Review Article

Consumption and sources of added sugar in Thailand: a review

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Background and Objectives: The present review examined the best available evidence regarding consumption levels and sources of added sugar in different population groups in Thailand. **Methods and Study Design:** Information was extracted from food balance sheets, household expenditure surveys, food consumption surveys, government reports, published and unpublished studies. **Results:** A total of 24 references were obtained, comprising 8 nationally representative reports and 16 individual studies. Results were inconsistent. The National Statistical Office reported an available supply of 83 g sugar per capita per day in 2010. The 2009 Food Consumption Survey of Thai Population showed median intake of sugar and sweeteners for all age groups ranging from 2.0 to 20.0 g per day among males and from 2.0 to 15.7 g per day among females (below the Thai recommendation of 40 to 55 g/day). Studies on children suggested intake levels between 25 to 50 g/day, while studies on adults were inconsistent. Frequently consumed sources were table sugar, sweetened beverages, and sweet snacks (traditional desserts, baked products, crispy snacks). **Conclusions:** Insufficient evidence exists regarding intake levels and sources of added sugar in Thailand. Limitations were the use of food frequency questionnaires or a single 24-h recall to assess intake, and outdated studies with small sample sizes. An updated nationally representative survey using improved methods is needed to determine the levels and sources of sugar intake in different population groups. These include biomarkers to establish levels of consumption and multiple 24-h recalls (at least two) to identify food sources that contribute significantly to excess sugar intake.

Key Words: sugar, processed foods, diet, Thailand, nutrient intake

INTRODUCTION

Traditional Southeast Asian diets are composed of roughly 70-80% carbohydrates, mostly from cereals mainly rice, and tubers.[1] However, development and urbanization have resulted in a nutritional transition characterized by a shift away from traditional diets towards an industrialized diet that includes both processed western foods as well as traditional foods with more added sugars and fat.[2] This transition in conjunction with reduced physical activity has contributed to a rapid increase in the prevalence of overweight and obesity in Asia.[3,4]

Obesity is now considered a serious health problem in Thailand.[5] The 2009 National Health Examination Survey showed that, among adults aged 20 and over, prevalence of overweight (BMI 23-24.9 kg/m^2), obesity class I (BMI 25-29.9 kg/m^2), and obesity class II (BMI ≥30 kg/m^2) were 17.5%, 26.0%, and 9.0%, respectively.[6] BMI increased by an average of 0.95 kg/m^2 from 1991 to 2009, one of the highest rates of increase in Southeast Asia. The average increase in BMI per decade was 0.8 kg/m^2 in men and 0.9 kg/m^2 in women.[6] Excessive waist circumference, based on waist-to-height ratio (WHR),[7] was shown to be a better indicator of centralized obesity and cardiometabolic risk among Asians than BMI[8-10] (cut-off com- puted as half of an individual's height). Excess WHR was found in 18.6% of males and 45.0% of females.[11] Among children, surveys by the Ministry of Public Health showed that overweight and obesity rose continuously from 1995 to 2009. In 2009, the prevalence of overweight and obesity was 8.5% among preschool children and 9.7% among primary schoolchildren aged 6 to 14 years.[11] Co-morbidities associated with overweight and obesity that have been observed in the Thai population (both adults and children) include metabolic syndrome and insulin resistance,[12-17] abnormal renal function (microalbuminuria) and chronic kidney disease,[18-20] type 2 diabetes mellitus,[17,21,22] cardiovascular risk factors including high blood pressure and dyslipidemia,[22-27] increased risk of breast cancer among women,[28] and dental caries in children.[29] Among pregnant women, pre-pregnancy overweight and obesity increased the risk for thyroid dysfunction, gestational hypertension, caesarean section, pre-eclampsia and diabetes mellitus.[30-32]

Increased intake of sugars and sweet foods is seen as a

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major factor contributing to excess weight and obesity.[33,34] The term "sugars" is conventionally used to describe the mono- and disaccharides.[35] Glucose and fructose are the most common dietary monosaccharides, while sucrose or table sugar (50% glucose, 50% fructose) is the most common disaccharide. WHO uses the term "free sugars" to refer to all monosaccharides and disaccharides added to foods by the manufacturer, cook or consumer, plus sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates.[36] The American Heart Association (AHA) uses the term "added sugars" to refer to sugars and syrup added to foods during processing or preparation, and sugars and syrups added at the table.[37]

Names for added sugars on food labels[38] include anhydrous dextrose, brown sugar, confectioner's powdered sugar, corn syrup, corn syrup solids. dextrose, fructose, high fructose corn syrup, honey, invert sugar, malt syrup, maltose, molasses, nectars (e.g., peach nectar, pear nectar), raw sugar, sucrose, white sugar, granulated sugar. Other names are cane juice, evaporated corn sweetener, fruit juice concentrate, crystal dextrose, glucose, liquid fructose, sugar cane juice, cane crystals, and fruit nectar.[38] In the US, the major food and beverage sources for added sugars are regular soft drinks, energy drinks and sports drinks, candy, cakes, cookies, pies and cobblers, sweet rolls, pastries, donuts, fruit drinks such as fruitades and fruit punch, dairy desserts such as ice cream.[38]

In its latest guideline for sugars intake,[36] WHO strongly recommended a reduced intake of free sugars throughout the life course, preferably less than 10% of total energy intake. On a 2000 calorie diet, this would translate into 50 g sugar per day. It also recommended further reduction of free sugars to below 5% (i.e., 25 g) of total energy intake (conditional recommendation) to minimize lifelong risk of dental caries.

WHO recommends reduction in sugar intake to halt the increasing prevalence of obesity and diabetes worldwide.[39] Data on diabetes in Thailand from the National Health Examination Survey (NHES) showed that the prevalence of type 2 diabetes in individuals aged 15 and over has increased continuously –i.e., 2.3% in 1991, 4.6% in 1997, 6.8% in 2005, to 6.9% in 2009. A recent news report[40] stated that 10.1% and 3.4% of Thais aged 45 to 59 and 30 to 44 years, respectively, are afflicted with diabetes but that half of these people are unaware of their condition. Type 2 diabetes is a lifestyle-associated disease, and given the magnitude of the problem in Thailand, it is important to develop preventive dietary interventions. Accurate knowledge regarding the levels and sources of added sugars in the diet is a first step for planning cost-effective and targeted actions.

The objectives of this review are to 1) summarize the best available information regarding levels of consumption of 'free' or 'added' sugars in Thailand, (expressed as gm/day and kcal/day), 2) identify the percentage contribution of added sugar to total energy and carbohydrate intakes of different population groups, 3) identify major food sources of added sugar including those frequently consumed, and 4) identify gaps and provide recommendations for future research.

METHODS

Search strategy

Information on levels of sugar consumption and sources of added sugar in Thailand was extracted from food balance sheets, household expenditure surveys, nutrition surveys, and national survey reports regarding food consumption, available in government and organization websites. An additional search for published research papers that included food consumption and dietary intake as a study variable was conducted on PubMed and Google. Search terms used were: sugar, added sugar, diet, food habits, dental caries, obesity, diabetes, food security, food consumption, processed foods, Thailand. Local journals, hard copies of government reports, and unpublished theses were hand searched. There were no language restrictions; findings from studies and reports in the local language were translated into English. Since the study used published materials, ethics approval was not required.

Inclusion criteria

Studies were included if they 1) examined eating habits, food consumption, and/or dietary patterns among different age and population groups; 2) examined subjects' intake of sugar and/or sweetened foods in terms of quantities and/or frequencies of consumption; 3) covered the period January 2001 to November 2014; 4) were conducted among non-institutionalized free-living populations. The characteristics of studies included in the review are shown in Table 1. Sources were few, and all available sources of primary data that conformed to the above criteria were included.

Exclusion criteria

Studies were excluded if they were conducted among populations with congenital disorders and those with some form of physical or mental disability.

Extraction of data

In studies that provided information on frequencies of consumption, proportions of subjects expressed as whole numbers were converted into percentages of the total population examined, to provide a standard picture of the population consuming foods with added sugar at different frequencies. For FAO food balance sheet data, the percentage contribution of sugar and sweeteners to total energy was estimated by dividing the calories from sugar and sweeteners by the total amount of calories available during the same period. In studies where information on total sugar intake was given, the caloric equivalent of 4 kcal/g sugar was used to convert the amount of sugar consumed into energy.

Sources of information on sugar consumption

As described in a previous paper,[41] food balance sheets (FBS) describe the amount of food available in a country for consumption. All food items are converted into nutrients (energy) available for consumption. Food balance is typically calculated by taking into account the quantity of foodstuffs produced in a country, added to the quantity imported and adjusted for any changes in stocks that have

Table 1. Characteristics of studies included in the review

Type of data	Author (year published)	Sampling method	Age in years (sample size)	Method of measurement	Level of added sugar intake identified	Sources of added sugars identified
National level data	FAO Food Balance Sheet (2015)[44]	---	N/A	Per capita supply of sugar and sweeteners available for consumption (kcal/capita/day)	Yes	No
	National Statistical Office, The 2013 Survey on Food Consumption Behavior (2014)[58]	---	N/A (26,520 households)	Food frequency questionnaire	No	Yes
	National Statistical Office and Office of Agricultural Economics of the Kingdom of Thailand, Food Security and Nutrition Status in Thailand 2005-2011 (2013)[45] AND National Statistical Office and Office of Agricultural Economics of the Kingdom of Thailand. Food insecurity assessment at national and subnational levels in Thailand (2012)[46]	Stratified two-stage sampling	N/A (52,000 households)	Household food expenditure and food balance sheet data	Yes	Yes
	Aekplakorn W. Food Consumption Survey of Thai Population, the Fourth National Health Examination Survey, Thailand 2009 (2011)[48]	Multi-stage cluster sampling	1 to >80 y (n=2969; 1467 males, 1502 females)	24-h recall	Yes	Yes
	National Bureau of Agricultural Commodity and Food Standards, Food consumption data of Thailand 2007-2010 (2010)[47]	Multi-stage cluster sampling stratified by region	0 to >65 y (n=18,746)	Semiquantitative food frequency questionnaire	Yes	Yes
	Lim et al (2009)[59]	National cohort of Thai adults (SukothaiThammithirat Open University students)	15-87 y (n=59,283)	Food frequency questionnaire for sugar-sweetened beverage (SSB) consumption	No	Yes
	Office of the Cane and Sugar Board (OCSB), Ministry of Industry, Thailand (2010)[49]	---	N/A	Utilization of sugar by food industries and by consumers (direct and indirect consumption)	No	Yes

--- Not specified; N/A – not applicable

Table 1. Characteristics of studies included in the review (cont.)

Type of data	Author (year published)	Sampling method	Age in years (sample size)	Method of measurement	Level of added sugar intake identified	Sources of added sugars identified
Individual studies						
Children	Peltzer et al (2014)[29]	Subsample from a prospective cohort study of Thai children (PCTC)	24-36 months (n=783) in Mueang Nan district, Northern Thailand	Interviewer-administered questionnaire on feeding practices by parents or caregivers	No	Yes
	Kongnoo et al (2014)[62]	---	3-12 y (n=116,201) in 538 schools from 9 provinces in 4 regions	---	No	Yes
	Krisdapong et al (2013)[64]	Stratified multi-stage sample selected from the 6th Thailand National Oral Health Survey	12 y (n=1100) 15 y (n=871)	Self-administered questionnaire on frequency of crispy packeted (sweet) snacks and fizzy drinks consumption	No	Yes
	Lueangpiansamut et al (2012)[65]	---	11-12 y (n=111) grades 4 to 6 from Nongbua Khamsaen school, Nongbua Lampoo province	Questionnaire on frequency of consumption of foods and drinks	No	Yes
	Thammasorn et al (2009)[53]	Stratified random sampling	--- 5th and 6th grade students from 9 schools in Rongkwang district, Phrae province (n=320)	Questionnaire on snack/sweet beverage consumption	Yes	Yes
	Korwanich et al (2008)[60]	Multistage sampling	4-5 y (n=219; control=43 boys, 41 girls; intervention=68 boys, 67 girls) in Phrae province	Food frequency questionnaire	No	Yes
	Prasertsom et al (2007)[54]	Convenient sampling method from 24 provinces of Thailand	3-12 y (n=5,764)	24-h recall	Yes	Yes
	Klunklin & Channoonmuang (2006)[61]	Two-stage sampling	2-6 y (n=170; 85=normal, 85=undernourished) in 18 rural villages, Roi-ed province	5-day food record	No	Yes
	Naini et al (2006)[55]	Stratified random sampling	10-12 y (n=85; 52 boys, 33 girls) in NakhonPathon province	Food frequency questionnaire that included 103 food items; questionnaire on food habits and eating behaviour	Yes	No
	Hiranras (2006)[51]	Purposive	3-5 y (n=205)	Parental interview using a questionnaire	Yes	Yes
	Wongkongkathep et al (2005)[52]	Purposive	Under 5 y (n=4556)	Parental interview using a questionnaire (35 items)	Yes	Yes

--- Not specified; N/A – not applicable

Table 1. Characteristics of studies included in the review (cont.)

Type of data	Author (year published)	Sampling method	Age in years (sample size)	Method of measurement	Level of added sugar intake identified	Sources of added sugars identified
Children						
	Chitchang et al (2004)[63]	Stratified random sampling from 6 provinces of Thailand	3-15 y (n=311)	24-h recall	Yes	Yes
	Yongvanichakorn & Junbang (2003)[66]	Convenience sampling	Primary school children	Data based on 486 discarded purchased food wrappings	No	Yes
	Petersen et al (2001)[67]	Random sample of 6- and 12-yr old children from urban and rural schools from 19 districts of one province	Grade 6 age 12 y (n=1084)	Structured interview concerning oral health behaviour	No	Yes
Adults	Promdee et al (2007)[56]	Purposive	18-22 y (n=202) 164 women, 38 men	3-day food record; enzymatic analysis of sucrose content of sweetened items consumed	Yes	Yes
	Piammongkol et al (2004)[57]	Random sampling	Pregnant women from 57 health centres in five Amphurs in Southern Thailand (n=166)	Modified food frequency questionnaire	Yes	No

--- Not specified; N/A – not applicable

occurred.[35] FBSs describe the consumption of foods or nutrients per capita of the population for a country, but do not represent food actually consumed. This is because they do not take into account waste or losses at a variety of levels, including the home. The advantage is that FBSs are readily available and regularly updated.[35]

National household expenditure surveys (HES) evaluate the consumption and welfare of a country's population.[42] While the main focus of these surveys has been on measuring households' total monetary expenditures as a proxy for income, the surveys also collect data on other aspects of people's well-being, such as education, housing, health, and food consumption. Food data collected in HESs reflect the quantity of food "acquired" by a household, including their food purchases, foods consumed from their own farms or gardens, and foods received in kind. Estimated quantities, expressed in metric units, serve as the basis for calculating indicators of food security such as diet quantity and diet quality.[43]

Nutrition surveys represent the best way to assess food actually consumed. However, many developing countries may not have the resources to mount large nutrition surveys.[35] In such cases, small studies done on specific groups serve as the main sources of information on individual intakes.[35]

FBS-based estimates of consumption are low-cost and easily available but imprecise. Individual food consumption data from national surveys are the most precise estimates of intake but are costly, making this type of data less available. HESs are collected regularly by most countries and provide a less costly third option. Values obtained from food consumption surveys are considered the most precise, followed by HES and lastly, FBS data.[43]

RESULTS

A total of 24 studies were included in the review – 8 were national level reports, 16 were individual studies. Table 1 shows the characteristics of the included studies.

Level of sugar consumption

Table 2 summarizes the results on levels of sugar consumption from FAO food balance sheet, nationwide surveys and reports, and individual studies. Nationwide food consumption surveys suggested low levels of intake that fell within WHO recommendations while individual studies (mostly among children) suggested higher levels of intake exceeding recommendations.

National level data

Per capita intakes based on FAO food balance sheet and nationwide surveys/reports

1) FAO Food Balance Sheet data[44]
   FAO food balance sheet data show that from 2007 to 2011, total available per capita calories from sugar (including sugar crops comprising cane and beet sugar, and sugar and sweeteners comprising raw sugar, honey, other sweeteners) increased from 396 kcal/day in 2007 (approximately 99 g/day) to 431 kcal/day (approximately 108 g/day) in 2011. This amount contributed 14.3 and 15.6 %, respectively, of total available calories per capita per day for these two periods.
2) Food Security and Nutrition Status in Thailand 2005-2011[45,46]
   The report analysed the food security situation in Thailand using food balance sheet data to assess the supply and utilization of food, and data from the 2011 Thailand Household Socio Economic Survey (THSES) to derive food security indicators at the national and sub-national levels. From 2005 to 2010, the amount of sugar & sweeteners available for consumption increased from 32 to 34 kg/person/year (i.e., 88 to 93 g/person/day), providing 313 and 333 kcal/person/day, respectively and contributing approximately 11% of per capita energy in 2010.
3) Food consumption data of Thailand 2007-2010, National Bureau of Agricultural Commodity and Food Standards, Thailand[47]
   The first national food consumption survey conducted in 2004 included 18,746 respondents aged 0 to >65 years. Average per capita sugar intake (including added sugar and sugar from sweetened food and beverage) was 22.9 g/day. Individuals who actually consumed sugar (eaters) ingested as much as 216.9 g/day.

Sugar consumption of different age groups from Food Consumption Survey of Thai Population, the Fourth National Health Examination Survey, Thailand 2009[48]

The 2009 Food Consumption Survey examined the intake of all types of sugars including honey among different age and sex groups, using a single 24-h recall.

Children aged 1-12 years. Sugar consumption increased with increasing age. Children aged 9 to 12 years had higher median intakes (7.8 and 10.0 g/day for males and females, respectively) than those in younger age groups.

Adolescents aged 13-18 years. Male adolescents aged 16 to 18 years consumed more sugar than other groups (median intake of 20 g/day).

Adults aged 19-59 years. Median sugar intake among adults ranged from 8.0 to 15.7 g/day, with females aged 51 to 59 years having the highest intake.

Consumption based on sugar utilization, Office of the Cane and Sugar Board (OCSB), Ministry of Industry Thailand[49,50]

Thailand's sugar industry uses two categories to classify sugar utilization: direct (i.e., refined table sugar) and indirect consumption (i.e., used as an ingredient in food products).[49]

From 2003 to 2010, the proportion of sugar as an ingredient in food products (indirect consumption) decreased slightly from 1.3 to 1.2%, while direct consumption increased slightly from 0.6 to 1.0%, respectively (Figure 1).[50]

Individual studies

Studies on children

a. Preschool children

Hiranras[51] examined the amount of daily sugar consumption among 205 preschool children aged 3 to 5 years in the paediatrics outpatient department of King Chulalongkorn Memorial Hospital using a parental interview questionnaire. Average sugar consumption was 41.3±24.1 g/day, with 90% of children consuming more

Table 2. Findings on level of sugar consumption in Thailand

Type of data	Source	Year	Age group examined (years)	Estimated level of sugar intake				Estimated percentage contribution of sugar to energy intake (%)
National level data	FAO Food Balance Sheet[44]	2011	N/A (per capita)	431 kcal available from sugar and sweeteners/capita/day (approximately 108 g sugar/day)				15.6%
	Food Consumption Survey of Thai Population, the Fourth National Health Examination Survey, Thailand 2009 [48]	2011	1 to >80 y	Consumption of all types of sugars (g/day) including honey by age and sex				Percentage contribution to total energy intake (male, female)
				N	Males (Median, Mean±SD)	N	Females (Median, Mean±SD)	
			1-3	69	2.0, 6.9±11.2	55	2.0, 5.1±8.9	2.7%, 2.2%
			4-5	69	4.0, 11.9±19.6	63	4.0, 8.4±13.8	4.0%, 3.0%
			6-8	101	6.2, 11.8±17.2	91	7.8, 20.3±32.9	3.6%, 6.5%
			9-12	159	7.8, 19.5±36.6	196	10.0, 19.5±27.6	5.7%, 5.9%
			13-15	86	10.3, 17.5±22.1	84	8.7, 19.2±26.4	4.3%, 6.2%
			16-18	43	20.0, 25.6±30.7	34	9.8, 18.3±21.3	5.7%, 5.8%
			19-30	72	14.7, 18.2±18.1	55	12.6, 19.1±22.7	4.7%, 6.2%
			31-50	248	12.0, 19.4±22.3	313	12.0, 20.9±25.9	4.7%, 6.4%
			51-59	132	10.0, 18.9±27.6	115	15.7, 24.7±30.3	4.8%, 7.6%
			60-69	287	11.0, 16.8±20.5	274	7.8, 14.0±9.6	4.9%, 5.4%
			70-79	160	10.5, 17.1±19.5	179	10.0, 17.4±26.6	5.5%, 6.9%
			>80	41	8.0, 16.9±20.6	43	10.0, 19.2±25.2	5.6%, 8.3%
	Food consumption data of Thailand 2007-2010[47]	2010	0 to >65 y	Mean per capita intake=22.9 g sugar/day Mean per *eater* intake=53 g sugar/day				---
	Food security and nutrition status in Thailand, National Statistical Office and Office of Agricultural Economics of the Kingdom of Thailand[45,46]	2013; 2012	N/A (per capita)	333 kcal available from sugar and sweeteners/capita/day (approximately 83 g sugar/day)				10.7%
	Ministry of Industry, Office of the Cane and Sugar Board[49]	2010	N/A	Proportion of sugar consumed - direct consumption 0.98% - indirect consumption 1.17%				---

--- Not indicated; N/A - not applicable.
[†]Computed from mean total calories per day.

Table 2. Findings on level of sugar consumption in Thailand (cont.)

Type of data	Source	Year	Age group examined (years)	Estimated level of sugar intake	Estimated percentage contribution of sugar to energy intake (%)
Individual studies					
Children	Thammasorn et al[53]	2009	5th and 6th grade students, mostly 12 y old	71.25% of students consumed sugar in school at a level >12 g/day Median sugar consumption in school was 19.11 g/day (approx. 5 tsp/day)	---
	Prasertsom et al[54]	2007	3-12 y	Mean sugar intake from beverages ranged from 26 to 30 g within a single school day	---
	Hiranras[51]	2006	3-5 y	Average daily sugar consumption=41.3±24.1 g/day; 90% of children have sugar intake >16 g/day or >4 teaspoons/day	---
	Naini et al[55]	2006	10-12 y	Sugar consumption was 1.2 kg/month (approximately 40 g/day)	---
	Wongkongkathep et al[52]	2005	Under 5 y	Average sugar consumed in snacks and drinks=30.4 g/day - 49.1% of children had sugar intake >24 g/day - 28.6% of children had sugar intake >40 g/day	---
Adults	Promdee et al.[56]	2007	17-29 y	Mean sucrose intake -Males=72±37 g/day (288 kcal/day; approx.. 18 tsp sucrose) - Females=68±39 g/day (282 kcal/day; approx. 17 tsp sucrose) - Both sexes=69±38 g/day (276 kcal/day; approx. 17 tsp sucrose)	---
	Piammongkol et al.[57]	2004	Adult pregnant women in third trimester	Sugar intake=27.8±21.9 g/day	8.6% †

--- Not indicated; N/A - not applicable.
†Computed from mean total calories per day.

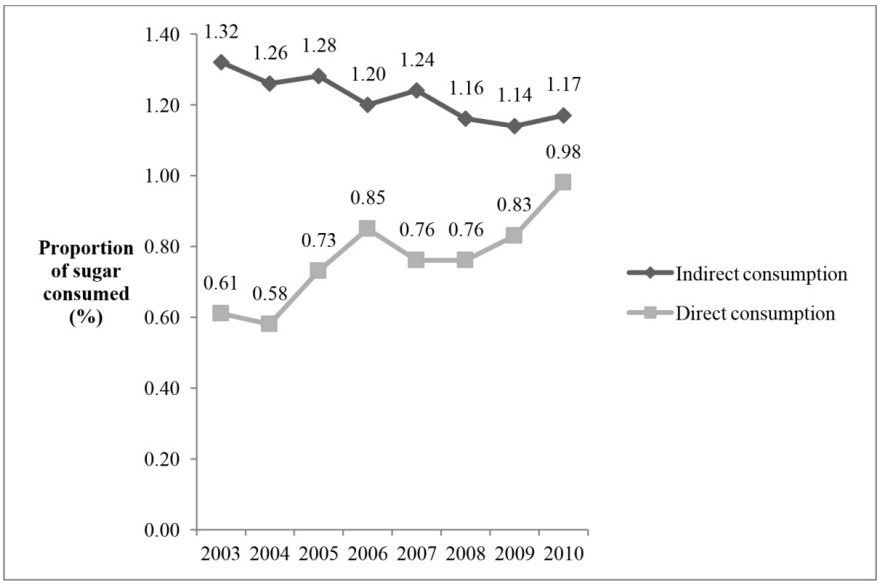

Figure 1. Proportion of direct and indirect sugar consumption, Thailand 2003-2010 50. Indirect consumption – sugar used as an ingredient in food products, direct consumption – refined table sugar.

than 16 g (4 teaspoons)/day. Wongkongkathep et al[52] examined the sweet food consumption behaviour of children below 5 years in relation to dental caries and obesity. The average sugar content in snacks and drinks consumed by children was 30.4 g/day. Forty-nine percent of children exceeded the recommended <24 g sugar/day, and 28.6% consumed more than 40 g/day.

b. School children

Two studies examined the level of sugar consumption within the school environment. Data from 320 students in 5th and 6th grades of 9 primary schools showed that 71.3% of students consumed >12 g/day sugar in school, with an average median consumption of 19.1 g/day.[53] The other study[54] surveyed snack and beverage consumption in children aged 3-12 years (preschool to sixth grade) using sugar content information from package labels. The average amount of sugars from beverages consumed by children ranged from 26 to 30 g per day. Naini et.al.'s[55] study on food habits of obese and normal weight schoolchildren aged 10-12 years in Nakhon Pathom Province showed that sugar consumption was approximately 1.2 kg/month (40 g/day) for both normal weight and obese subjects.

Studies on adults

Studies among adults showed varying results. Promdee et al[56] examined the amount of added sucrose consumed by undergraduate students at Khon Kaen University, using 3-day food records. Enzymatic analysis of sucrose in each type of sweetened food was undertaken. Average amount of sucrose consumption per day was calculated, based on sucrose content of the foods examined and corresponding amounts ingested. Results showed an average sucrose (from sweetened processed foods) consumption of 69±38 g/day for both sexes, (72±37 g for males, 68±39 g for females), ranging from 4 to 182 g/day. Average daily energy intake derived from sucrose was 276 kcal/person/day, translating into an average of 17 teaspoons sucrose/day, but does not include corn syrup, honey, other sweeteners. Investigators concluded that actual intake of added sugars is likely to be higher than that found in the study. Piammongkol et al's[57] study on food consumption patterns of Thai-Muslim pregnant women showed that mean daily consumption of sugar was 27.8±21.9 g/day, contributing approximately 8.6% of total daily calories.

Sugar as percentage of carbohydrate intake

The Food Security and Nutrition Status in Thailand 2005-2011 report[45] showed that, from 2005 to 2010, per capita consumption of carbohydrates increased from 518 to 589 g/capita/day. In the same period, per capita sugar intake increased from 78 to 83 g/capita/day (Table 3). However, the corresponding contribution of sugar to carbohydrate intake decreased slightly from 15% to 14%, indicating that consumption of other carbohydrate foods increased to a much larger extent than that of sugar. A study among Thai-Muslim pregnant women showed that sugar contributed approximately 12.2% of total carbohydrate intake.[57]

Sources of added sugar

Table 4 summarizes the sources of added sugar from nationwide surveys and individual studies. Both types of studies suggest that common food sources in all age groups were sweetened drinks, Thai desserts, table sugar, and confectionery. Among children, additional sources were sweetened crispy snacks, sweetened milk and milk products.

National level data

1) The 2013 Survey on Food Consumption Behavior[58]
   The survey was conducted by the National Statistical Office to examine food consumption behaviour in 26,520 households. The following foods were consumed weekly by the population aged 6 years and over: sweet non-alcohol drinks (63.6%), soft drinks (58.3%), snacks (49.3%), while the following foods were consumed daily: sweet non-alcohol drinks (25.6%), soft drinks (6.5%), snacks (6.9%).

Table 3. Estimated contribution of sugars to per capita carbohydrate intake/day

Year	Carbohydrate intake (g/person/day)	Estimated sugar intake per person/day,† and its estimated % of carbohydrate intake [gm sugar/person/day (% of carbohydrate intake)]
Food balance data[45]		
2005	518	78 (15.1%)
2006	537	89 (16.5%)
2007	527	79 (15.0%)
2008	523	81 (15.4%)
2009	534	71 (13.3%)
2010	589	83 (14.3%)
Piammongkol et al, 2004[57]	227.10	27.8 (12.2%)

†Computed as (dietary energy supply (kcal/person/day) from sugar & sweeteners and sugar crops shown in food balance sheet data ÷ 4 kcal/g sugar).

2) National cohort of Thai adults[59]
Lim et al[59] used data from 59,283 adult Sukothai Thammithirat Open University students residing throughout Thailand to examine consumption frequency of sugar sweetened beverages (SSBs defined as soda or carbonated sweetened beverages without distinguishing from diet soft drinks). Approximately 40% of males and 31% of females consumed SSBs on a weekly basis. Five percent of adults (both sexes) consumed SSBs once a day or more, while 11% (14% males, 10% females) consumed these beverages 3 to 6 times/week.

3) Food Security and Nutrition Status in Thailand 2005-2011[45,46]
The Thailand Household Socio-economic Survey (THSES) collects food data within 14 categories (e.g., beef fresh meat, beef dried meat, tomatoes, etc.) including home-cooked items such as rice. In 2011, data from 52,000 households showed that sweetened foods providing the greatest amount of calories per capita were Thai desserts, white sugar, baked desserts/cake, followed by soft drinks and Milo/cocoa.

4) Food Consumption Survey of Thai Population, the Fourth National Health Examination Survey, Thailand 2009[48]
Children aged 2 to14 years reported daily consumption of the following foods: candy and chocolate (19.2%), carbonated beverage (15.3%), ice cream (14.4%), while consumption almost everyday of these same foods was reported by 15.5%, 18.2% and 15.8%, respectively. For individuals aged 15 years and above, consumption of carbonated beverage everyday and almost everyday was reported by 7.9% and 8.3%, respectively.

5) Food consumption data of Thailand 2007-2010, National Bureau of Agricultural Commodity and Food Standards, Thailand[47]
The first national food consumption survey reported that 73.5% of respondents aged 3 to 65 years added white sugar to foods and the following proportions consumed sweetened foods: sweetened beverages (51.6%), sweet condensed milk (45.4%), all types of ice cream (44.3%), jam and jelly (34.4%), honey (21.1%).

6) Thailand's Sugar Industry in 2007, Office of the Cane and Sugar Board (OCSB), Ministry of Industry Thailand[49]
Food products accounting for indirect consumption of sugar in 2007 were processed food/canned fruits and juices (51%), beverages (34%), others (11%), and candies (3%). Sugar used in processed food accounted for 69% of utilization while direct consumption of refined sugar (table sugar) accounted for 31% of utilization.

Individual studies

Studies on children

a. Infants and preschoolers

Peltzer et al[29] used data from a prospective cohort in Northern Thailand to investigate risk factors for caries increment among 783 children aged 24 to 36 months. Data showed that 47.6% of mothers introduced softdrinks at 6-12 months. At 30 months, 78.3% gave their children sweet candy 0-2 times a week, and 21.7% gave sweet candy 3-7 times a week. Korwanich et al[60] evaluated the effects of a healthy eating policy on 219 preschool children's snack intakes in Phrae Province using a 3-day dietary record. Baseline data showed that cariogenic snacks (i.e., sweets, cake and bread with sugar, confectionery, peanuts with coated flavors and sugar, crispy snacks with sugar, sugary drinks, Thai desserts) were the most frequently consumed type of snacks. Klunklin and Channoonmuang[61] examined the pattern of snack consumption among 170 preschool children (85 normal, 85 undernourished) aged 2 to 6 years living in 18 rural villages, using 5-day food records. The most common snack consumed by children (21 g/day) was a crispy snack. This was followed by beverages (11.1 g/day) and desserts (6.3 g/day). Hiranras' study[51] among pediatric outpatients aged 3 to 5 years showed that the amount of added sugar ingested from sweetened and chocolate milk was 10.8±7.9 g/day.

b. School children

Kongnoo et al[62] examined food consumption behavior among school children aged 3 to 12 years participating in school lunch programs in 538 schools from 9 provinces. In 2013, 42.7% of participating school children drank sweetened beverages (down from 54.1% in 2009), and 40.2% added sugar to foods such as noodle and fried rice (down from 60.8% in 2009). Prasertsom et al's[54] study among children aged 3 to 12 years showed that sweetened beverages consumed frequently were yogurt drinks (18.2%), soft drinks (16%), and sugar sweetened drinks/fruit juice (14%). Chitchang et al[63] studied snack and light meal consumption behavior of children aged 3-15 years old from 6 provinces, using a 24 h recall. Milk

Table 4. Findings on sources of added sugar in Thailand

Type of data	Source of information	Year	Age group examined	Sources of added sugar
National level data	National Statistical Office, The 2013 Survey on Food Consumption Behavior[58]	2014	Population aged 6 y and over	Food items and percentage of the population consuming these items

	Weekly consumption (%)	Daily consumption (%)
Sweet non-alcohol drinks	63.6	25.6
Soft drinks	58.3	6.5
Snacks	49.3	6.9

Lim et al. National cohort of Thai adults[59]	2014	15-87 y	Consumption frequency of sugar-sweetened beverages (SSB) in 2009

	Females (%)	Males (%)	Both sexes (%)
Once a day or more	5	5	5
3-6 times/wk	10	14	11
1-2 times/wk	16	21	19
1-3 times/mo	28	31	30
Never or <1x/mo	41	29	35

Food Security and Nutrition Status in Thailand 2005-2011[45,46]	2013 2012	N/A; per capita	Sweetened food items and amount of dietary energy supplied by these items

	Quantity consumed (g/person/day)	Energy supplied (kcal/person/day)	Estimated percentage of total energy consumption/day (%)†
Thai dessert	11.7	33	1.6
White sugar	7.6	30	1.4
Baked dessert/cake	5.8	20	1.0
Soft drink	17.7	7	0.3
Milo/cocoa	1.1	5	0.2

Aekplakorn W. Food consumption survey of Thai population. 4th National Health Examination Survey[48]	2009	2 to 14 y & 15 y and above	Daily consumption of sweetened foods (% of subjects) -2 to 14 y – carbonated beverages (15.3%), ice cream (14.4%), candy & chocolate (19.2%) -15 y and above – carbonated beverages (7.9%) Almost daily consumption of sweetened foods (% of subjects) -2 to 14 y – carbonated beverages (15.5%), ice cream (18.2%), candy & chocolate (15.8%) -15 y and above – carbonated beverages (8.3%)

† Based on average energy consumption of 2090 kcal/person/day[45]

Table 4. Findings on sources of added sugar in Thailand (cont.)

Type of data	Source of information	Year	Age group examined	Sources of added sugar			
National level data	Food consumption data of Thailand 2007-2010[47]	2010	0 to >65 y	Sources	Age group (y)	Mean per capita intake (g/d)	Mean per *eater* intake (g/d)
				Sugar (white)	0-3	0.95	3.87
					3-5	3.91	11.07
					6-9	4.36	11.74
					9-16	5.05	13.13
					16-19	5.27	13.66
					18-35	6.05	14.11
					35-65	6.99	14.58
					>65	5.44	12.55
				Sugar (brown)	0-3	---	---
					3-5	0.27	10.63
					6-9	0.24	11.74
					9-16	0.38	13.92
					16-19	0.44	14.20
					19-35	0.56	15.24
					35-65	0.66	14.78
					>65	0.45	12.08
				Honey	0-3	0.20	8.59
					3-5	0.22	8.66
					6-9	0.27	10.25
					9-16	0.31	10.47
					16-19	0.32	10.76
					19-35	0.34	11.31
					35-65	0.37	10.74
					>65	0.34	10.58
				Sweet condensed milk	0-3	1.40	15.29
					3-5	2.48	15.53
					6-9	2.26	15.94
					9-16	2.00	16.70
					16-19	1.52	16.60
					19-35	1.65	17.17
					35-65	2.19	17.09
					>65	2.54	16.43
				Coconut sugar	0-3	---	---
					3-5	0.06	11.75
					6-9	0.09	14.37
					9-16	0.13	14.00
					16-19	0.10	13.91
					19-35	0.11	14.44
					35-65	0.13	14.93
					>65	0.18	13.01

Table 4. Findings on sources of added sugar in Thailand (cont.)

Type of data	Source of information	Year	Age group examined	Sources of added sugar			
National level data	Food consumption data of Thailand 2007-2010[47]	2010	0 to >65 y	Sources	Age group (y)	Mean per capita intake (g/d)	Mean per *eater* intake (g/d)
				Sweet beverage including carbonated drink	0-3	9.93	250.06
					3-5	66.21	596.96
					6-9	89.85	677.85
					9-16	114.92	736.55
					16-19	120.25	741.63
					19-35	95.23	763.53
					35-65	45.54	736.66
					>65	17.0	670.38
				Candy, Jelly	0-3	4.25	37.46
					3-5	8.34	44.23
					6-9	8.92	49.29
					9-16	7.21	51.26
					16-19	4.38	49.63
					19-35	2.06	47.78
					35-65	0.63	43.76
					>65	0.18	39.96
				Ice cream	0-3	4.99	79.0
					3-5	19.54	172.9
					6-9	22.22	186.1
					9-16	19.64	193.0
					16-19	13.91	195.1
					19-35	8.12	195.4
					35-65	4.16	190.2
					>65	2.06	174.9
				-73.5% of respondents aged 3-65 y added white sugar to foods -% of subjects who consumed the following foods: sweetened beverages (51.6%), all types of ice cream (44.3%), sweet condensed milk (45.4%), jam and jelly (34.4%), honey (21.1%)			
	Thailand's Sugar Industry in 2007, Office of the Cane and Sugar Board (OCSB), Ministry of Industry Thailand [49]	2007	N/A	Food products responsible for indirect consumption of sugar (i.e., sugar from processed foods) and % of indirect consumption: -Processed food/canned fruits & juices (51%) -Beverages (34%) -Others (11%) -Candies (3%) Sugar used in processed food accounted for 69% of utilization while direct consumption of refined sugar (table sugar) accounted for 31% of utilization.			

Table 4. Findings on sources of added sugar in Thailand (cont.)

Type of data	Source of information	Year	Age group examined	Sources of added sugar
Individual studies				
Children	Peltzer et al[29]	2014	24 to 36 months	At 6-12 months, 47.6% of mothers introduced softdrinks. At 30 months, 21.7% of mothers gave sweet candy 3 to 7 times/wk; 78.3% gave sweet candy 0 to 2 times/wk
	Kongnoo et al[62]	2014	3-12 y	42.7% of children drank sweetened beverages; 40.2% added sugar to foods
	Krisdapong et al[64]	2013	12 y & 15 y	

Type of food & consumption frequency	Age 12 y (% consuming)	Age 15 y (% consuming)
1.Crispy packeted (sweet) snacks		
-Rarely/never	24.3	23.8
-Sometimes/everyday	75.7	76.2
2.Fizzy drinks		
-Rarely/never	36.0	26.5
-Sometimes/everyday	64.0	73.5

Lueangpiansamut et al[65] 2012 11-12 y

Food item	Consumption frequency of snacks and sweetened drinks, n (%)			
	Everyday	Always	Sometimes	Never
Sweet milk, soy milk, fermented milk	19 (17.1)	29 (26.1)	63 (56.8)	0 (0.0)
Dried squid/fish, cereal	8 (7.3)	22 (20.0)	80 (72.7)	0 (0.0)
Ice cream	20 (18.0)	31 (27.9)	60 (54.1)	0 (0.0)
Soft drinks	2 (1.8)	9 (8.1)	98 (88.3)	2 (1.8)
Tea, coffee, chocolate malt drinks	4 (3.6)	32 (28.8)	74 (64.0)	4 (3.6)

Thammasorn et al[53] 2009 12 y

1. Median amount of sugar consumed from snacks and beverages within school environment: snacks (5.33 g/day), beverages (12.5 g/day)
2. Mean sugar consumption from food items available in school (g/day)
   - Jelly (25.45), fruit juice (23.81), syrup water (23.81), crispy snack (23.73), Thai dessert (23.49), cake/bread (23.33), ice cream (22.99), chocolate (20.89), milk yogurt (19.6)

Korwanich et al[60] 2008 Preschool children

Snack item consumed	Frequency/day - control schools (n=84) (mean±SD)	Frequency/day – intervention schools (n=135) (mean±SD)
-Cariogenic snacks (sweets, cake and bread with sugar, confectionery, peanuts with coated flavors and sugar, Thai desserts group, crispy snacks with sugar, sugary drinks group)	1.03±0.73	1.12±0.79
-Thai desserts (kautommud, khanomchan and Thai custard)	0.11±0.25	0.23±0.40
-Crispy snacks (potato chips, instant noodles, crispy snacks with sugar and crispy snacks without sugar)	0.67±0.57	0.91±0.77
-Sugary drinks (25% fruit juice, soft drinks, flavoured milk with sugar, drinking yoghurt with sugar, sugar containing drinks, ice cream)	0.18±0.28	0.31±0.41

Table 4. Findings on sources of added sugar in Thailand (cont.)

Type of data	Source of information	Year	Age group examined	Sources of added sugar				
Children	Prasertsom et al[54]	2007	3-12 y	Sweetened beverage item			% of children consuming	
				-Yogurt drink			18.16	
				-Soft drink			15.78	
				-Sugar sweetened drink or fruit juice			14.40	
				-Sweetened milk			8.15	
				-Chocolate drink			6.82	
				-Soymilk with sugar			5.85	
				-Green tea			3.41	
				Average amount of sugars from beverages consumed by children in school using sugar content from nutrition facts on package labels				
					No. of children	Mean sugar intake from beverages (g)	Minimum (g)	Maximum (g)
				Preschoolers	1348	26.68	0	708.0
				Grade 1	696	30.35	0	371.0
				Grade 2	689	26.56	0	281.5
				Grade 3	713	26.12	0	176.9
				Grade 4	785	27.83	0	380.0
				Grade 5	772	29.87	0	317.0
				Grade 6	761	28.33	0	175.9
	Klunklin & Chanoonmuang[61]	2006	2-6 y	Frequency of snack consumption and amount consumed				
						Frequency per day (mean no. of times/day)	Estimated mean consumption (g/person/day)	
				Commercial package snack (crispy snack)		1.3	20.9	
				Desserts		0.14	6.3	
				Beverage		0.14	11.1	
	Hiranras[51]	2006	3-5 y	Children consume 1.6 box sweetened milk per day; amount of added sugar consumption from sweetened and chocolate milk=10.8±7.9 g/day				

Table 4. Findings on sources of added sugar in Thailand (cont.)

Type of data	Source of information	Year	Age group examined	Sources of added sugar		
	Chitchang et al[63]	2004	3-15 y	Food product category	% of children who consumed	Type of sweetened food products often consumed (% of product category consumption)
				Milk and milk products	32.2	Sweetened milk (20%) Yogurt drinks (20%) Chocolate drinks (13%) Soymilk (11%)
				Sugar-sweetened beverages/soft drinks/ice cream	24.9	Sugar-sweetened beverage/fruit juice (41%) Soft drink (30%) Ice cream (13.5%) Jelly (6%)
				Crispy starch (crispy snack, potato chip, crispy instant noodle)	9.9	Sweet crispy starch (48%)
				Soft bread (cake, donut, stuff bread, jam/sugar coated bread)	9.0	Jam/sugar coated bread (35%), stuff bread (32%)
				Wafer/cookie/biscuit	5.8	Sugar coated (24%), cream stuff (20%)
				Thai sweets (coconut milk added sweets, syrup sweets)	4.3	Coconut milk added sweets (45%)
				Candy/chocolate	4.0	Hard candy (44%), chewy candy (24%), chocolate (15%)
	Yongvanichakorn & Junbang[66]	2003	Primary schoolchildren in Nonthaburi province	80.86% of snacks consumed by children contained sugar and starch; 45.06% of children ate crispy snacks, 34.76% ate ice cream and sweet ice		
	Petersen et al[67]	2001	12 y	Percentage of children reporting daily consumption of the following foods -Soft drinks (24%), milk with sugar (34%), tea with sugar (26%)		
Adults	Promdee et al[56]	2007	18-22 y	Average consumption of sucrose from sweetened food items		
				Food item	Men (g/day)	Women (g/day)	Both sexes (g/day)	% of total sucrose consumed/d (%)	Mean sucrose content of food item (g/pack±SD)
				Sweetened beverage (non-diet softdrink, fruit juice, lemonade)	135	114	118	59	24.0±20.0
				Bakery (cakes, cookies, pies, doughnuts, crackers, slide bread)	31	40	38	19	13.2±9.1
				Thai sweets (*lodchong*, *roti* with egg (banana), sweets w/ coconut milk topping)	22	27	26	13	24.6±25.4
				Candy (plain candy, candies with chocolate, jellies)	11	9	9	5	6.0±5.9
				Snacks (chocolate bar, squid, potato chip, popcorn, grain-based snacks)	7	7	7	4	9.5±11.0

and milk products (including sweetened milk) were consumed by the most number of respondents (32.2%) followed by sugar-sweetened beverages/soft drinks/ice cream (24.9%).

Krisdapong et al[64] examined sociodemographic factors and dental caries in a nationally representative sample of 12- and 15-year old Thai children. More than 75% of children aged 12 and 15 years reported consuming crispy packeted snacks frequently, while 64% and 73%, respectively, of the two age groups reported consuming fizzy drinks. In a study of dental caries among 111 students age 11 to 12 years, Lueangpiansamut et al[65] found that frequently consumed sweetened foods were ice cream, sweet milk/soy milk/fermented milk, and tea/coffee/chocolate malt drinks, consumed by 43.2, 45.9 and 32.4% of children, respectively. Thammasorn et al's[53] study among 5th and 6th grade primary school students found that the median amount of sugar from snacks and beverages consumed in school was 5.33 g/day (range 0.0-39.58) and 12.5 g/day (range 0.0-83.5), respectively. Specific sources of sugar within the school environment were jelly, fruit juice, syrup water, crispy snacks, Thai desserts, cake/bread, ice cream, and milk yogurt. Yongvanichakorn and Junbang[66] examined snack consumption of primary schoolchildren in Nonthaburi province for one day by collecting their snack wrappings. Eighty percent of wrappings came from foods containing sugar and starch (45% from crispy snacks, 35% from ice cream and sweet ice). Petersen et al's[67] study on dental caries among grade 6 children age 12 years from rural and urban schools in one province showed daily consumption of softdrinks, milk with sugar, and tea with sugar by 24%, 34%, and 36% of children, respectively.

Studies on adults

Promdee et al's[56] study among 202 undergraduate students showed 337 kinds of sweetened foods and drinks consumed. These foods were placed in five categories: candy, snack, bakery, sweetened beverage, and traditional Thai sweets. Sweetened beverages represented the largest source of sugar consumption (i.e., 59%), with an average sucrose content of 24.0 g/bottle. Other foods which accounted for sugar consumption were bakery products (19%; average sucrose content of 13 g/piece), traditional Thai sweets (13%; average sucrose content of 25 g/pack), candies (5%; average sucrose content of 6 g/pack), and snacks (4%; average sucrose content of 9.5 g/piece).

DISCUSSION

Level and sources of sugar intake

Level of sugar intake

While results of food balance sheet and household expenditure surveys suggest the possibility of high levels of sugar intake in the population (>50 gm/capita/day),[44-47] results of the latest national food consumption survey[48] based on a single 24-h recall showed low levels of sugar intake among the different age and sex groups (i.e., below the Thai recommended cut-off of 40-55 g/day). This reported data was likely underestimated due to the limitation of the food composition database used. INMUCAL-N V.2.0 was the software used at that time wherein information on sugar content was available for only 81% of foods. Aside from this, the database does not reflect discretionary sugar content of all mixed dish items, when normally in Thai cuisine, sugar is added during cooking and in the dish before eating. It is also important to note that the levels of sugar intake reported in this review refer to total sugar rather than added sugar. It is not possible to determine the amount of added sugar in processed foods due to the absence of such information. Food composition tables only reflect the amount of total sugar in food (i.e., the sum of endogenous (naturally occurring) and exogenous (added) sugars), and chemical analysis is unable to distinguish between the two.

Few individual studies examined sugar consumption levels (five among children and two among adults). Results of studies among children varied, with some studies suggesting higher levels of sugar intake (i.e., above 25 g)[51,54,55] while two[52,53] were inconclusive as they estimated intake for only part of the day (i.e., during school hours). All studies were outdated (i.e., the latest in 2009) and thus may not reflect current consumption patterns. A similar trend is seen for studies among adults, with one study showing high intake levels exceeding 50 g[56] while the other[57] showed a lower intake level (below 50 g but above 25 g).

Sources of added sugar

Recent nationwide surveys[45,58,59] and individual studies showed that frequently consumed sources of added sugar were sweetened beverages (including soft drinks, juices, milk and dairy products, coffee/tea/chocolate drink), sweetened snacks (including traditional Thai desserts, baked desserts/cakes, crispy snacks), and table sugar. While semi quantitative food frequency questionnaire (SFFQ) used in the first National Food Consumption survey could provide food items contributing to sugar intake, the method may not capture some high sugar food items particularly those that were not included in the SFFQ. Except for the work of Promdee et al[56] individual studies did not indicate the amount of each food item consumed by different groups. Therefore the amount of sugar from ingested foods could not be estimated and it is not clear how much these foods actually contributed to total caloric intakes in different population groups.

Using market sales data from Euromonitor, Baker and Friel[68] identified carbonated soft drinks and baked goods as the most significant vectors for sugar in a selection of Asian countries that included Thailand. The authors presented data showing Thailand as one of the countries to have undergone the most rapid increase in total per capita processed food consumption for the period 1999 to 2012, with carbonated soft drinks exhibiting the greatest increase in consumption among processed foods. Thailand's carbonated soft drinks consumption in 2012 was estimated at 39.2 L per capita or approximately 107.4 mL per day, contributing about 12 g sugar per capita per day.

In summary, information on sugar consumption levels in Thailand varied depending on the type of survey, with food balance sheet and household surveys suggesting high levels of intake, and the food consumption survey showing low levels of intake. Food sources that contributed high levels of sugar in the diets of different age/sex groups were difficult to identify, as most studies did not

provide information on quantities of ingested foods with added sugar and total caloric intakes of these groups. Thailand is currently undergoing rapid economic transition, and food habits change as the environment changes. Information from the food consumption survey done in 2009 and most of the individual studies are outdated, making it necessary to undertake new studies and surveys using improved dietary assessment methods.

Sugar and the requirement for carbohydrates

Food balance sheet data[44] and one study[57] suggested that sugar comprised approximately 14.3% and 12.2%, respectively, of ingested carbohydrates. As discussed previously,[41] carbohydrates in the form of glucose serve as the body's major source of energy. Using the brain's requirement for glucose as the basis for estimating carbohydrate requirements, the Institute of Medicine has recommended 130 g carbohydrates/day for both men and women age 19 y old and above.[69] WHO/FAO has recommended that whole grains, legumes, intact fruits and vegetables are the most appropriate sources of carbohydrates[70] rather than added sugars. The Food-based Dietary Guideline for Thai[71] includes the statements "Avoid sweet and salty foods", and "Eat adequate rice (particularly unpolished or brown rice) or alternate carbohydrate." In terms of quantities consumed, the Guideline states that no more than 10% of food energy should be obtained from sugar, and that daily intake should not exceed 40 to 55 g or 3 to 4 tablespoons sugar per day. The present review shows that sugar comprises a significant proportion (>10%) of ingested carbohydrates in Thailand, and that carbohydrate requirements can be met even without consuming sugar.

Limitations and gaps

Methodological limitations of the Thai national food consumption survey

As discussed in an earlier paper,[41] an important objective of food consumption surveys is to describe usual intakes of a population using individual-level measurements for group-level analysis.[72] Usual intake is defined as long-term average daily intake, taking into account both consumption and nonconsumption days.[73] The concept takes account of the fact that dietary recommendations are intended to be met over time and diet-health hypotheses are based on dietary intakes over the long term.[73] Self-report instruments are used to describe intakes, the most common of which are food frequency questionnaires (FFQ) and 24-h recalls. All dietary measurement methods are prone to some degree of measurement error, defined as the difference between the observed or measured value and the true value.[74] Twenty-four hour recalls are considered less prone to measurement error than FFQs.[74]

The latest food consumption survey in Thailand made use of a single 24-h recall. Twenty-four hour recalls are considered more accurate than FFQs because they are not limited by a finite food list, can capture rich details about daily intake of every item consumed (when, how much, with what), and are less prone to cognitive difficulties in recalling typical intake over a long period (as in the case of FFQs).[73,75] Its limitation is that more than one day of recall is needed to estimate usual intakes and statistical methods are required to adjust for measurement error.[73,75] While a single 24-h recall can characterize mean usual intakes of a group, it does not define the group's usual intake distribution and is unable to assess with a certain degree of precision the proportion of individuals who are at risk of inadequate (or excess) intakes.[75] Thus, due to the fact that a single day's recall was used, information obtained from the 2009 Thai food consumption survey is considered insufficient and less reliable as a measure of the population's usual (or habitual) sugar consumption, than if multiple days were used.

Use of biomarkers to validate intake

As pointed out in an earlier paper,[41] biomarkers are the gold standard for measuring sugar intake. Biological markers obtained from the same individuals overcome the limitations of traditional dietary assessment methods as these are independent of measurement errors present in dietary instruments.[76] Predictive biomarkers exhibit a direct relationship between absolute intake and tissue values, are sensitive, stable, time-dependent, show a dose-response relationship with intakes, and can be used as reference measures to assess and correct for error in dietary data.[76] Biomarkers that have been shown to predict sugar intake include 24-h urinary fructose and sucrose,[77] abundance of the stable isotopes $\delta^{13}C$ and $\delta^{15}N$ in hair, red blood cells, and plasma, and the carbon isotope ratio of alanine $\delta^{13}C$alanine in red blood cells.[77,78] But due to the cost of analysis, it is difficult for Southeast Asian countries including Thailand to utilize these measures.

New findings and future research directions

Metabolic effects of fructose

Studies have shown that glucose and fructose (both found in sucrose or table sugar) are metabolized in different ways, and that fructose has a role in the etiology of metabolic syndrome and diabetes.[79-82] While glucose is converted to glycogen in the liver through the action of insulin, fructose is converted to pyruvate and acetyl CoA by a different metabolic pathway. Acetyl CoA serves as a source of energy but in excessive amounts, it is a substrate for hepatic de novo lipogenesis (DNL). DNL can lead to accumulation of fat in the liver, which subsequently triggers inflammation and hepatic insulin resistance. DiNicolantonio et al's[79] discussion of evidence from basic science, observational studies, and human clinical trials regarding the metabolic effects of fructose concluded that fructose is a primary driver of diabetes development, and that protection from diabetes and its consequences can be achieved by limiting added fructose consumption. Animal studies indicate that fructose-induced metabolic syndrome does not require increased energy intake and that disease can be induced in metabolic syndrome-prone rats with caloric restriction provided the diet is high (40%) in sucrose.[82] One proposed mechanism is through increased production of uric acid resulting from fructose metabolism. Uric acid causes oxidative stress that stimulates fat accumulation in the absence of increased energy intake.[82]

Using data from Thailand's Health Survey for Prevention of Hypertension and Type 2 diabetes, Pingmuangkaew et al[83] found that elevated serum uric acid

was significantly associated with abdominal obesity, hyperglycemia, hypertriglyceridemia, oxidative stress, and metabolic syndrome among adults aged 47 years and above after adjusting for covariates. Similarly, Jaipakdee et al[14] found an association between serum uric acid and metabolic syndrome among adults in Bangkok aged 36 to 60 years, confirming the association of uric acid with increased risk of vascular disease and type 2 diabetes.

It has been argued that total energy intake in excess of an individual's energy requirement, rather than sugar intake per se, is the underlying cause of obesity and other chronic diseases. While obesity is a risk factor for chronic disease, studies show that Asians have certain characteristics (e.g., increased percent body fat and pancreatic beta-cell dysfunction) that increase the risk for chronic disease particularly diabetes in the absence of obesity.

Increased body fat among Asians

Studies on body composition showed that at the same BMI level, Asians have more percent body fat than Caucasians,[84-86] with the magnitude of differences greater in females than in males.[84] Yoon et al[4] suggested that the high proportion of body fat and prominent abdominal obesity in Asians compared with Caucasians predispose Asians to insulin resistance at lower levels of BMI, and may explain the epidemic of diabetes in the region. Visceral or abdominal obesity (excess intra-abdominal adipose tissue accumulation) is associated with cardiometabolic risk factors including hypertriglyceridemia, increased free fatty acid availability, adipose tissue release of proinflammatory cytokines, liver insulin resistance and inflammation, increased liver VLDL synthesis, and other metabolic alterations.[87] The risk of dysglycemia at an early stage in the increment of visceral fatness was found to be greater for Asians than for Europeans.[4] Dietary fructose has been identified as one mechanism responsible for increased visceral fat storage.[87]

Studies confirmed that Thais develop diabetes at lower levels of BMI. The InterAsia study, a nationally representative cross-sectional survey to estimate the prevalence of cardiovascular risk factors in the Thai population, found that optimal cut-off points for BMI in predicting diabetes, dyslipidemia, or having 2 or more CVD risk factors were 22-23 kg/m^2 in men and 24-25 kg/m^2 in women.[10] Aekplakorn et al[88] developed a diabetes risk scoring system to identify individuals likely to develop diabetes in the near future. Risk factors for predicting diabetes were BMI ≥23 kg/m^2 and waist circumference ≥90 cm in men and 80 cm in women. Samsen et al[89] determined appropriate BMI and waist circumference cut-off points to identify at least one cardiovascular risk factor (hypertension, dyslipidemia, type 2 diabetes) using data from the Thai Epidemiologic Stroke (TES) study. Cut-offs for BMI were 23 kg/m^2 for men and 24 kg/m^2 for women, while those for waist circumference were 80 cm for men and 78 cm for women.

Pancreatic beta-cell dyfunction

In a normal population, postprandial hyperglycemia is a risk factor for all-cause cardiovascular mortaliy, and there is a significant association between risk of cardiovascular death and 2-h postload glucose in subjects with normal fasting glucose levels.[90,91] Dickinson et al[90] reported increased postprandial hyperglycemia and hyperinsulinemia among lean young Southeast Asian (i.e., Thai and Vietnamese) adults. Results of a white bread meal showed that Southeast Asian (SEA) subjects had significantly greater glycemia, with the incremental area under the curve (AUC) 100% higher than that of matched European Caucasians. Incremental insulin AUC was 2.4 times higher in SEA subjects than in European Caucasians, and their plasma glucose concentrations at 120 min were elevated, with 4 of the 10 SEA subjects showing impaired glucose tolerance. SEA subjects also showed reduced insulin sensitivity compared with other ethnicities, as determined by euglycemic-hyperinsulinemic clamp, despite similarities in age, BMI, WC, birth weight, and diet. The authors suggested that insulin secretory capacity is likely compromised in lean young SEA adults and that reduced insulin sensitivity and impaired carbohydrate tolerance (rather than excess lipids) might precede development of other features of metabolic syndrome. The study included only two Thai subjects, therefore larger sample sizes are needed to determine if the condition is common in the Thai population.

Pancreatic beta-cell dysfunction is characterized by impaired acute-phase insulin secretion in response to glucose, and is accompanied by higher circulating concentrations of intact and split proinsulin (PI).[92] The predominant processing pathway in beta-cells is the conversion of PI to des-31,32-PI by prohormone convertase (PC) 1/3, and conversion of des-31,32-PI to insulin and C-peptide by PC2.[92] A recent study by Katsuta et al[92] among non-obese Japanese subjects showed increased circulating levels of proinsulin and decreased PC 1/3 activity in prediabetic and type 2 diabetic subjects, compared with non-diabetic subjects. The authors suggested that impaired proinsulin conversion in pancreatic beta-cell insulin secretory granules is associated with type 2 diabetes in the non-obese Japanese population. Further studies are needed to confirm if this might be the case among Southeast Asians.

Conclusion

There is insufficient evidence to accurately establish the level of sugar intake in the Thai population and to identify significant sources of sugar. This is due to varying information obtained from different studies, limitations in the methods used to estimate dietary intakes (including absence of biomarkers to validate intakes and inadequate or unavailable food composition data), and outdated national surveys and individual studies. A 2013 report from the National Statistical Office showed an available supply of 83 g sugar per capita per day, while the 2009 Food Consumption Survey of Thai Population reported mean intakes of sugar and sweeteners among all age groups ranging from 6.9 to 25.6 g per day (median 2.0 to 20.0 g/day) among males and from 5.1 to 24.7 g per day (median 2.0 to 15.7 g/day) among females. An updated nationally representative survey using improved methods is needed to determine the levels and sources of sugar intake in different population groups in Thailand. These methods include the use of biomarkers to establish levels of sugar consumption and multiple 24-h recalls (at least two) to identify dietary sources that put the population at risk

of excessive intakes.

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