Obesity in China: What are the Causes?

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Abstract: To address the causes for obesity in all of China is not feasible in a single article. There are hundreds of ethnic groups over a vast number of provinces. The diet and lifestyle of each is different based upon cultural/ethnic traditions and the environment. Several studies mentioned in this review have been done in particular areas and/or on specific population groups with regards to obesity and health risks associated with being overweight. Obesity is a multifactorial disease that is associated with genetic, physiological, environmental, and cultural/traditional perspectives in order to provide a broadened view on this epidemic in China. In this review, we will assess specific obesity gene and environment interactions, childhood obesity etiology, metabolic syndrome, and dietary and behavioral causes. We attempt to discuss obesity issues particularly in the Han Chinese population ranging from children, adolescents, adults to geriatrics.

Keywords: Obesity, overweight, China, insulin resistance, hypertension, type 2 diabetes mellitus, metabolic syndrome, dyslipidemia.

INTRODUCTION

Obesity in China is becoming a pandemic disease resulting from a shift in energy balance caused by altered genes, a sedentary lifestyle, and neurohormonal imbalances. It is spreading to low-income and middle-income countries, such as China, as a result of novel dietary habits, promoting chronic diseases and premature mortality [1]. Work-related activities declined recently in industrialized countries, whereas leisure time is dominated by television/computer programs and other physically inactive pursuits [2,3]. In China, overweight rates doubled between 1991 and 2006, and the number of obese individuals tripled [4]. The prevalence of obesity in men was 10.5% in mainland China [5], and 16.3% in the Hong Kong population [6]. The prevalence of diabetes in China parallels that in the United States, with more than 92 million cases [7]. More importantly, related health care costs are also substantial [7].

Obesity and can be used to predict T2DM, hypertension, cardiovascular disease, gall bladder disease and specific cancers [13,14]. Certain studies on Asian populations have shown that the Chinese have more body fat at a lower BMI and WC than Western populations [15,16]. Therefore, to obtain a better picture of the weight status of an individual, BMI should be measured along with waist circumference (WC) and waist-hip ratio (WHR) [17]. Thus, WHR correlates with BMI and WC [18,19,20]. Salivary ghrelin levels have been found to be negatively correlated with body fat and WC [22]. Serum and saliva ghrelin levels were correlated with BMI [23]. Saliva has been used as a simple, non-invasive diagnostic tool [24]. Parotid and submandibular glands were the primary sources of ghrelin [23]. Hence, this may be a useful application in Chinese obesity clinics. In the following sections, the potential causes for obesity in China will be discussed in detail.

GENE-ENVIRONMENT INTERACTION

Gene-environment interaction is defined as “the response or the adaptation to an environmental agent, a behavior, or a change in behavior is conditional on the genotype of the individual” [25]. Mechanisms for this phenomenon consist of decreased resting metabolism and lipid oxidation rate, and poor appetite control with increased fat mass [26]. McMillen et al. [27] suggested that specific periods during pregnancy predisposed individuals to obesity, therefore maternal nutrition and perinatal lifestyle played a major role in fetal programming. Over-nutrition during pregnancy led to larger offspring or gestational diabetes associated with obesity, while breastfeeding could counter the effects of obesity [28]. For example, in Fujian province, the rate of obesity has increased due to poor nutrition before and during pregnancy, economic development, urbanization and improved living standards [29].

Two recent studies [30,31] identified novel genetic variants associated with obesity and/or BMI. The genetic loci were: NER1, SEC16B-RASAL2, TMEM18, SFRS10-ETVS-DGKG, GNPD1, NECR3-AIF1-BAT2, LG4-LIN7CBDNA, MTCH2, BCDN3D-FAIM2, SH2B1-ATP2A1, KCTD15, FTO (fat mass and obesity associated) [32,33,34] and MC4R (melanocortin 4 receptor) [35,36]. The FTO gene is present in all tissues and encodes a non-heme (FeII)-dioxygenase that adapts to hypoxia, lipolysis, or DNA methylation [37,38]. This key protein may serve as a link between the central nervous system and energy homeostasis.

Several studies associated FTO variants (rs8050136 and rs9939609) with obesity and BMI in Hong Kong, Taiwan, and Singapore populations [32,33,34]. On the other hand, Li et al. [39] found no association of the FTO variants with obesity and BMI in Shanghai and Beijing individuals. Obesity-associated genetic vari-
ants studied in Caucasians impacted the development of obesity in the Chinese. For all obesity-associated single-nucleotide polymorphisms (SNPs), researchers observed higher odds ratios than previously reported [30,31]. This may be caused by differences in genetic compositions between Chinese and Caucasian populations, even though these SNPs are less common in the Chinese. There was a 17-23% increased risk of obesity for every unit increase in the combined genetic risk scores. Further research needs to be done on obesity susceptibility genes for clinical applications. The estimated heritability of BMI in Chinese ranged from 0.42 to 0.54 [40,41,42]; however, 4.1% of this could be correlated with seven obesity-associated SNPs [43]. Associations with BMI and WC were observed for rs10938397, rs17782313, and rs8050136 [43]. Identification of the A allele associated with WC and IR in Chinese [57]. This relationship was confirmed in Taiwan and the Chinese population [49,50]. One study found a relationship between FTO SNP rs8050136 and BMI. It showed that the additive genetic risk of SNPs may be useful in predicting obesity [43], perhaps in the Chinese population.

Furthermore, rs9939609 was associated with BMI in Taiwan [51], rs9939609 and other SNPs coupled with obesity were found in those living in Singapore [52]. The rs9939609 A allele frequency was lower in Chinese and Japanese subjects compared to that in Europeans [53]. rs9939609 SNP was strongly associated with obesity and T2DM in Chinese adults [54]. AA/AT genotype carriers had higher obesity and BMI prevalences than the TT genotype [53]. The rs9939609 A allele frequency was lower as compared with the Europeans [53]. Only 1.2% of the Chinese were homozygous for the A allele [53]. The A allele was indeed linked to obesity in Chinese adults [54]. On the other hand, there has been conflicting information with regards to rs9939609 or rs8050136 polymorphisms of the FTO gene and obesity in the Chinese population [55]. One study concluded that FTO polymorphisms were associated with obesity but not with T2DM in China [56]. Another study demonstrated a strong association between FTO and MC4R with BMI in Chinese individuals [57]. BMI of subjects with three or four risk alleles outweighed those without the FTO or MC4R risk allele [57]. The FTO rs9939609 A allele was associated with obesity and BMI mostly in women [57]. FTO may also regulate gender-specific development of obesity and insulin resistance in all people [57]. The Chinese are thus at risk for T2DM at a lower level of obesity due to their increased predisposition to abdominal fat deposition and decreased pancreatic β-cell function [58]. The Chinese have different genetic architecture, hence these SNPs act differently in them [57]. On the other hand, variants in the FTO gene were not associated with obesity in Chinese subjects [39]. The reason for this inconsistency is unknown. Possible explanations include different environmental exposures or lifestyle factors between the populations [52]. Associations of the A allele with T2DM remained significant with adjustment for age, sex and BMI [54].

Finally, the adiponectin (ADIPOQ) gene in T2DM and obesity has been reported. The synonymous and intronic polymorphisms in the ADIPOQ gene were found to be associated with BMI in Japanese, Korean, Chinese and Caucasian individuals [59,60,61,62]. AC3 genetic polymorphisms decreased the risk of obesity in Chinese adults [63]. The AC3 genetic effect on BMI may interact with factors relating to ageing and the environment [63].

**ETIOLOGY OF CHILDHOOD OBESITY**

In China alone, the prevalence of obese children aged 2-6 years increased from 1.5% to 12.6% in urban areas from 1989 to 1997 [64]. Parents and extended family members play a crucial role in shaping their children’s eating and exercise habits [65]. Approximately 22% of Chinese parents regarded their children as underweight even if their children weren’t. Meanwhile, 23% of overweight children were perceived by their parents as being normal [66]. Parental assessment of the weights of their children was associated with the physical appearance of the parents themselves [67]. Overweight daughters were more likely to be criticized by their mothers [68,69]. Children elevated their ‘pressure to eat’ strategy being ‘strong and healthy’ [69]. Mothers’ perception of their children could be influenced by emotional factors rather than known facts about obesity and body image, which could be related to their educational level [70]. Studies showed that parents’ and other family members’ ‘pressure to eat’ strategy was correlated with children’s caloric consumption [71] and overall fat mass [72].

Another important factor leading to childhood obesity is that a high proportion of Hong Kong school children spends too many hours watching television (TV) and playing computer or video games [73]. Overweight or obese adolescents had a tendency to view TV programs and become less physically active. Childhood obesity in Hong Kong children is associated with other factors, such as obstructive sleep apnea [73]. A cross-sectional cohort study conducted in 2003 demonstrated that study participants had high systolic blood pressure, increased IR, elevated abdominal fat mass (their sensitivity C-reactive protein level), low high-density lipoprotein-cholesterol levels and high alanine aminotransferase levels; these were all independently associated with obesity [74].

As mentioned before, TV is a potential cause of increased obesity in children and adolescents [75]. In China, access to Westernized TV programming and food advertising has increased [76]. Over a decade ago, urban Chinese children spent 17.2 hours a week (1.7 hours on weekdays, and more than 8 hours on weekends) watching TV [77]. Advertisements for food products, such as soft drinks and salty snacks, constituted more than 80% of commercials in China [78]. According to mothers surveyed in urban areas in China, many children have their own spending money, and they often use this money to buy snacks and beverages [79]. Chinese children reported using TV as a main source of information about junk food [79], and Chinese parents stated that their children influenced most of their purchases, especially of snacks [80]. This can be witnessed in most Chinese cities with large supermarkets today. Children especially are snacking more than adults [81]. In Xi’an, 19% of adolescents were overweight or obese and some reported drinking sugar-sweetened beverages (SSB) one to four times per week [82]. In 2004, 11.4% of young Chinese children were overweight or obese. The rate of child obesity had more than doubled since 1991 [83]. In theory, attention gained from TV advertisements regarding snacks, SSB, and other food products would increase the chances of children wanting to buy and/or consume those products. TV exposure alone can be linked to snacking behaviors [84]. For example, people who are affected by food cues in the environment will be more likely to eat when exposed to those food cues even though they may not be hungry [85]. Food products and restaurant chains seen in TV programs and commercials provide food cues to children, thus enhancing the need to snack while watching TV [86]. TV is present in almost every Chinese household, and TV advertis-
ing in China increasingly promotes high-calorie foods [87]. Chinese viewers who paid attention to TV commercials were more persuaded to engage in advertised snacking [84]. Chinese teenagers were more likely to report buying advertised food, but less likely to request snacks from their parents. This group in general makes more independent purchases [80]. Low-income families spent more hours watching TV than their counterparts [88,89]. However, snacks seen on TV tended to be purchased more by those with higher incomes [81]. One study in 1997 did not find significant differences in TV (and video) use and snacking behaviors among overweight and normal weight Chinese children [90]. All in all, this evidence portrays that non-physical entertainment does play a major role in weight management in young people.

**METABOLIC SYNDROME**

This is defined as “a combination of clinical disorders that increase the risk for diabetes and cardiovascular disease, including atherosclerosis, stroke and hypertension” [9]. The components of MetS include abdominal fat, atherogenic dyslipidemia, hypertension, pro-inflammatory state, pro-thrombotic state and IR with or without glucose intolerance [91]. Other criteria include impaired glucose tolerance, IR, blood pressure ≥140/90 mmHg, triglyceride levels ≥1.695 mmol/L, high density lipoprotein cholesterol (HDL-C) levels ≤0.9 mmol/L (men) or ≤1.0 mmol/L (women), WHR >0.90 (men) or >0.85 (women), BMI ≥30 kg/m^2, microalbuminuria or urinary albumin excretion ratio ≥20 mg/min, and albumin:creatinine ratio ≥30 mg/g [91]. These figures are incorporated into the low grade inflammation hypothesis which states that macrophages and T-lymphocytes in accumulating fat are a source of various cytokines/chemokines that modulate the innate and adaptive immune responses [92,93]. Fat cells along with macrophages have been shown to respond to lipopolysaccharide (LPS)-induced inflammation by increasing pro-inflammatory nuclear factor kappa beta (NFκB) production which triggers inflammatory cytokine synthesis such as serum amyloid A3 (SAA3) and interleukin-6 (IL-6). The adipocytes then express LPS-activated Toll-like receptors-4 (TLR-4) [93,94]. Another condition is adipocyte hyperplasia/hypertrophy which may trigger the local inflammatory responses and cause fat deposition in skeletal muscle, liver, and pancreas resulting in non-alcoholic steato-hepatitis (NASH) [95]. Hypertension accompanying obesity is based on leptin resistance and a putative perivascular adipose tissue factor that sensitizes vascular tissues to endogenous contractile agonists [96,97]. Based on the leptin resistance theory, leptin exerts a sympatho-excitatory effect and at high levels, it causes increased sympathetic nervous system activity leading to hypertension [98]. In other major players in diagnosing MetS is resistin, which is an adipocyte hormone that initially caused IR in mice [99]. Resistin causes the production of inflammatory cytokines such as tumor necrosis factor alpha (TNF-α), IL-1, IL-6, and IL-12 via NFκB [100,101]. Therefore, obesity, MetS and IR development have been associated with increasing resistin levels causing inflammation specifically in T2DM [102]. Hyperglycemia is also a major contributing factor to MetS in that it reduces glutathione peroxidase (GPx), glutathione (GSH) and catalase while increasing thiobarbituric acid reactive substance (TBARS) levels (markers for oxidative stress) [103,104]. High blood sugar levels promote activation of the stress-activated protein kinase (SAPK/JNK) pathway described as glucose toxicity which inhibits pancreatic beta cell function leading to IR [105].

Studies have found that MetS has been linked to the development of cancer [106,107,108]. Obesity, dyslipidemia and hyperglycemia are all risk factors for colorectal cancer [109-112]. Interestingly, only a large WC was linked with the development of colon adenoma [113]. Furthermore, BMI and high triglyceride levels were also related to the development of cancer [114,115]. Another study found a relationship between colorectal adenoma and MetS symptoms of inflammation, IR and oxidative stress [117]. The actual makeup of adipose promotes procarcinogenic inflammatory cytokine production [118-120]. Another study found that the high-sensitivity C-reactive protein level was higher in MetS patients with adenoma [116].

One study showed that MetS was very common in southern China [63]. Researchers found that 42.1% of hypertensive patients and 73.1% of diabetics had MetS [63]. Studies in Japan [121], Korea [122] and China [123,124] indicated that decreased insulin secretion contributed more to T2DM. Other research [125] demonstrated that both IR and impaired β-cell function occurred prior to abnormal glucose tolerance. Latest surveys indicated that the prevalence of total diabetes in China was about 9.7% [126]. Two thirds of Chinese diabetics had an HbA1c level less than 5% [127]. The Chinese theoretically have less IR compared to obese Westerners [128]. Non-obese, normal-glucose tolerant, first-degree relatives of diabetics have a higher IR [128]. IR was found to be independent of obesity and blood glucose level [128]. Increased plasma free fatty acids (FFA) in obese Chinese people was an important link between obesity and IR, and plasma FFA levels were negatively correlated with insulin sensitivity [129,130,131]. The Chinese exhibited impairment of peripheral insulin sensitivity and elevated circulating FFA levels [128]. For example, in Han Chinese adults living in Shanghai, risk factors for obesity included lower education levels, family history of T2DM, cigarette smoking, high systolic blood pressure, glyceria and dyslipidemia. Over 70% of T2DM cases were between 45 and 65 years old [132]. The Chinese were five times more likely to have a family history of T2DM than normal subjects [133].

Abdominal fat distribution may also be associated with metabolic risks than BMI [134,135]. In 2005, it was recommended that BMI and WC be used to classify obesity-related cardiovascular disease (CVD) risk in adults [136,137]. Another study confirmed that both BMI and WC were ideal screening tools used to assess CVD risk in China [138]. Hong Kong Chinese asymptomatic patients with central obesity had a high rate of CVD risk factors [139]. For example, 19% of these patients had carotid atherosclerotic plaques and 10% of them had abnormal carotid intima-media thickness. As a result, this could serve as an appropriate screening tool in diagnosing atherosclerosis in the centrally obese middle-aged Chinese population [139].

In summary, those in the north or urban areas of China have more problems with obesity, T2DM, dyslipidemia, hypertension, and MetS [140]. In northeast China, the local cuisines are high in sodium and fat, with wheat as the staple food due to the dry arctic winter. Atherosclerosis cases are increasing as influenced by a Westernized lifestyle [141-143]. Finally, in middle-aged and elderly Chinese living in northeast China, there was a higher incidence of MetS and cardiovascular disease, especially atherosclerosis [144].

**DIETARY ALTERATIONS**

China can be portrayed as a “double burden of malnutrition” where under-nutrition coexists with obesity [145]. A fifth of overweight and obese individuals are located in China [146]. Mortality rate related to over-nutrition is estimated to reach 3 million by 2030 in China [147]. Since 1989, every 1,000 kcal increase in energy intake was associated with a 0.28 increase in BMI [148]. Another study showed a smaller 0.18 BMI increase for every 1,000 kcal increase in energy intake since 2006 [149].

The world-wide shift in food selection and consumption has resulted in a diet that is more energy-dense and laden with saturated animal fat and processed sugars, and is low in complex carbohydrates, fiber, and fresh fruits and vegetables [150-152]. Socioeconomic factors play a major role in influencing diet and the general health of the population. For instance, such as in China. Underprivileged individuals tend to stock up on non-nutritious, high-calorie foods as low-budget staples, whereas nutrient-rich foods and high-quality diets are consumed by more affluent customers [154]. Continuous
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Increasing the consumption of SSB on a global scale leads to obesity [156,157]. In Hong Kong, women who consumed higher amounts of SSB had an 8% higher rate of central obesity and a 1.5 cm larger WC. On the other hand, the men were more likely to drink SSB frequently (20% vs. 10%), to eat more meat (2.30 vs. 2.14 portions), and were less likely to exercise (31% vs. 39%). Younger individuals were also more likely to consume SSB [158]. To date, most of the data associated with SSB and obesity came from cross-sectional studies in children and teenagers [159,160]. In China, SSB is a major food source with a high glycemic index [161,162]. Another study found associations between frequent SSB intake and obesity predominantly in Chinese women, while lack of exercise, smoking, and high meat consumption increased the risk for greater weight gain [158].

Diets in Asian countries have undergone a nutritional transition, shifting from more traditional plant-based diets to Westernized, highly-processed foods with added animal products [163]. Recent malnourished Asian populations are more susceptible to obesity [164]. One study found that overweight children and adolescents consumed more energy, protein, and fat than their counterparts [163]. They consumed less grain, fewer vegetables, more fruits, meats and cooking oil, eggs, fish, milk, and legumes. Those who ate at least 25g of cooking oil, 200g of meat, and 100g of dairy products had a higher chance of being overweight [165].

From a recent cross-sectional survey done in Jiangsu Province, researchers found that a higher socio-economic status and urban residency were associated with energy-dense foods such as animal and dairy products, soft drinks, Western food, and increased snacking/breakfast skipping behaviors [166]. Rural and lower income students normally consumed rice porridge, a traditional, thin breakfast gruel. However, they also preferred hamburgers, ice cream, milk, fruits, chocolate, and SSB [166]. The traditional Chinese high-glycemic diet consists of a variety of high-glycemic staple rice products such as boiled rice, rice congee, and glutinous rice which pose adverse cardiovascular and MetS risks [167]. When the Chinese population was lean and active, this diet did not pose as much risk. However, China today has an obesity epidemic and a dietary transition shifting toward more processed foods such as SSB [167]. Chinese overweight and obese children’s and adolescents’ metabolic risk factors were due to their higher high-glycemic diets [163]. Dependence on processed foods and foods consumed outside the home has been observed among Chinese youth [166]. The reason is that these foods are “appetizing, convenient and ready to eat, portable, affordable in single portions,” and widely marketed for the younger generation. These include soft drinks, biscuits, snacks, and fast-food sandwiches [163]. Higher incomes in China allow families to purchase SSB, snacks, and fast food. Supermarkets are packed with highly-processed, energy-dense, nutrient-poor, and lower-priced foods. Preferences include polished grains/white rice products, because Chinese consumers are unaware of the benefits from whole grains [163]. Global trading and the food industries’ aggressive marketing have also increased the availability of more affordable, palatable over-processed foods [163].

Another major dietary component is glutamate, which is a major taste ingredient of dietary protein described as ‘Umami’ [168]. Free glutamate functions as a signal to regulate protein intake and energy homeostasis [169-173]. Major public concern has been raised in modern countries with regards to the use of monosodium glutamate (MSG) as a flavor enhancer [174]. Findings concluded that MSG had no long-term, serious health consequences [175]. Studies in primates, mice and rats provided some evidence that weight gain may be associated with MSG intake [176-178]. Human studies linking MSG and obesity were limited, but increasing obesity in Westernized nations with the addition of MSG to commercially prepared foods is evident [179]. In one study, MSG intake in Jiangsu province was not associated with obesity or weight gain after 5 years [179]. A study of underweight, protein and energy malnourished infants found that they preferred higher concentrations of MSG due to a heightened sensory response to amino acids to relieve this protein deficiency [170]. Another study found that enhancing the taste of the meal increased protein intake in geriatric patients, but it did not lead to a higher overall energy intake or weight gain [180]. There was a positive association between MSG consumption and the socio-economic status in rural China [179]. For instance, highly seasoned restaurant food contained as much as 5g or more of MSG [174]. Both rice and wheat are staple foods in southern China, whereas wheat starch is a staple food in northern China [179], which can be easily made more palatable with MSG.

Kazaks, Uyghurs and Mongolians are the major minorities in Xinjiang. The Kazaks have been reported to have hypertension [181], while obesity is common in the Uyghurs and Mongolians [182]. Significant differences in mean blood pressure between Han, Kazaks, Uyghurs and Tibetan ethnic groups were deemed to be caused by different diet-related habits. It is well-known that alcohol, high-sodium foods and meat are traditionally popular among these groups, which are associated with surviving the cold weather in Xinjiang. Traditionally among Kazaks, Uyghurs and Mongolians in Xinjiang, alcohol consumption is paired with eating large amounts of animal fat or salty dishes, which could lead to an increase in fibrinogen levels. Males in particular traditionally drink spirits to deal with the cold. Additionally, salted milk tea is consumed in large amounts; vegetables are also rare in this region, hence they are not commonly consumed [183].

BEHAVIORAL CAUSES

Eating disorders ranged from 1.3% to 5.21% among young Chinese females [184-188]. However, these data do not represent the entire population. Currently, there is little knowledge about weight control concerns and behaviors in China. BMI, dieting, and eating disorder symptoms are not clearly defined [189]. BMI was associated with eating disorders as well as obesity among teenagers [190-194]. One study demonstrated that those that were overweight or obese exhibited greater weight control concerns or behaviors compared to controls because they were more likely to be actively trying to lose weight and thus place themselves at risk [189]. Greater shape and weight concerns were observed among overweight females [195,196]. Another important study of adolescents in China found a strong association between smoking and the belief that smoking was important in weight control [197].

CONCLUSIONS

There exists a vast amount of knowledge on the topic of obesity, yet more research needs to be conducted in the Chinese population. Obesity in China is a multifactorial disease where intervention is not always clear-cut or applicable. For instance, specific general therapy may be available in the future to prevent childhood and adulthood weight gain and endocrine disorders. Lifestyle and behavioral changes need to be addressed and applied to prevent unhealthy physiques. Alternative medicine intervention, such as acupuncture and Traditional Chinese Medicine remedies, may be most appropriate for this part of the world. Overall, obesity is preventable and now is the ideal time in implementing current scientific methods and techniques to battle this epidemic.

CONFLICT OF INTEREST

The authors report no conflict of interest.

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