Non-communicable diseases are the leading causes of mortality worldwide (5). The impact of non-communicable diseases is steadily rising.

Metabolic syndrome is a group of cardiovascular risk factors that includes central obesity (indicated by a high waist circumference or high BMI), hypertension, high fasting glucose, low HDL cholesterol and high fasting triglycerides. The prevalence of metabolic syndrome is increasing quickly due to sedentary lifestyles and childhood and teenage obesity globally. Metabolic syndrome not only occurs in adults but also occurs very early in children and adolescents (4), particularly in people with obesity. Metabolic syndrome indicates a future risk of non-communicable diseases, such as diabetes and heart disease, in adulthood (6). Traditionally, pediatric metabolic syndrome was thought to be rare, but with pediatric obesity on the rise, metabolic syndrome is being diagnosed at younger ages. The concurrent emergence of pediatric metabolic syndrome in Vietnam has also been documented, though data are still limited. A cross-sectional study of adolescents in Ho Chi Minh City reported an overall prevalence of metabolic syndrome of 4.6% among 13– to 17–year–olds, using the IDF pediatric criteria. Notably, in that study, adolescents with overweight/ obesity had a 3.3-fold higher prevalence of metabolic syndrome compared to those with normal BMI (11.8% vs. 3.3%). The rising prevalence of both obesity and metabolic syndrome among Vietnamese children is thus a worrisome trend that merits detailed investigation into contributing factors. These findings underscore that beyond body weight, poor metabolic health is an important consequence of excessive adiposity in children (16).

Consuming too much sugar has been linked to higher energy intake, a lower quality diet and a higher risk of obesity (7). Sugar-sweetened beverages have been associated with clinical cardiometabolic risk, such as body mass index (BMI), waist circumference, type 2 diabetes, blood pressure and blood glucose. Consuming more than 1.3 servings of sugar-sweetened beverages daily can increase the risk of cardiometabolic diseases and obesity (8). High consumption of sugar-sweetened drinks showed increased triglycerides and decreased HDL-C in adolescents (9).

According to the World Health Organization Guidelines, a strong recommendation is to reduce sugar intake to less than 10% of total energy intake, which translates to consuming less than 50g of free sugar per day. Moreover, the World Health Organization's conditional recommendation is for a further reduction in sugar intake to less than 5% of total energy intake, which translates to consuming less than 25g of sugar per day for both adults and children. This recommendation is motivated by evidence linking high free sugar consumption (especially from sugar-sweetened beverages) to unhealthy weight gain, dental caries, type 2 diabetes, and cardiovascular risk factors (10).

From many countries in the world, there are some reports about sugar intake in children and adolescents. Children and adolescents in the US consumed 98.6g/day (11), adolescents in the Netherlands consumed 84.5g/day (12), children in Taiwan consumed 51.6g/day (13) and children in Japan consumed 24.7g/day (14). The increase in the prevalence of obesity, metabolic syndrome is associated with high sugar intake in the US (15).

Obesity in Vietnamese children may be caused by excessive sugar consumption, although this is unclear because there is no Vietnamese sugar composition table. The objectives of this study is to create a Vietnamese sugar composition table, determine the latest sugar intake in Vietnamese children, and find the association between sugar intake and obesity and metabolic syndrome in Vietnamese children.

High intake of free sugars – sugars added to foods and drinks or naturally present in honey, syrups, and fruit juices – is widely recognized as a dietary factor that can promote weight gain and metabolic disturbances when consumed in excess. Sugar-sweetened beverages (SSBs) are a major source of fructose, which can drive hepatic fat synthesis and insulin resistance when consumed in excessive amounts. A cross-sectional study in Australia reported that consuming excessive sugar-sweetened beverages can lead to overweight and obesity in children (17). A longitudinal study in Tehran reported that children in the top quartile of sugary drink intake had three times higher odds of developing metabolic syndrome over 3.6 years compared to those in the lowest quartile. Specifically, high consumers of carbonated SSBs had a significantly greater risk of abdominal obesity and hypertension in that cohort (18). These data suggest that habitual high sugar intake can contribute not only to obesity but also to the development of metabolic syndrome traits in youth.

On the other hand, not all studies have found a clear association between sugar intake and obesity. Some cross-sectional surveys, particularly in Asian populations, have reported no significant difference in total sugar consumption between obese and non-obese children. For example, a study of schoolchildren in Kaohsiung, Taiwan found that while average sugar intake was high (~51.6 g/day) and exceeded WHO recommendations, there was no observable relationship between sugar intake and BMI (13). Similarly, a comparative study of Cambodian and Japanese children noted that mean daily sugar intakes were within recommended limits and did not correlate with body weight or BMI among those children (14). These findings suggest that the link between sugar and obesity may sometimes be obscured by other factors (like overall diet quality, physical activity, genetics, or underreporting of intake). Nevertheless, the preponderance of evidence – especially from intervention trials and longitudinal studies – supports the notion that reducing consumption of sugary drinks and high-sugar foods can help prevent unhealthy weight gain in children. Given the global shift towards higher sugar diets and the parallel rise in pediatric obesity, investigating this relationship in the Vietnamese context is highly pertinent.

In Vietnam, there have been few detailed studies of children's sugar intake. The national Food Composition Tables historically did not list free sugars for most foods, making it difficult to estimate added sugar intake from dietary surveys. Some prior research in Asia (e.g., Japan, Taiwan, Malaysia) has involved chemical analysis of foods to determine sugar composition, but comparable data for Vietnamese foods are lacking (13) (14). Understanding which local foods contribute the most sugar is important for nutritionists and policymakers to target interventions (for example, identifying popular snacks or beverages with very high sugar content that could be reformulated or regulated).

STUDY 1: MAKING FREE SUGARS COMPOSITION TABLE IN VIETNAMESE FOODS

INTRODUCTION

Free sugars include monosaccharides and disaccharides added to food and beverages by cooking, manufacturing and sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates (10). Monosaccharides include one sugar molecule; disaccharides include two monosaccharide sugar molecules.

Monosaccharides are organic compounds that contain 3 to 7 carbon atoms in a straight chain or ring. Monosaccharides possess strong reducing properties and directly provide energy for the oxidation process, releasing energy for cellular activities. The most common monosaccharide is glucose (19). Monosaccharides include glucose and fructose.

Glucose (dextrose) is a monosaccharide with the molecular formula $C_6H_{12}O_6$. Glucose is a colorless crystalline substance, with a molecular weight of 180.16 g/mol, a density of 1.54 g/cm^3, easily soluble in water, insoluble in organic solvents, and non-volatile. There are two forms of glucose: the form that occurs most naturally is D-glucose, where the plane of linearly polarized light is rotated to the right. In contrast, the form L-glucose shifts linearly polarized light to the left. L-glucose is produced synthetically in relatively small quantities (21).

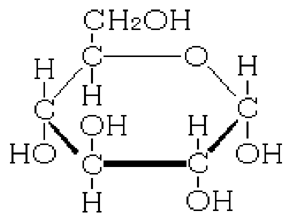

Figure 1. Chemical structure of glucose

Fructose is a monosaccharide with the molecular formula $C_6H_{12}O_6$, with a molecular weight of 180.16 g/mol, a density of 1.694 g/cm^3, is non-volatile (21). Fructose is found in many plants, honey and some fruits.

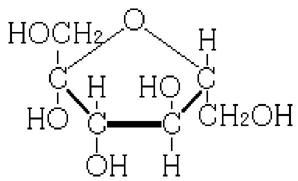

Figure 2. Chemical structure of fructose

Disaccharides are formed when a glycosidic bond links two monosaccharide molecules and removes one water molecule (20). Sucrose is the most common disaccharide, consisting of two monosaccharides, α-glucose and β-fructose, linked together by a 1,2 α-glycosidic bond, making it non-reducing, with the molecular formula $C_{12}H_{22}O_{11}$.

Sucrose exists in solid form under normal conditions, is colorless, odorless, has a molecular weight of 342.3 g/mol, a density of 1.587 g/cm^3, melts at 186 degrees Celsius. Sucrose has a sweet taste and is highly soluble in water, slightly soluble in alcohol, and does not evaporate (21).

Sucrose is produced from sugar cane or sugar beets. Sucrose is often found in food processing because it is both a sweetener and an essential ingredient in many foods such as confectioneries, ice creams and fruit juices, and assists in food preservation.

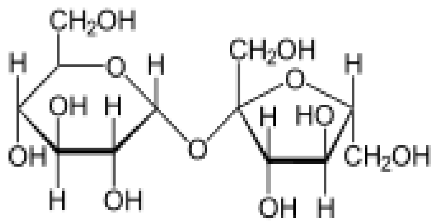

Figure 3. Chemical structure of sucrose

Lactose is a disaccharide consisting of a β-D-galactose and a β-D-glucose linked together by a β 1-4 glycosidic bond, with the molecular formula $C_{12}H_{22}O_{11}$, and a solubility of 0.216 g/ml (21). Lactose (also known as milk sugar) is found mainly in milk.

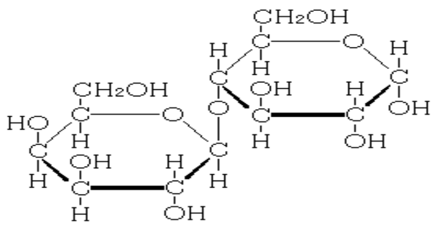

Figure 4. Chemical structure of lactose

Nowadays, isomerized sugar is commonly used in the production of cold beverages as a sweetener because it is sweeter and less expensive than sucrose. Isomerized sugar (also known as high fructose corn syrup) is a sweetener derived from starch. In the production of conventional corn syrup, the starch is broken down into glucose by enzymes. To produce isomerized sugar, the corn syrup is further processed by D-xylose isomerase, which converts some of its glucose into fructose. The combination of fructose and glucose creates isomerized sugar. In nature, isomerized sugar is sweet at low temperatures and liquid. In recent years, manufacturers have often used isomerized sugar because it is cheaper than other sugars. The most common forms of isomerized sugar are HFCS-42 and HFCS-55. HFCS 42 and HFCS 55 contain 42% and 55% fructose, respectively, with the remaining part being glucose. HFCS 42 is usually used in processed food, breakfast cereal and some beverages. HFCS 55 is used mainly in the production of soft drinks (22).

The sweetness of sugars depends on time and temperature. The sweetness of sucrose slowly appears and slowly disappears. The sweetness of fructose appears very quick and disappears quickly, so it lasts only briefly. Thus, fructose has a sharp sweetness. Glucose is less sweet than sucrose and fructose (23). At lower temperatures, the sweetness of fructose is at its highest, but it decreases at higher temperatures. Sucrose always maintains its sweetness at all temperatures. Glucose is less sweet than fructose and sucrose. Therefore, in nature, isomerized sugar is sweet at low temperatures.

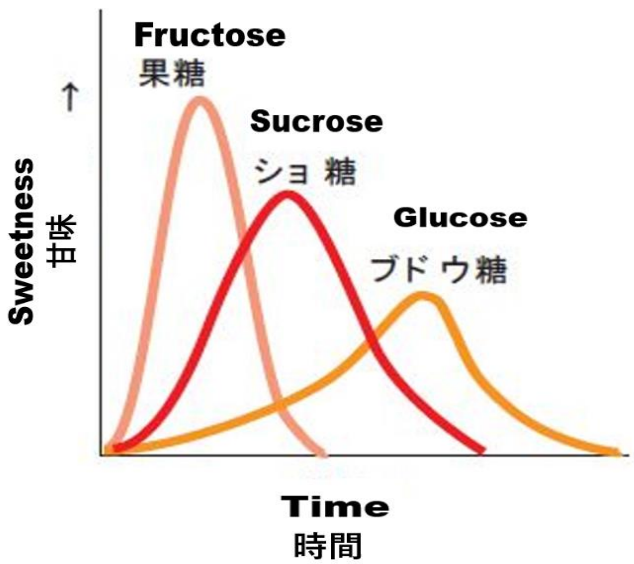

Figure 5. Effect of time on sweetness of free sugars

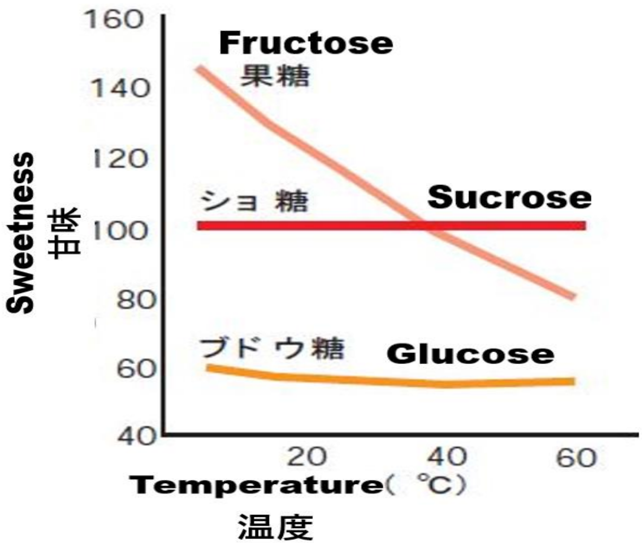

Figure 6. Effect of temperature on sweetness of free sugars

METHOD

There were 57 foods from supermarkets and 18 products manufactured in retail stores. Commercial products were collected from big supermarkets in Hanoi. Products manufactured in retail stores were collected randomly from vendors near school gates, open markets and other public locations. After collecting, these products were analyzed for sugar contents (glucose, fructose, lactose and sucrose) by the High-Performance Liquid Chromatography (HPLC) method.

The HPLC method was conducted using HPLC systems. Before the analysis, preparation includes separating liquid samples and solid samples.

There are two sample preparation methods. The solid samples were homogenized into a powder form by using a mixer. Then, 0.5 g of the sample was taken for the next step. If the sample is in a liquid form, it was pipetted at 0.5 mL for the next step.

After the preparation, the sample was mixed with 35 mL of distilled water inside a flask, vortexed for 2 minutes and warmed at 70 °C in a water bath for 30 minutes. Next, 5 mL of Carrez I and 5 mL of Carrez II were added to the solid samples. After 20 minutes, filled the flask with distilled water to a volume of 50 mL, and prepared for centrifugation. After centrifuging at 6000 rpm for 10 minutes, the sample was filtered through a 0.45 µm membrane, pipetted into vials, and injected into the HPLC system. HPLC was calibrated with standard solutions of each sugar to generate a calibration curve for quantification. Calibration standards and quality control samples were run periodically to ensure instrument accuracy.

The peak area for each sugar was recorded. The concentration of each sugar in the sample (g/100 g for solid samples, g/100mL for liquid samples) was calculated by comparing the peak areas to those of the calibration standards, using the software integrated with HPLC system. Microsoft Excel was used to compile the results and perform further calculations, such as total sugar content (sum of glucose, fructose, lactose and sucrose) for each sample.

Figure 7. HPLC system

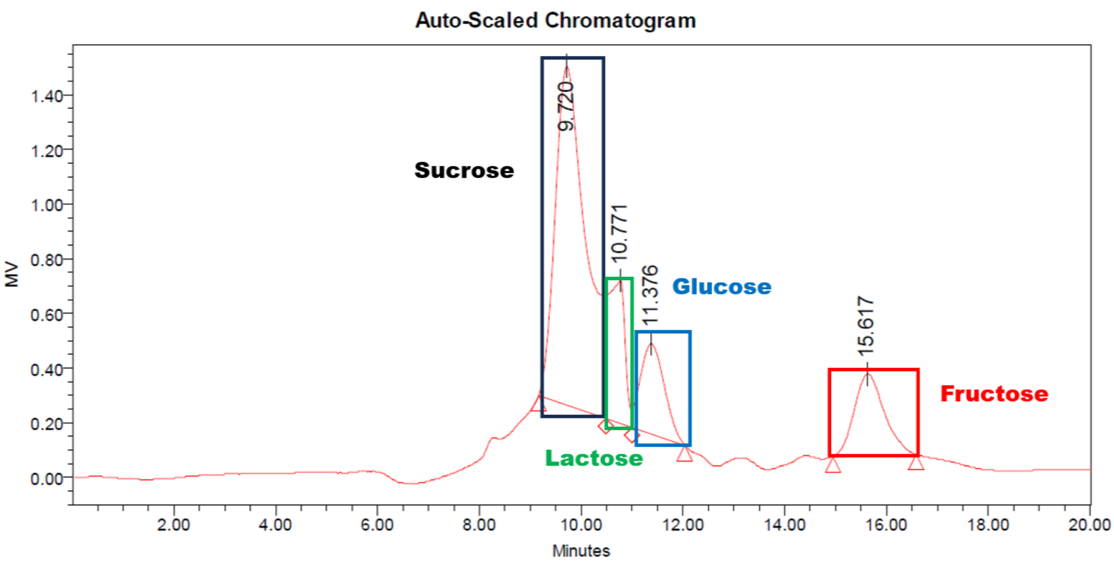

Figure 8. HPLC chart of fruit tea contains all 4 types of free sugar content

RESULTS

Table 1. Free sugar content in commercial snacks (g/100g)

Product	Sucrose	Lactose	Glucose	Fructose	Total
Rice crackers (n = 5)	12.46 ± 3.25	0.40 ± 0.79	1.96 ± 2.00	0.00	14.82 ± 4.14
Sponge cakes (n = 5)	23.42 ± 2.01	2.25 ± 5.04	1.24 ± 1.52	0.00	26.91 ± 4.88
Chocolate cakes (n = 3)	30.00 ± 6.74	1.94 ± 3.35	2.68 ± 3.70	0.00	36.62 ± 10.04
Biscuits (n = 3)	20.25 ± 11.26	2.86 ± 2.81	0.00	0.00	23.11 ± 13.25
Biscuits with cream (n = 4)	23.45 ± 4.98	6.70 ± 4.87	0.00	0.00	30.15 ± 5.95
Nutritious cereals (n = 10)	26.88 ± 15.48	0.00	4.77 ± 4.64	1.13 ± 2.78	28.89 ± 14.21

Values are Mean ± SD

Table 1 shows the sugar content in commercial snacks. The main sugar in commercial snacks is sucrose. Meanwhile, glucose, fructose, and lactose are found in smaller amounts compared to sucrose.

Table 2. Free sugar content in commercial beverages (g/100 mL)

Product	Sucrose	Lactose	Glucose	Fructose	Total
Cokes (n = 2)	1.11 ± 1.57	0.00	2.89 ± 0.29	5.76 ± 0.03	9.76 ± 1.83
Fruit juices (n = 4)	2.22 ± 1.41	0.00	1.74 ± 0.18	2.37 ± 0.46	6.33 ± 1.60
Energy drinks (n = 5)	5.01 ± 4.13	0.00	3.43 ± 0.98	4.95 ± 1.79	13.39 ± 2.66
Tea drinks (n = 9)	4.87 ± 1.87	0.00	1.68 ± 0.86	2.24 ± 1.21	8.79 ± 2.39
Fruit juices with milk (n = 2)	8.44 ± 0.40	0.55 ± 0.02	0.83 ± 0.05	1.27 ± 0.02	11.08 ± 0.49
Isotonic drink (n = 1)	1.80	0.00	0.15	1.62	3.62
Carbonated drinks (n = 4)	1.01 ± 1.10	0.00	1.22 ± 0.39	1.8 ± 0.49	4.03 ± 0.78

Values are Mean ± SD

Table 2 shows the sugar content in commercial beverage products. Almost all commercial beverages contain a high amount of fructose and glucose, which may be from isomerized sugar.

Table 3. Free sugar content in street foods (g/100g)

Product	Sucrose	Lactose	Glucose	Fructose	Total
Sponge cake	11.74	1.31	0.30	0.00	13.35
Crepe cake	7.03	0.79	0.17	0.00	7.99
Sweet corn fritters	5.85	0.00	0.00	0.00	5.85
Sweet potato fritters	6.34	0.00	0.00	0.00	6.34
Banana fritters	5.71	0.70	0.27	0.00	6.68
Deep-fried glutinous rice ball	11.29	0.72	0.00	0.00	12.01
Pudding	8.71	3.29	1.11	0.39	13.51
Vietnamese mixed sweet soup	12.88	0.00	0.00	0.00	12.88
Ice cream	23.84	1.89	0.00	0.00	25.73
Black rice yogurt	11.20	1.71	0.00	0.00	12.92
Cookie cream	13.77	0.00	0.00	0.00	13.77
Peach tea	14.07	0.00	0.44	0.00	14.51
Lemon tea	8.68	0.00	0.00	0.00	8.68
Kumquat tea	7.70	0.00	0.00	0.00	7.70
Fruit tea	7.99	2.91	1.57	2.62	15.09
Bubble milk tea	4.53	0.00	1.32	1.19	7.03

Table 3 presents the sugar content in products sold by street vendors. Ice cream, fruit tea and peach tea contain the highest sugar in street foods. The major sugar content in both dry foods (sponge cake, crepe cake, sweet corn fritters, sweet potato fritters, banana fritters, deep-fried glutinous rice ball) and liquid foods products (pudding, Vietnamese mixed sweet soup, ice cream, black rice yogurt, cookie cream, peach tea, lemon tea, kumquat tea, fruit tea and bubble milk tea) is sucrose. Isomerized sugar is found in lower amounts in a few items such as pudding, bubble milk tea and fruit tea.

STUDY 2: THE RELATIONSHIP BETWEEN FREE-SUGAR INTAKE AND OBESITY AND METABOLIC SYNDROME

METHOD

I. Study design

A case-control design was conducted at five secondary schools in Hanoi (the national capital, a large urban city in the north) and Haiphong (a large port city with slightly lower urbanization) from October to December 2024. Participants were 7th-grade and 8th-grade students who were healthy, their caregivers agreed to participate in the study, had no congenital defects and had no scoliosis.

II. Sample size selection

Screening test

$$n \geq Z^2_{1-\alpha/2}\ \frac{p.(1-p)}{(p\epsilon)^2}$$

n: sample size for the screening test

α: Statistical significance level, $\alpha = 0.05$

$Z_{1-\alpha/2} = 1.96$ with $\alpha = 0.05$ corresponding to 95% confidence level

p: The prevalence of overweight and obesity in secondary school children, based on the past research was 29.9% (24)

Є: Relative value (Є = 0.08)

After replacing all the data into the formula, 1408 subjects for each city are necessary

The total subjects are necessary is 1408 x 2 = 2816 subjects

There were 2911 students participated in the screening to determine their anthropometric status. This screening provided to select case and control subjects for the detailed sugar intake assessment and selecting obese children for the metabolic syndrome assessment.

Assess free sugar intakes

$$n \geq \frac{\left\{Z_{1-\frac{\alpha}{2}}\sqrt{2P_2(1-P_2)}+Z_{1-\beta}\sqrt{P_1(1-P_1)+P_2(1-P_2)}\right\}^2}{(P_1-P_2)^2}$$

$Z_{1-\alpha/2} = 1.96$, standard normal variate

$\beta = 0.1$ (probability type 2 error)

$Z_{1-\beta} = 0.9$

$P_1 = 0.9$ (estimate rate of consuming sugar-rich foods in obese children is 90%) (25)

$P_2 = 0.69$ (estimate rate of consuming sugar-rich foods in normal children is 69%) (25)

After replacing all the data into the formula, 76 children for each group are necessary

The total subjects are necessary is 76 x 2 = 152 children.

III. Study plan

Figure 3. Study plan for study 2

1. Screening test

We selected five secondary schools randomly in Hanoi and Haiphong cities. We measured children's height and weight to assess their anthropometric status using body mass index (BMI) according to the WHO standard. Trained nutritionists and health staff visited schools to measure each child's height and weight. Height was measured to the nearest 0.1 cm using a portable stadiometer, with children standing straight and shoeless. Weight was measured to the nearest 0.1 kg using a TANITA calibrated digital scale, with children in light school uniform (without coats or heavy items).

BMI was calculated as weight (kg) divided by height (m) squared. The nutritional status was assessed using WHO 2007 growth reference for 5-19-year-old. BMI-for-age z-score (BAZ) was computed using the software WHO AnthroPlus version 1.0.4 for children above 5 years old. Children were classified as obese, overweight, normal or thin according to cut-offs: Obesity was defined as BAZ > +2SD, overweight as BAZ > +1SD (but ≤ +2SD), normal as -2SD ≤ BAZ ≤ +1SD, and thin as BAZ < -2SD (26).

Figure 9: Measurement of children’s height and weight

2. **Assess metabolic syndrome**

From the screening test, children who were obese (BAZ > +2) were chosen to assess metabolic syndrome. 337 obese children were identified in the screening (11.6% of 2911); a total of 80 obese children agreed to and had parental consent for further study. Waist circumference, blood pressure and blood biochemistry to determine metabolic syndrome using the International Diabetes Federation (IDF) criteria for children aged 10-16 years (29).

Waist circumference was measured by using a non-stretch tape, with an accuracy of 0.1 cm at the midpoint between the lowest rib and the top of the iliac crest, with the child standing and breathing normally.

Blood pressure was measured twice using the OMRON Blood Pressure Monitor. The average result was calculated from two blood pressure measurements, with the second measurement taken 15 minutes after the first.

A trained phlebotomist took fasting blood samples from each child after an overnight fast of at least 10 hours. Blood samples were centrifuged, blood serum was kept cool and transported to the National Institute of Nutrition laboratory for analysis. We analyzed fasting glucose, high-density lipoprotein cholesterol (HDL-C), and triglycerides using enzymatic methods on an automated biochemical analyzer, the AU480 with appropriate quality control calibration.

Metabolic syndrome was defined according to the IDF consensus criteria for children aged 10-16 years. This definition requires the presence of central obesity (waist circumference ≥ 80 cm in girls and ≥ 90 cm in boys) plus any 2 of the following 4 criterias: Triglycerides ≥ 1.7 mmol/L, HDL-C < 1.03 mmol/L, high blood pressure (systolic ≥ 130 or diastolic ≥ 85 mmHg), and fasting glucose ≥ 5.6 mmol/L.

Figure 10: Equipments were used to assess metabolic syndrome

3. Assess sugar intake

To find the free-sugar consumption, we selected a subset of the study population for detailed dietary surveys. We formed 2 groups for comparison: an obese group and a group with normal anthropometric status. From the screening survey, we identified students who met the criteria for obesity (BAZ > +2) as obese group. A random sample of obese children was invited to participate in the case group for assessment of sugar intake. Meanwhile, children with a normal anthropometric status were considered as normal group. We informed the chosen students who agreed to provide informed consent. Ultimately, 80 obese children (40 boys and 40 girls) and 92 children (46 boys and 46 girls) of normal anthropometric status were recruited for the case-control analysis of sugar intake assessment. In both the obese and normal groups, we adjusted the number of males to equal the number of females for more comparability.

To qualify for free-sugar consumption, we conducted detailed dietary interviews with the selected case and control children (80 obese and 92 normal anthropometric children). Trained researchers interviewed each child using a food photobook (27) and the nutritional values of some street foods and fast foods published by the Vietnam National Institute of Nutrition (28) to estimate serving sizes. A dietary survey was conducted using the 24-hour recall method on three non-consecutive days (two weekdays and one weekend day). Researchers interviewed each child using a food photobook (27), using the nutritional values of some street foods and fast foods published by the Vietnam National Institute of Nutrition (29) to estimate serving sizes.

Figure 11: Nutrition values of some street foods and fast foods

Figure 12: Food photobook

4. Data analysis

Anthropometric and blood biochemistry data were analyzed by using SPSS version 27 software. Sugar intake data (including sucrose, lactose, glucose, fructose) were calculated using the developed Vietnamese sugar composition table by Microsoft Excel 2016. The data were shown as mean ± SD. The difference in sugar intake between normal children and obese children and the difference in sugar intake between metabolic syndrome children and non-metabolic syndrome children were tested by using the Mann-Whitney U test. The p-values of less than 0.05 were considered statistically significant. The OR of sugar intake exceeding 50 g/day between case groups and control groups were tested using Pearson Chi-square Test. The p-values of less than 0.05 were considered statistically significant.

IV. Ethics approval and consent to participate

The study protocol was approved by the Ethics Committee of the Vietnam National Institute of Nutrition, Hanoi, Vietnam (document number 542/QLKH-VDD, dated June 17, 2024) (Appendix I). School administrators gave permission to conduct the study. Before conducting the survey, all children and their caregivers were informed of the study's nature and signed the consent form if they agreed to participate (Appendix II). Children assented to the measurements and interviews and were free to withdraw at any time. Individual results were communicated to parents along with counseling or referral as appropriate.

RESULTS

Table 4: Anthropometric status by BMI (n = 2911)

Classification	Definition	Number (%)
Obesity	> 2SD	337 (11.6)
Overweight	> 1SD – 2SD	639 (22.0)
Normal	-2SD – 1 SD	1818 (62.5)
Wasting	< -2SD	117 (4.1)

Abbreviation: BMI, body mass index; SD, standard deviation

Table 4 shows the anthropometric status of 2911 children who participated in the screening survey. The prevalence of overweight was 22.0% and obesity was 11.6%. The prevalence of overweight and obesity in children aged 12-13 years was very high, about 33.6%.

Table 5: Free sugar intakes in obese and normal students

	Obese (n = 80)	Normal (n = 92)	p†
Glucose intake (g/day)	3.0 ± 3.2	3.2 ± 3.6	0.79
Fructose intake (g/day)	4.0 ± 4.9	4.7 ± 5.6	0.42
Sucrose intake (g/day)	18.1 ± 16.5	16.1 ± 12.5	0.72
Lactose intake (g/day)	1.4 ± 2.0	1.9 ± 2.0	0.25
Total sugar intake (g/day)	26.5 ± 21.1	25.8 ± 16.7	0.91

Values are presented as mean ± SD

† Mann-Whitney U Test

Table 5 presents a comparison of the mean sugar intake between obese and normal children. We assessed dietary free-sugar intake in a case-control subset of 172 students (80 obese and 92 normal). There is no statistically significant difference between the mean specific types of sugar intake (glucose, fructose, lactose and sucrose) in obese children and normal children

Table 6: Relationship between high free sugar intake and obesity by Chi-square test

	Obese n (%)	Normal n (%)	p†	OR (95% CI)
Free sugar intake ≥ 50g/day	13 (16)	22 (24)	0.2	0.7
Free sugar intake < 50g/day	67 (84)	70 (76)		(0.3 – 1.2)

† Pearson Chi-square test

Table 6 shows the relationship between high sugar intake and obesity in children. There is no statistically significant relationship between high sugar intake and obesity in children.

Table 7: Nutrient and energy intakes in obese and normal students

Nutrients	Obese (n = 80)	Normal (n = 92)	p*
Energy (kcal)	2265 ± 603	2096 ± 605	**0.04**
Carbohydrate (g)	306 ± 89	296 ± 95	0.41
Protein (g)	77 ± 27	74 ± 29	0.35
Lipid (g)	64 ± 20	59 ± 22	**0.05**

Values are Mean ± SD

* Mann-Whitney U test

Table 7 shows nutrient intakes in obese and normal students. There is no statistically significant difference between obese group and normal group in carbohydrate intake and protein intake. There are statistically significant differences in energy intake and lipid intake between the obese group and the normal group.

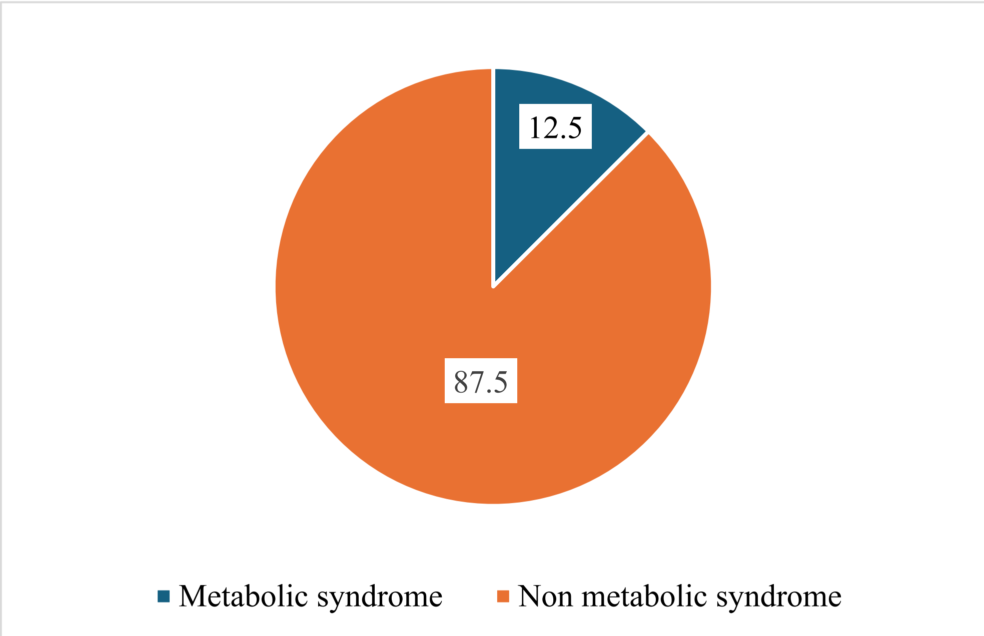

Figure 13: Prevalence of metabolic syndrome in obese children (n = 80)

Figure 13 shows the prevalence of metabolic syndrome in obese children. The prevalence of metabolic syndrome was 12.5% in obese children.

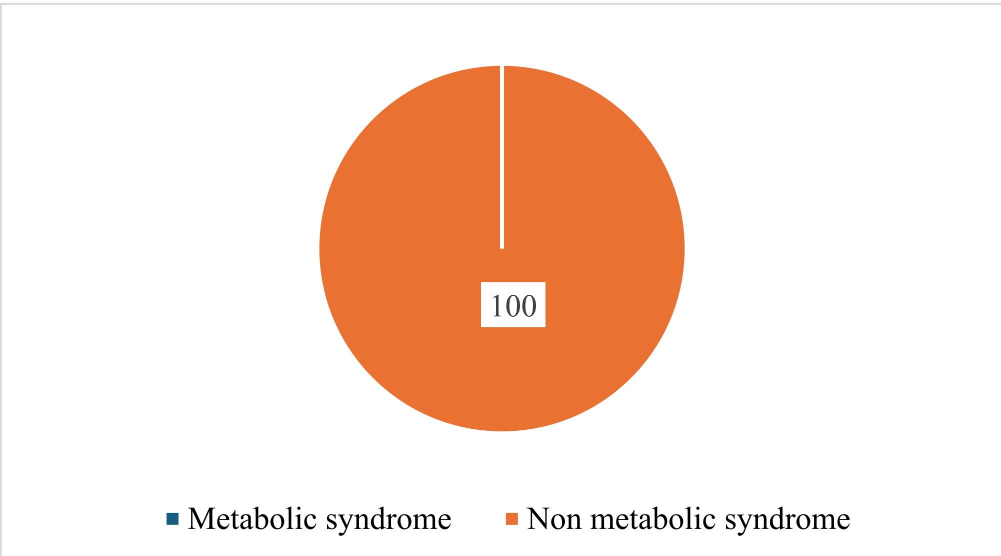

Figure 14: Prevalence of metabolic syndrome in normal children (n = 92)

Figure 14 shows the prevalence of metabolic syndrome in normal children. The prevalence of metabolic syndrome was 0% or there was no child in normal group had metabolic syndrome.

Table 8: The comparison in sugar intake between students with metabolic syndrome and students without metabolic syndrome

	Metabolic syndrome (n = 10)	Non-metabolic syndrome (n = 70)	p†
Glucose intake (g/day)	5.0 ± 6.6	2.7 ± 2.4	**0.03**
Fructose intake (g/day)	7.4 ± 10.5	3.6 ± 3.4	**0.02**
Sucrose intake (g/day)	19.5 ± 14.9	18.0 ± 16.9	0.71
Lactose intake (g/day)	1.4 ± 1.7	1.5 ± 2.1	0.93

Values are presented as mean ± SD

† Mann-Whitney U Test

Table 8 presents a comparison of the mean sugar intake between children with metabolic syndrome and children without metabolic syndrome. There is no statistically significant difference in sucrose intake and lactose intake between children with metabolic syndrome and children without metabolic syndrome. Children with metabolic syndrome consumed more isomerized sugar (fructose and glucose) than children without metabolic syndrome ($p < 0.05$).

DISCUSSION

About food samples collection, we collected 57 commercial products (including snacks and beverages) from big supermarkets and 18 products were manufactured in retail stores. All commercial products are commonly sold in both big supermarkets and grocery stores in Vietnam. Products manufactured in retail stores were collected randomly from vendors near school gates, open markets and other public locations. After collecting, these products were transported to the laboratory and were analyzed for sugar contents (glucose, fructose, lactose, and sucrose) by HPLC method.

The HPLC method was used to analyze sugar content in foods. The HPLC method used in this study is a highly accurate and reliable method. The HPLC method has been validated in accordance with the International Standard for Testing and Calibration Laboratories. Additionally, the accuracy of the HPLC method has been evaluated through participation in the FAPAS proficiency test, with the results meeting the requirements. The HPLC method is the most widely used today and has been applied in many previous studies to determine sugar content in foods across various countries (30-32).

The isomerized sugar, commonly known as High Fructose Corn Syrup, is commonly used nowadays because it is sweeter and less expensive than sucrose. For a health perspective, consuming fructose in large amounts may cause metabolic risks such as promoting lipogenesis and insulin resistance, so high content of fructose in beverages are a concern (10). According to the findings in Study 1, isomerized sugar was detected in almost all commercial beverages. In contrast, fruit juices mixed with milk contained higher levels of sucrose, as sucrose is an added sugar in Vietnamese milks (33). There are some concerns that frequently consuming isomerized sugar can lead to obesity, some non-communicable diseases and metabolic syndrome (34).

Findings from Study 1 indicate that sucrose was the main sugar found in commercial snacks and street food products. In snack products, sucrose is used because it is sweet at high temperatures. Sucrose is widely used in Vietnamese commercial snacks, some beverages and street food products.

However, there are some limitations in Study 1. The findings represent only the most common commercial snacks and beverages in Vietnam and do not represent all products. In addition, vendor product samples were purchased only in Hanoi. Therefore, the results of sugar content in vendor products were unable to represent the entire range of vendor products in Vietnam. Future analysis of product samples from other study locations in Vietnam will provide valuable information about potential variations.

Study 2 has some strong points. It is one of the first case-control studies in Vietnam to rigorously quantify free sugar intake in children and relate it to both obesity and metabolic syndrome outcomes. We used a detailed 24-hour recall method on multiple days, complemented by a customized food composition database for free sugars, which enhances the accuracy of sugar intake estimation in the local context. The matching of cases and controls by school and demographic factors reduces potential confounding by socio-economic or environmental variables (since all participants were from similar urban schools). Moreover, we employed standardized measurements for anthropometry and biochemical profile, using established criteria (WHO and IDF) to define obesity and metabolic syndrome, lending credibility and comparability to our findings. Additionally, we conducted this study using a large sample size from the screening test to determine the anthropometric status of children in the city accurately. Besides, to determine metabolic syndrome, we need to take blood, which is a complicated work because we can only collect this data with the agreement of children's parents or caregivers.

The high prevalence of overweight and obesity in urban Vietnamese children is a clear indication of ongoing nutrition transition. This figure aligns with other recent data from Vietnam. A national survey reported that the prevalence of overweight and obesity in Vietnam has increased by 19% and obesity by 8.1% in 2020 (35), and urban cities like Ho Chi Minh City had already reached 21.9% a decade ago (36). The study 2 focused on 2 major cities in the North of Vietnam (Hanoi and Haiphong cities) and similarly found roughly one-third of early adolescents were overweight and obese. From the results of study 2, there was no association between high free sugar intake and obesity in children. Similar surveys from Taiwan, Japan and Cambodia have also reported no significant difference between free sugar consumption and obesity in children (13-14). Obese children had mean intake of energy higher than that of normal children with statistically significant difference. Obesity may be caused by many other factors such as sedentary habits, high caloric food intake or genetic predispositions. These factors might be more decisive in driving weight gain than sugar intake in children (13).

The prevalence of metabolic syndrome is 12.5% in obese children. Meanwhile, there was no child among normal children who had metabolic syndrome. These findings find an association between obesity and metabolic syndrome. This prevalence is similar to other areas in Vietnam. For instance, a study in Ho Chi Minh City in 2007 found that 11.8% of obese adolescents had metabolic syndrome, and only 3% of normal adolescents had metabolic syndrome. (37). The higher prevalence of metabolic syndrome in obese group marks obesity as a significant risk factor for the development of metabolic syndrome (38). Metabolic syndrome comprises a cluster of conditions, including abnormal obesity, insulin resistance, dyslipidemia and elevated blood pressure, which increase the risk of cardiovascular disease and type 2 diabetes (29).

In comparison to the metabolic syndrome outcome, findings in study 2 found statistically significant differences between high fructose intake, glucose intake (mainly from isomerized sugar) and metabolic syndrome among children. These results pointed out that high fructose intake can increase visceral adiposity, induce lipogenesis, leading to raise triglycerides and reduce insulin sensitivity (39). Moreover, a high intake of fructose is associated with a decrease in HDL-C levels and an increased risk of dyslipidemia in adolescents (9, 40). Additionally, high fructose intake is associated with increased blood pressure and may contribute to the development of hypertension (41). High intake of sweet beverages is also associated with high waist circumference and fasting glucose (40).

It is important to acknowledge the limitations of this study. Firstly, the dietary intake data were self-reported (with parental help for recall when needed). Even with 24-hour recall methods, some degree of measurement error is inevitable. If obese children underreport their intake more than normal children, it would lead to biased comparisons. Secondly, the case–control design for the diet survey means we cannot infer temporality – whether high sugar intake led to obesity or metabolic syndrome, or whether obese or metabolic syndrome children changed their eating habits. A longitudinal study would be better suited to address causality. Thirdly, our metabolic syndrome assessment was only done on obese children, so we do not know if any normal children had metabolic syndrome components (though likely very few). Due to only 12.5% of obese children having metabolic syndrome, the number of children with metabolic syndrome is small. We therefore focused on the differences within obese individuals, but the small number of metabolic syndrome cases (n = 10) means that the results should be interpreted with caution. Lastly, our study focused on urban schoolchildren in two cities, so the findings may not be generalizable to rural areas or other age groups. Despite these limitations, the study benefits from a fairly large screening sample and detailed dietary analysis, and it addresses an important research question in a context (Vietnam) where data on sugar intake and metabolic outcomes in youth have been limited.

CONCLUSION

Although high free sugar intake was not a direct cause of obesity, it was suggested that isomerized sugars (fructose, glucose) contained in cold drinking water may contribute to the development of metabolic syndrome. High energy intake is a cause of obesity in Vietnamese junior high school students.

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Finally, I would like to extend my gratitude to my family and friends for their great encouragement and support in my academic progress and for helping me overcome many obstacles in my life.

Appendix I: Ethical Approval

(In Vietnamese)

BỘ Y TẾ
VIỆN DINH DƯỠNG

Số: 542 /QLKH-VDD

CỘNG HOÀ XÃ HỘI CHỦ NGHĨA VIỆT NAM
Độc lập - Tự do - Hạnh phúc

Hà Nội, ngày 17 tháng 6 năm 2024

CHỨNG NHẬN CHẤP THUẬN CỦA
HỘI ĐỒNG ĐẠO ĐỨC TRONG NGHIÊN CỨU Y SINH HỌC CẤP CƠ SỞ

Căn cứ Quyết định số: 599/QĐ - VDD ngày 15 tháng 4 năm 2024 của Viện trưởng Viện Dinh dưỡng về việc thành lập Hội đồng Đạo đức trong nghiên cứu y sinh học xét duyệt các vấn đề đạo đức trong nghiên cứu của nhiệm vụ khoa học;

Căn cứ biên bản họp ngày 16/4/2024 (có biên bản kèm theo) của Hội đồng Đạo đức trong nghiên cứu y sinh học cấp cơ sở đã họp xét duyệt hồ sơ các khía cạnh đạo đức nghiên cứu của nhiệm vụ;

Hội đồng Đạo đức trong nghiên cứu y sinh học Viện Dinh dưỡng chấp thuận về các khía cạnh đạo đức trong nghiên cứu đối với nhiệm vụ khoa học sau:

1. Tên nhiệm vụ:

   "Đánh giá mức tiêu thụ thực phẩm chứa tranfat, đường đơn, đường đôi và mối liên quan tới rối loạn đường máu, lipid máu, tăng huyết áp và thừa cân béo phì ở trẻ em 12 - 13 tuổi tại Hà Nội và thành phố Hải Phòng"

2. Chủ trì nhiệm vụ: ThS. Lê Thị Hằng
3. Kinh phí: 235.000.000đ (Phòng chống bệnh không lây nhiễm năm 2024).
4. Thời gian thực hiện: Tháng 3/2024 - 12/2024.
5. Địa điểm triển khai: Hà Nội, Hải Phòng.

CHỦ TỊCH HỘI ĐỒNG
PHÓ VIỆN TRƯỞNG

VIỆN DINH DƯỠNG

PGS.TS. Trương Tuyết Mai

Appendix II: Consent Form

(In Vietnamese)

BẢN THOẢ THUẬN THAM GIA NGHIÊN CỨU CHO ĐỐI TƯỢNG THAM GIA

Tên em là: ……………………………………Lớp…………………………………….

Trường: ……………………………………………………………………………….

Em được nghe giải thích về hoạt động: Đánh giá mức tiêu thụ thực phẩm chứa transfat, đường đơn, đường đôi và mối liên quan tới rối loạn đường máu, Lipid máu, tăng huyết áp và thừa cân béo phì ở trẻ em 12 -13 tuổi tại Hà Nội và Thành phố Hải Phòng.

Gồm các nội dung chính sau đây:

- Mục đích của chương trình:
  + Tìm hiểu thực trạng thừa cân – béo phì và hội chứng chuyển hóa ở trẻ em lứa tuổi THCS.
  + Mức tiêu thụ thực phẩm chứa transfat, đường đơn, đường đôi ở học sinh.

Khi tham gia em sẽ được:

+ Cân đo nhân trắc xác định tình trạng dinh dưỡng miễn phí

+ Được nhận bồi dưỡng cho việc trả lời phỏng vấn và được bác sỹ tư vấn dinh dưỡng miễn phí.

- Nghĩa vụ của học sinh tham gia: trả lời trung thực các câu hỏi trong phiếu phỏng vấn.
- Những thông tin cá nhân sẽ được mã hóa để giữ bí mật.
- Đảm bảo bí mật riêng tư đối với người tham gia nghiên cứu: Những thông tin cá nhân sẽ được mã hóa để giữ bí mật và chỉ dùng cho mục đích nghiên cứu.

- Phương thức liên hệ với cán bộ Viện Dinh dưỡng: Khi có bất cứ thắc mắc gì, em liên lạc trực tiếp với bác sỹ Lê Thị Hằng, số ĐT: 0983599585

Em hoàn toàn tự nguyện đồng ý tham gia và tuân thủ các hướng dẫn của Cán bộ Viện dinh dưỡng.

Đại diện Nghiên cứu **Người tham gia**

Appendix III: Conference presentation

<u>Le Anh Hoa</u>, Vu Thi Thu Hien, Tran Thuy Nga, Le Thi Hang. Relationship between free sugar intake and obesity, metabolic syndrome in Vietnamese children. 2025 Field Epidemiology Training Program Conference.

Expected time: September 18th, 2025.

Location: Can Tho University of Medicine and Pharmacy, Can Tho City, Vietnam.

Acceptance letter for conference presentation (in Vietnamese)