

Current Status and Trends in Dietary Energy from Sugar in Thailand: International Comparisons and Ecological Associations with Obesity and Diabetes

Nicha Thungpaphong¹



Nicha Thungpaphong

¹ Medisci Biointegrative Anti-aging Center,
Bangkok, Thailand

* Address Correspondence to author:
Nicha Thungpaphong
Medisci Biointegrative Anti-aging Center
58/59 Chinnakhet, Ngamwongwan
Lak Si, Bangkok 10210, Thailand
email: dr.nicha@gmail.com

Abstract

OBJECTIVES: To describe and compare temporal trends in dietary energy from sugar, obesity, and diabetes in Thailand and selected regions, contextualize Thailand's sugar availability in relation to WHO recommendations, and examine the ecological association between obesity and diabetes prevalence.

MATERIALS AND METHODS: This ecological study used national-level secondary data. Dietary energy from sugar and sweeteners (kcal/capita/day, 2010–2023) was obtained from FAOSTAT Food Balance Sheets, while obesity and diabetes prevalence (%) among adults (2010–2022) were obtained from the WHO Global Health Observatory. Descriptive statistics and indexed trends (2010 = 100) were used to summarize temporal changes for Thailand and comparator regions (Asia, South-East Asia, the Americas, Africa, and Europe). Spearman's rank correlation coefficient was used to assess the association between annual obesity and diabetes prevalence in Thailand, with statistical significance set at $p < 0.05$.

RESULTS: From 2010 to 2023, dietary energy from sugar in Thailand declined from 490.6 to 435.4 kcal/capita/day (−11.3%), while Asia (+9.8%) and South-East Asia (+25.3%) showed rising trends. Despite this decline, Thailand's dietary energy supply from sugar remained more than twice the Asian average and was comparable to that of the Americas, the region with the highest sugar availability among the comparator regions. Meanwhile, obesity prevalence in Thailand rose from 9.1% to 15.3% (+68.1%) and diabetes prevalence rose from 8.7% to 12.3% (+41.4%) between 2010 and 2022. In Thailand, annual obesity and diabetes prevalence were positively correlated (Spearman's $\rho = 1.00$, $p < 0.001$).

CONCLUSION: Although dietary energy from sugar in Thailand declined during 2010–2023, it remained high when considered in relation to WHO recommendations and most comparator regions, while obesity and diabetes prevalence continued to rise. Sugar reduction alone is unlikely to sufficiently curb the burden of diet-related NCDs; future public health efforts should integrate sugar reduction with broader interventions targeting the food environment and lifestyle-related risk factors.

Keywords: dietary sugar, obesity, diabetes, ecological study

The prevention and control of non-communicable diseases (NCDs) has become a major public health priority in Thailand, where the burden of obesity, type 2 diabetes mellitus (T2DM), cardiovascular diseases, and other chronic conditions continues to increase. Long-term NCD control requires a comprehensive approach that extends beyond medical treatment alone, emphasizing primary prevention through health promotion, disease prevention, and improvements in health literacy to support sustainable healthy lifestyle behaviours.¹ Dietary modification is a key component of these preventive strategies, and reducing excessive sugar consumption has been identified as an important public health target.

Population-level sugar consumption has increasingly been recognized as an important dietary factor contributing to the global burden of non-communicable diseases (NCDs), including obesity, type 2 diabetes mellitus

Received: April 7, 2026
Revision received: July 6, 2026
Accepted after revision: August 05, 2026
BKK Med J 2026;22(2): 110-116.
DOI: 10.31524/bkkmedj.2026.21.005
www.bangkokmedjournal.com

(T2DM), cardiovascular diseases, and other metabolic disorders.² Among dietary sources, sugar-sweetened beverages are a major contributor to free sugar intake and have consistently been associated with obesity, metabolic syndrome, and non-alcoholic fatty liver disease.³ Consequently, reducing excessive sugar consumption has become a global public health priority.

Evidence suggests that diets high in added sugars contribute to metabolic diseases through both direct and indirect mechanisms. Fructose may directly impair lipid and carbohydrate metabolism, while excessive sugar intake indirectly promotes positive energy balance, weight gain, and adiposity, thereby increasing the risk of metabolic diseases.^{4,5} These effects involve chronic low-grade inflammation, insulin resistance, ectopic fat accumulation, and oxidative stress.^{4,6} Obesity is one of the strongest risk factors for type 2 diabetes and has also been identified as a causal factor for at least 13 types of cancer.⁷ Although obesity and type 2 diabetes are closely related, their biological pathways differ. Excessive sugar intake is more directly associated with obesity, whereas its relationship with type 2 diabetes is largely mediated through adiposity, insulin resistance, and impaired glucose metabolism.⁸ Moreover, diabetes develops over a relatively long metabolic latency period and is influenced by multiple determinants, including ageing, genetic susceptibility, physical activity, obesity, sleep patterns, smoking, and access to healthcare services. Consequently, changes in dietary sugar intake are likely to be reflected more rapidly in obesity than in diabetes prevalence at the population level.

Recognizing these health consequences, the WHO recommends limiting free sugar intake to <10% of total daily energy intake and suggests a further reduction to <5% for additional health benefits.⁹ WHO also recommends the percentage of total energy derived from free sugars (% energy from sugar) as a population-level indicator because it enables standardized monitoring and meaningful comparisons across populations and over time.

In Thailand, awareness of excessive sugar consumption and its role in the prevention of non-communicable diseases (NCDs) has increased substantially in recent years, accompanied by several national sugar reduction initiatives.¹⁰ Nevertheless, comprehensive evidence describing the current level and long-term trends of dietary energy from sugar remains limited. Consequently, it is unclear whether sugar intake in Thailand is consistent with WHO recommendations, how it compares with regional benchmarks, and whether national trends differ from global patterns.^{11,12}

To address these knowledge gaps, this study aimed to describe and compare temporal trends in dietary energy from sugar, obesity, and diabetes in Thailand and selected regions, contextualize Thailand's sugar availability in relation to WHO recommendations, and examine the ecological association between obesity and diabetes prevalence using national-level secondary data.

Materials and Methods

This ecological study used national-level secondary data. Data on dietary energy from sugar and sweeteners were obtained from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT), which is based on the Food Balance Sheets and provides annual national food supply data. The primary exposure variable was dietary energy from sugar and sweeteners (kcal/day per capita), using data from 2010 to 2023. Health outcome data were obtained from the WHO Global Health Observatory, covering the period from 2010 to 2022¹³, the most recent year for which data were available. The health outcomes included the prevalence of adult obesity (%) and diabetes prevalence (%).

Statistical analysis

All data management and analysis were performed using R version 4.5.3 (RStudio version 2026.05.0). Descriptive statistics were used to present the annual dietary energy from sugar and sweeteners (kcal/capita/day) and the prevalence of obesity and diabetes for Thailand and the comparator groups (Asia, South-East Asia, the Americas, Africa, and Europe). Temporal trends over 2010–2023 were examined and presented as line graphs, as well as absolute change and percent change. For Thailand, to compare the relative changes of the indicators on a common scale, each data series was indexed to its 2010 baseline value (index, 2010 = 100). In addition, the association between annual obesity and diabetes prevalence in Thailand was assessed using Spearman's rank correlation coefficient (ρ), with statistical significance set at $p < 0.05$.

Ethical Considerations

This study used publicly available, de-identified, and aggregated data. No human participants were involved, and no identifiable individual-level data were accessed. Therefore, ethical approval was not required, and informed consent was not required.

Results

Table 1 summarizes changes in dietary energy supply from sugar and sweeteners, obesity prevalence, and diabetes prevalence in Thailand and the selected regions. From 2010 to 2023, dietary energy supply from sugar and sweeteners in Thailand decreased from 490.6 to 435.4 kcal/capita/day, representing an overall reduction of 11.3%. In contrast, dietary energy supply from sugar and sweeteners increased in Asia and South-East Asia, with South-East Asia showing the largest increase (25.3%).

Despite varying trends in sugar availability across regions, obesity and diabetes prevalence increased consistently between 2010 and 2022. In Thailand, obesity prevalence increased by 68.1%, while diabetes prevalence increased by 41.4%. South-East Asia showed the largest relative increases in both obesity (86.8%) and diabetes (83.3%). The Americas maintained the highest obesity prevalence despite a decline in dietary energy supply from sugar and sweeteners during the study period (Table 1).

Table 1: Summary of changes in dietary energy supply from sugar and health indicators

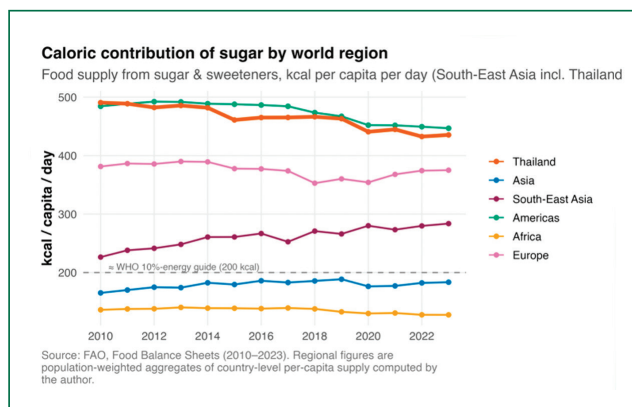
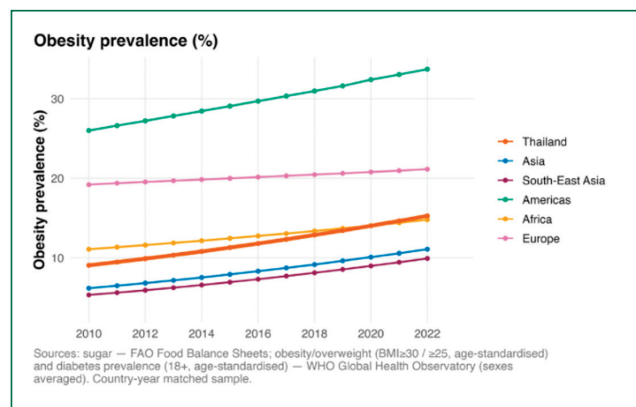
Indicator	Region	2010	Latest available	Change	% Change
Dietary energy supply from sugar (kcal/capita/day), 2010–2023	Thailand	490.6	435.4	−55.2	−11.3
	Asia	170.7	187.4	+16.7	+9.8
	South-East Asia	226.4	283.7	+57.3	+25.3
	Americas	484.4	446.8	−37.6	−7.8
	Africa	136.3	127.6	−8.7	−6.4
	Europe	381.3	375.0	−6.3	−1.7
Obesity prevalence (%), 2010–2022	Thailand	9.1	15.3	+6.2	+68.1
	Asia	6.2	11.1	+4.9	+79.0
	South-East Asia	5.3	9.9	+4.6	+86.8
	Americas	26.0	33.7	+7.7	+29.6
	Africa	11.1	14.8	+3.7	+33.3
	Europe	19.2	21.1	+1.9	+9.9
Diabetes prevalence (%), 2010–2022	Thailand	8.7	12.3	+3.6	+41.4
	Asia	11.8	17.2	+5.4	+45.8
	South-East Asia	7.2	13.2	+6.0	+83.3
	Americas	10.8	13.1	+2.3	+21.3
	Africa	9.6	12.0	+2.4	+25.0
	Europe	6.2	7.3	+1.1	+17.7

A similar declining trend in food supply from sugar and sweeteners was seen in the Americas, with a decrease from 484 to 447 kcal per capita per day (7.8%). Europe showed only a slight decline, from 381 to 375 kcal per capita per day (1.7%), while Africa decreased from 136 to 128 kcal per capita per day (6.4%). In contrast, dietary energy supply from sugar and sweeteners increased in both Asia and South-East Asia, rising from 170.7 to 187.4 kcal/capita/day (9.8%) and from 226.4 to 283.7 kcal/capita/day (25.3%), respectively, as shown in Figure 1.

In Thailand, obesity prevalence rose steadily during the study period, from 9.1% in 2010 to 15.3% in 2022, representing a 68.1% overall increase. A similar upward trend was observed in all regions. The Americas consistently recorded the highest obesity prevalence, rising from 26.0% to 33.7% (29.6%). Europe showed a smaller increase, from 19.2% to 21.1% (9.9%), whereas Africa rose from 11.1% to 14.8% (33.3%). Although Asia had the lowest obesity prevalence throughout the study period, it increased from 6.2% in 2010 to 11.1% in 2022, representing a 79.0% relative increase. A similar trend was observed in South-East Asia, where obesity prevalence rose from 5.3% to 9.9%, corresponding to the largest relative increase (86.8%) among the regions examined as shown in Figure 2.

Trends in diabetes prevalence among adults between 2010 and 2022 are shown in Figure 3. Diabetes prevalence increased across all regions during the study period. In Thailand, it rose from 8.7% in 2010 to 12.3% in 2022, an absolute increase of 3.6 percentage points and a 41.4% relative increase. Asia consistently had the highest diabetes prevalence, increasing from 11.8% to 17.2%. South-East Asia showed the largest relative increase, rising from 7.2% to 13.2% (83.3%). By 2022, diabetes prevalence in South-East Asia had exceeded that of Thailand and approached the level observed in the Americas (13.1%). In comparison, diabetes prevalence in the Americas increased from 10.8% to 13.1%, while Africa increased from 9.6% to 12.0%. Europe maintained the lowest diabetes prevalence throughout the study period, with a modest increase from 6.2% to 7.3%, as shown in Figure 3.

While focusing on Thailand, Figure 4 shows the relative changes in dietary energy from sugar, obesity prevalence, and diabetes prevalence between 2010 and 2022, using 2010 as the reference year (index = 100). Dietary energy from sugar gradually declined over the study period, whereas both obesity and diabetes prevalence increased steadily.

**Figure 1:** Trends in dietary energy supply from sugar and sweeteners in Thailand and selected regions, 2010–2023.**Figure 2:** Trends in adult obesity prevalence in Thailand and selected WHO regions, 2010–2022.

Current Status and Trends in Dietary Energy from Sugar in Thailand: International Comparisons and Ecological Associations with Obesity and Diabetes

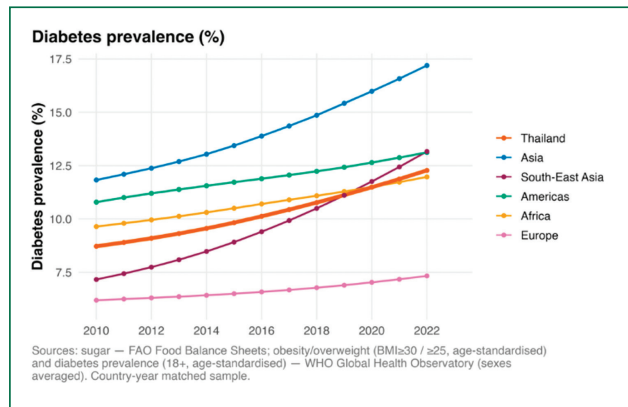


Figure 3: Trends in adult diabetes prevalence in Thailand and selected WHO regions, 2010–2022.

Annual obesity and diabetes prevalence in Thailand were positively correlated (Spearman's $\rho = 1.00, p < 0.001$), indicating that both outcomes followed similar upward trends during 2010–2022 (Table 2).

Table 2: Correlation between obesity and diabetes prevalence in Thailand, 2010–2022

Variables	Spearman's ρ	p -value
Obesity prevalence vs diabetes prevalence	1.00	< 0.001

Discussion

This study shows that although dietary energy from sugar and sweeteners in Thailand declined between 2010 and 2023, the overall level of consumption remained high. Thailand's intake was more than twice the average level reported for Asia and was comparable to that of the Americas, the region with the highest sugar intake worldwide. These findings suggest that, despite a downward trend, Thailand continues to have one of the highest levels of sugar consumption compared with many other regions.¹⁴

During the study period, dietary energy from sugar and sweeteners decreased by 11.3%, from 490.6 to 435.4 kcal per capita per day. However, this decline largely reflects a reduction from an exceptionally high baseline rather than a shift toward an optimal level of intake. Assuming an average daily energy intake of 2,000 kcal, the estimated energy obtained from sugar accounted for approximately 22% of total daily energy intake. However, because FAOSTAT Food Balance Sheet data represent national food supply rather than actual individual free-sugar intake, this comparison with WHO recommendations should be interpreted cautiously. When considered in relation to the WHO recommendation, this level appears high; however, WHO recommends that free sugars contribute less than 10% of total energy intake, with a further reduction to below 5% providing additional health benefits.⁹ These findings indicate that Thailand continues to face a substantial gap between current sugar consumption and

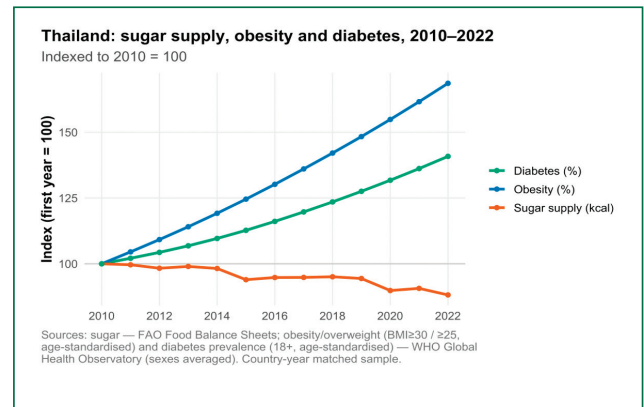


Figure 4: Relative trends in dietary energy supply from sugar, obesity prevalence, and diabetes prevalence in Thailand, 2010–2022.

public health targets. Although sugar intake has declined over time, the reduction is unlikely to be sufficient to produce measurable improvements in the population burden of obesity and diabetes. Both conditions are multifactorial non-communicable diseases influenced not only by sugar intake but also by a wide range of dietary, behavioral, and environmental risk factors.¹⁵

One possible explanation for Thailand's consistently high sugar intake is that the country is one of the world's leading sugar producers and exporters, ranking second only to Brazil.¹⁶ In addition, the Thai sugar sector has long been supported by a dedicated legal and institutional framework governing sugar production, domestic distribution, imports, and exports. This policy environment may have contributed to the stable availability of sugar for both household consumption and food manufacturing, making sugar and sugar-containing products widely available and relatively affordable to consumers.¹⁷

In addition, Thai dietary patterns may also contribute to the persistently high sugar intake. Sugar is widely incorporated not only into desserts and sugar-sweetened beverages but also into savory dishes, sauces, condiments, tea and coffee beverages, street foods, and processed foods.¹⁰ Consequently, sugar is consumed from a wide variety of food and beverage sources throughout the day rather than only from traditional sweets or sugar-sweetened beverages. This characteristic of the Thai food system and dietary culture may partly explain why reducing population-level sugar intake is more challenging than in countries where sugar consumption is concentrated in only a few food categories. These findings are consistent with the concept that the food system and food environment strongly influence dietary behaviors by determining the availability, affordability, accessibility, and promotion of foods.¹⁸

Another factor that may explain these findings is the changing food environment in Thailand. Over recent decades, the rapid expansion of processed and ultra-processed foods has altered dietary patterns, with increasing consumption of processed foods, ready-to-eat meals, and foods prepared outside the home. These products are typically high in added

sugars, fat, and energy, while remaining affordable, convenient, and widely available. As a result, people may be exposed to added sugars from a broader range of foods than in the past, contributing to persistently high sugar intake.¹⁹ While these changes in the food environment may help explain Thailand's persistently high sugar intake, they do not fully account for the increasing burden of obesity and diabetes.

Dietary energy from sugar declined steadily over the study period, whereas the prevalence of obesity and diabetes continued to rise. This contrasting temporal pattern should not be interpreted as evidence that lower sugar intake increases the risk of obesity. Instead, it reflects the multifactorial nature¹⁵ of obesity and type 2 diabetes, which are influenced by a wide range of dietary, behavioral, demographic, and environmental factors, including total energy intake, overall diet quality, consumption of ultra-processed foods, physical inactivity, sedentary behaviour, sleep, population ageing, and broader socioeconomic factors.²⁰

Furthermore, changes in disease prevalence may lag behind changes in dietary exposure because of the cumulative effects of long-term metabolic risk. Therefore, the contrasting temporal patterns observed in this ecological study are more likely to reflect multiple population-level changes occurring over time than a direct biological relationship between changes in dietary energy from sugar and disease prevalence.²¹

These findings suggest that lower sugar intake alone is unlikely to substantially reduce the burden of diet-related non-communicable diseases. A similar pattern has also been observed across several regions based on FAOSTAT food supply data and WHO Global Health Observatory estimates, where dietary sugar availability remained stable or declined while the prevalence of obesity and diabetes continued to increase, including the Americas, Africa, and Europe.

The multifactorial nature of obesity may explain this apparent paradox. Beyond sugar intake, multiple determinants including greater consumption of ultra-processed foods, excessive total energy intake, insufficient physical activity, and other lifestyle factors are likely to contribute to the continued rise in obesity and diabetes, indicating that diet-related non-communicable diseases are driven by multiple interacting factors rather than sugar intake alone.¹⁵ This interpretation aligns with the conceptual framework proposed by Turner et al.,²² who argued that effective prevention of diet-related non-communicable diseases requires interventions that extend beyond individual dietary behaviors to address the broader food environment. They further emphasized the importance of strengthening the research agenda on food environments, particularly in low- and middle-income countries, to generate context-specific evidence that can guide effective nutrition policies and public health interventions. Therefore, national-level strategies should focus not only on limiting sugar consumption but also on improving the overall food environment. This includes food reformulation, increasing access to healthier foods, and restricting the availability and marketing of energy-dense, nutrient-poor foods.

In the Thai context, the decline in dietary energy from sugar observed in this study may, at least in part, reflect the cumulative effects of public health policies implemented over the past decade. These include the introduction of the sugar-sweetened beverage tax, mandatory nutrition labeling, and the voluntary Thailand Healthier Choice Logo (THCL)²³, introduced in 2016 to promote healthier food choices. The increasing uptake of the THCL appearing on 10.7% of all food products and 39.5% of eligible products²⁴ together with policies encouraging product reformulation, may have contributed to reducing dietary sugar availability from foods and beverages available in the Thai food supply.

However, existing policies may have a limited impact if they continue to focus primarily on sugar-sweetened beverages or selected food products. In Thailand, sugar is commonly added to a wide range of foods, including savory dishes, beverages, desserts, and processed foods. Therefore, reducing population-level exposure to sugar is likely to require a broader approach that addresses the overall food environment rather than focusing solely on individual product categories. Such an approach should combine product reformulation with policies that improve access to healthier foods.

Such an approach is supported by experiences from several countries, where national-level reductions in sugar consumption have been achieved through comprehensive policy packages that combine sugar-sweetened beverage taxation, product reformulation, restrictions on the marketing of unhealthy foods and beverages to children, front-of-pack nutrition labeling, and other measures to create healthier food environments. Evidence from the United Kingdom indicates that industry-led product reformulation, together with changes in consumer purchasing behavior, contributed to reductions in the amount of sugar sold in soft drinks.²⁵ Similarly, Mexico's sugar-sweetened beverage tax was associated with a sustained reduction in purchases of taxed beverages,²⁶ while Chile's comprehensive food labeling and advertising law, introduced in 2016, combined front-of-package warning labels, restrictions on child-directed marketing, and school food policies, resulting in healthier food purchasing patterns and reduced purchases of sugar-sweetened beverages.²⁷

These international experiences also provide useful lessons for strengthening future sugar reduction policies in Thailand. Building on the national Less-Sweet Drink Policy and Campaign, the Ministry of Public Health has recently introduced a new policy initiative encouraging participating beverage vendors to redefine the default level of sweetness ("regular sweetness") to 50% of the original recipe. By changing the default option rather than relying solely on individual consumer choice, this initiative aims to modify the food environment and gradually reduce national-level preference for sweet tastes.²⁸

Given its recent implementation, the policy has not yet been formally evaluated for its impact on sugar consumption or health outcomes. Nevertheless, it represents a promising

population-based strategy that warrants systematic monitoring and evaluation. Future evaluation over the next 5–10 years should include both short-term indicators, such as changes in dietary sugar consumption, consumer acceptance of lower sweetness levels, and product reformulation by the food and beverage industry, as well as longer-term outcomes, including trends in obesity, diabetes, and other diet-related non-communicable diseases. Such outcomes are unlikely to be observed in the short term because these conditions have a relatively long latency period and are influenced by multiple interacting determinants.

Taken together, these findings highlight the need for comprehensive and sustained strategies to reduce sugar consumption at the population level.

Policy implications and recommendations

1. Continue implementing sugar reduction strategies through sustained collaboration among government agencies, the food and beverage industry, academia, and other key stakeholders. Thailand's experience with the national sodium reduction strategy demonstrates the value of multisectoral collaboration in implementing population-based nutrition policies and may provide a practical model for future sugar reduction efforts.²⁹
2. Develop a long-term sugar reformulation roadmap with progressive reduction targets, supported by a national monitoring and evaluation system. The roadmap should draw on international experience with gradual product reformulation, allowing consumers to adapt to lower sweetness levels while maintaining product acceptability.³⁰
3. The newly introduced default sweetness policy should be evaluated as a natural policy experiment through systematic monitoring of changes in dietary sugar consumption, consumer acceptance of lower sweetness levels, industry reformulation, and obesity- and nutrition-related indicators over the next 5–10 years. As diabetes and other diet-related non-communicable diseases have long latency periods and multifactorial etiologies, obesity and nutrition-related indicators should serve as intermediate outcomes for assessing

the short-term impact of sugar reduction policies, whereas diabetes and other chronic diseases should be monitored as longer-term outcomes.³¹

Strengths and limitations

This study has several limitations. First, because it was an ecological study based on population-level data, its findings may be subject to ecological fallacy. Second, dietary energy from sugar was estimated using FAOSTAT Food Balance Sheet data, which reflect national food supply rather than actual individual consumption. These estimates do not account for household food waste, retail losses, or variations in food distribution and individual dietary intake. Finally, the analyses did not adjust for important potential confounders, including overall dietary patterns, consumption of ultra-processed foods, total energy intake, physical activity, socioeconomic conditions, and other lifestyle factors that may influence obesity and diabetes. Consequently, the findings should be interpreted as national-level ecological trends rather than evidence of direct causal relationships.

Conclusion

This study demonstrated that although dietary energy from sugar and sweeteners in Thailand declined during 2010–2023, it remained more than twice the average level observed in Asia and high when considered in relation to WHO recommendations. At the same time, the prevalence of obesity and diabetes during 2010–2022 continued to rise. These findings should not be interpreted as evidence that reducing sugar intake is ineffective. Rather, they reflect the multifactorial nature of non-communicable diseases, in which obesity and diabetes are influenced by multiple dietary, behavioral, environmental, and socioeconomic determinants. Therefore, reducing sugar intake should be considered an essential component of primary prevention, but one that needs to be implemented alongside broader interventions targeting the food environment, health literacy, and lifestyle-related risk factors. These findings provide valuable baseline evidence for monitoring trends in dietary sugar intake, evaluating the effectiveness of emerging sugar reduction policies, and supporting evidence-based nutrition policy development in Thailand.

References

1. World Health Organization. Health literacy development for the prevention and control of noncommunicable diseases. Volume 4: case studies from WHO National Health Literacy Demonstration Projects. Geneva: World Health Organization; 2022.
2. Prada M, Saraiva M, Garrido MV, et al. Perceived associations between excessive sugar intake and health conditions. *Nutrients*. 2022;14(3):640. doi: 10.3390/nu14030640.
3. EFSA Panel on Dietetic Products, Nutrition and Allergies. Scientific opinion on dietary reference values for carbohydrates and dietary fibre. *EFSA J*. 2010;8(3):1462. doi: 10.2903/j.efsa.2010.1462.
4. Farhangi MA, Nikniaz L, Khodarahmi M. Sugar-sweetened beverages increase the risk of hypertension among children and adolescents: a systematic review and dose-response meta-analysis. *J Transl Med*. 2020;18(1):344. doi: 10.1186/s12967-020-02511-9.
5. Stanhope KL, Schwarz JM, Havel PJ. Adverse metabolic effects of dietary fructose: results from recent epidemiological, clinical, and mechanistic studies. *Curr Opin Lipidol*. 2013;24(3):198-206. doi: 10.1097/MOL.0b013e3283613bca.

6. Deshpande G, Mapanga RF, Essop MF. Frequent sugar-sweetened beverage consumption and the onset of cardiometabolic diseases: cause for concern? *J Endocr Soc.* 2017;1(11):1372-85. doi: 10.1210/js.2017-00151.
7. Wickramasinghe K, Williams J, Rakovac I, et al. Key messages of the WHO European Regional Obesity Report. *Eur J Public Health.* 2022;32(Suppl 3):ckac129.354. doi: 10.1093/eurpub/ckac129.354.
8. Chandrasekaran P, Weiskirchen R. The role of obesity in type 2 diabetes mellitus—an overview. *Int J Mol Sci.* 2024;25(3):1882. doi: 10.3390/ijms25031882.
9. World Health Organization. Guideline: sugars intake for adults and children. Geneva: World Health Organization; 2015.
10. Kriengsinyos W, Chan P, Amarra MSV. Consumption and sources of added sugar in Thailand: a review. *Asia Pac J Clin Nutr.* 2018;27(2):262-83. doi: 10.6133/apjcn.042017.08.
11. Weeratunga P, Jayasinghe S, Perera Y, et al. Per capita sugar consumption and prevalence of diabetes mellitus—global and regional associations. *BMC Public Health.* 2014;14:186. doi: 10.1186/1471-2458-14-186.
12. Muangsri K, Tokaew W, Sridee S, et al. Health communication to reduce sugar consumption in Thailand. *Funct Foods Health Dis.* 2021;11(10):484-98. doi: 10.31989/ffhd.v11i10.833.
13. World Health Organization. Global Health Observatory: noncommunicable diseases—risk factors and conditions [Internet]. Geneva: World Health Organization; [cited 2026 May 5]. Available from: <https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/ncd-risk-factors>
14. Food and Agriculture Organization of the United Nations. FAOSTAT: Food Balances (2010–2023) [Internet]. Rome: Food and Agriculture Organization of the United Nations; 2025 [cited 2026 May 5]. Available from: <https://www.fao.org/faostat/en/#data/FBS>
15. Młynarska E, Bojdo K, Bulicz A, et al. Obesity as a multifactorial chronic disease: molecular mechanisms, systemic impact, and emerging digital interventions. *Curr Issues Mol Biol.* 2025;47(10):787. doi: 10.3390/cimb47100787.
16. Organisation for Economic Co-operation and Development, Food and Agriculture Organization of the United Nations. OECD-FAO agricultural outlook 2020–2029. Paris: OECD Publishing; 2020. doi: 10.1787/1112c23b-en.
17. Thailand. Sugar Cane and Sugar Act, B.E. 2527 (1984). Royal Thai Government Gazette; 1984.
18. Swinburn BA, Sacks G, Hall KD, et al. The global obesity pandemic: shaped by global drivers and local environments. *Lancet.* 2011;378(9793):804-14. doi: 10.1016/S0140-6736(11)60813-1.
19. Bhadrakom C. Trends in dietary patterns and consumer policies in Thailand [Internet]. Taipei: Food and Fertilizer Technology Center for the Asian and Pacific Region; 2018 [cited 2026 May 5]. Available from: <https://ap.ffc.org.tw/article/1317>
20. Ahmed SK, Mohammed RA. Obesity: prevalence, causes, consequences, management, preventive strategies and future research directions. *Metabol Open.* 2025;27:100375. doi: 10.1016/j.metop.2025.100375.
21. World Health Organization Regional Office for Europe. WHO European Regional Obesity Report 2022. Copenhagen: WHO Regional Office for Europe; 2022.
22. Turner C, Aggarwal A, Walls H, et al. Concepts and critical perspectives for food environment research: a global framework with implications for action in low- and middle-income countries. *Glob Food Sec.* 2018;18:93-101. doi: 10.1016/j.gfs.2018.08.003.
23. Nguyen Ngoc H, Ditmetharoj M, Rojroongwasinkul N, et al. Assessing the healthfulness of pre-packaged beverages and investigating sugar thresholds for revising front-of-pack labels: a case study in Thailand. *Front Nutr.* 2025;12:1564216. doi: 10.3389/fnut.2025.1564216.
24. Nguyen Ngoc H, Photi J, Tangsuphoom N, et al. Uptake of front-of-package nutrition labeling scheme after 5 years of adoption in Thailand: an analysis of newly launched pre-packaged food and beverage products. *Nutrients.* 2023;15(14):3116. doi: 10.3390/nu15143116.
25. Bandy LK, Scarborough P, Harrington RA, et al. Reductions in sugar sales from soft drinks in the UK from 2015 to 2018. *BMC Med.* 2020;18(1):20. doi: 10.1186/s12916-019-1477-4.
26. Colchero MA, Rivera-Dommarco J, Popkin BM, et al. In Mexico, evidence of sustained consumer response two years after implementing a sugar-sweetened beverage tax. *Health Aff (Millwood).* 2017;36(3):564-71. doi: 10.1377/hlthaff.2016.1231.
27. Taillie LS, Reyes M, Colchero MA, et al. An evaluation of Chile's Law of Food Labeling and Advertising on sugar-sweetened beverage purchases from 2015 to 2017: a before-and-after study. *PLoS Med.* 2020;17(2):e1003015. doi: 10.1371/journal.pmed.1003015.
28. Chotivichien S, Rungtrakun L, Reanraengklin S, et al. Less-sweet drink policy and campaign—Thailand's success story. *Lancet Reg Health Southeast Asia.* 2025;38:100620. doi: 10.1016/j.lansea.2025.100620.
29. Kantachuvesiri S, Chailimpamontree W, Kunjang A, et al. Mobilizing champions for sodium reduction in Thailand. *Lancet Reg Health Southeast Asia.* 2024;26:100406. doi: 10.1016/j.lansea.2024.100406.
30. Hawkes C, Smith TG, Jewell J, et al. Smart food policies for obesity prevention. *Lancet.* 2015;385(9985):2410-21. doi: 10.1016/S0140-6736(14)61745-1.
31. Freudenberg N, Franzosa E, Sohler N, et al. The state of evaluation research on food policies to reduce obesity and diabetes among adults in the United States, 2000–2011. *Prev Chronic Dis.* 2015;12:E182. doi: 10.5888/pcd12.150237.