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Review

# Ethnic differences in body composition and the associated metabolic profile: A comparative study between Asians and Caucasians

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ABSTRACT

It is estimated that Asia will be the home of more than 100 million people with type 2 diabetes by the year of 2025. This region combines a high proportion of the world's population with rapidly rising diabetes prevalence rates. The increase in diabetes in Asia differs from that reported in other parts of the world: it has developed in a shorter time, in a younger age group, and in people with lower body-mass index (BMI).

Studies reported that for the same BMI, Asians have a higher body fat percentage, a prominent abdominal obesity, a higher intramyocellular lipid and/or a higher liver fat content compared to Caucasians. These characteristics may contribute to a higher predisposition to insulin resistance at a lesser degree of obesity than Caucasians. The differences in body composition are more pronounced depending on the region. For the same BMI, among three major ethnic groups in Asia, Asian Indians have the highest body fat, followed by Malay and Chinese.

Lower insulin sensitivity is already observed in Asian Indian adolescents with a higher body fat and abdominal obesity compared to Caucasian adolescents. In general, Asian adolescents share the same feature of body composition such as higher body subcutaneous fat, lower appendicular skeletal muscle and lower gynoid fat compared to Caucasian adolescents. This unfavourable body composition may predispose to the development of insulin resistance at later age. Genetics may play a role and the interaction with environmental factors (changes in lifestyle) could increase the risk of developing the metabolic syndrome.



**Contents**



## 1. Introduction

By the year 2025, 300 million people will have diabetes and among them more than 100 million people live in Asia [1]. This region combines a high proportion of the world's population with rapidly rising diabetes prevalence rates [2] due to the pronounced demographic, epidemiologic and socioeconomic changes in recent decades [3]. The increase of diabetes in Asia differs from that reported in other parts of the world: it has developed in a shorter time (3–5-fold increase within 30 years), in a younger age group (45–64 years old), and in people with a lower body-mass index (BMI) compared to that in Western countries [3].

BMI is significantly correlated with adiposity [4,5] and can predict body fat percentage adequately as long as age and gender

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are taken into account [6]. Excess adiposity (body fat) has been shown to be an independent risk factor for diabetes, cardiovascular disease, dyslipidaemia and hypertension [7]. The phenomenon in Asians, is most likely due to a higher percentage of body fat accumulation at a given BMI level compared to Caucasians [8], as pointed out by a series of comparative studies from Deurenberg et al. [9–11]. Hence, the relationship between body fat percentage and BMI is ethnic-specific [12]. Increased body fat percentage may affect individuals differently due to differences in genetic make-up, intra-uterine (developmental) environment, or dietary and physical activity patterns [8].

## 2. Comparative studies in body composition and fat distribution

### 2.1. Body composition

Numerous comparative studies reported that for the same BMI, age and gender, Asians had a higher body fat percentage compared to Caucasians. The studies were performed among South Asian Indians/Pakistani [13–18], East Asian Hong Kong Chinese [19], Japanese [20], Korean women [21] and Taiwanese [22] as well as Southeast Asian Indonesian [23], Singaporean [11] and Philipino [24]. Some studies reported no differences [11,25,26].

For the same BMI as Caucasians, the body fat percentage in Asians would be 5–7% higher in Indian men [13–15,17], 8% in Indian women [16–18], 1–4% in Japanese women [20], 5% and 7% for Indonesian men and women from Malay ancestry respectively [23], and 1.3% and 1.7% for Indonesian Chinese men and women respectively [23]. Interestingly, there was a tendency that the difference in body fat percentage became smaller with increasing BMI and age [20]. In Asians, it was predicted that with increasing age, the body fat percentage increased to a lesser degree than in Caucasians [17,21].

Among Asians, Indians have the highest body fat percentage followed by Malays and Chinese. The suggested BMI cut-off points for obesity are 26 kg/m$^2$ for Indians, 27 kg/m$^2$ for Malays and 27.5 kg/m$^2$ for Chinese, as compared to 30 kg/m$^2$ for Caucasians [27]. Pongchaiyatkul et al. [28] also suggested for Thai, the obesity cut-off point should be lowered to 27 kg/m$^2$ and 25 kg/m$^2$ for men and women respectively.

It can be concluded that the difference in body fat percentage between Asians and Caucasians is dependent on the region/ethnicity. It is most pronounced in South (Indians), than Southeast (Malay) and than East Asian (Chinese/Japanese). Ethnic differences in the relationship between BMI and % body fat may be explained by the difference in body build and frame size [9], in part by differences in muscularity and bone mineral content [16] as well as fat distribution and relative leg length [17].

### 2.2. Body fat distribution

Asians tend to have a higher abdominal fat mass compared to Caucasians as measured anthropometrically as waist circumference and waist to hip ratio or using computed tomography as subcutaneous abdominal and visceral fat content. This unfavourable fat distribution was found in Indians [16,17,25], Pakistani [29], Japanese [30,31], and Philipino [24]. For the same waist circumference as Caucasian, Philipino women [24] and Japanese men [30] had a higher visceral fat and visceral/subcutaneous abdominal fat ratio. While, Park et al. [32] reported that among East Asians the difference in visceral adipose tissue was only found in women. In addition, Gallagher et al. [33] found that the visceral fat depot was not significantly different between East Asians and Caucasians at low levels of adiposity.

In contrast, Chandalia et al. [14] reported that the higher abdominal adipose tissue in young Asian Indian men was mostly found in subcutaneous abdominal, while for the intraperitoneal abdominal fat there was no difference with Caucasians. It is important to notice that for the same level of subcutaneous abdominal fat, adipocyte size was higher in Indians.

High levels of fatty acids along with the inability of adipose tissue to store more lipid, induces lipid overflow to other tissues (ectopic fat depot) [34]. One study showed that Asian Indian had a higher intramyocellular lipid content compared to European Caucasians [13], while another study among Asian Indians reported no difference compared to American Caucasian [15]. With increasing adiposity, East Asians tended to accumulate fat as visceral fat but not intramyocellular [33]. Japanese men also developed a higher liver fat content compared to Caucasian men even with lower mean BMI [31].

In conclusion, Asians in general tend to have a higher abdominal fat compared to Caucasians. There was some inconsistency as to where exactly in the abdominal region the fat was stored. South Asians (Indian) stored more fat in the subcutaneous abdominal region, while East and Southeast Asians were found to store more fat viscerally.

## 3. The metabolic profile associated with the “unfavourable” body composition in Asians

The “unfavourable” body composition in Asians implicates some metabolic consequences. As Asians were found to have a higher risk to develop the metabolic syndrome at a relatively lower BMI [3], they were identified as metabolically obese but normal body weight (MONW) [35]. The existence of a subgroup of normal-weight individuals displaying an obesity-related phenotype was first proposed in 1981 by Ruderman et al. [36]. These individuals might be characterized by hyperinsulinemia and/or insulin resistance, hypertriglyceridemia and high blood pressure despite having a normal BMI ($< 25$ kg/m$^2$). When compared to control subjects, MONW subjects showed an altered insulin sensitivity, a higher abdominal and visceral adiposity, a more atherogenic lipid profile, a higher blood pressure and a lower physical activity energy expenditure. Additionally, they were at higher risk for developing diabetes and cardiovascular disease [35].

Among Asians, the metabolic consequences seemed to be more pronounced in Asian Indian as shown by the high prevalence of the metabolic syndrome, compared to other Asian countries [1,3]. Dhawan et al. [37] reported that Asian Indian who either lived in the UK or in India, had a higher total insulin, higher triglycerides and lower HDL than Caucasians, and that the waist to hip ratio (WHR) was the strongest independent predictor of the blood lipid profile. Forouhi et al. [13] and Misra et al. [38] confirmed that insulin sensitivity correlated with the WHR in South Asian men, but not with visceral fat, intramyocellular lipid, BMI and body fat. In contrast, Kamath et al. [18] reported an adverse blood lipid profile in Indian and Pakistani women compared to White Americans despite of no differences in WHR. In South Asian men, insulin resistance was observed to occur without a higher intraperitoneal fat depot, but was related to a large adipocyte size in subcutaneous abdominal fat. Hence, it appears to be related more to the excess truncal fat and dysfunctional adipose tissue than excess visceral fat [14].

After adjusting for BMI and waist circumference, Japanese were reported to have significantly higher blood levels of triglycerides, total-, HDL-, and LDL- cholesterol compared to Caucasians [39]. The liver fat content was also higher despite a lower BMI and it correlated with triglyceride levels, insulin resistance and C-reactive protein [31]. Egusa et al. [40] showed that among Japanese, the WHR of American-born Japanese was the highest followed by

Japanese migrants and Japanese who lived in Japan. The adverse fat distribution was followed by higher fasting insulin, serum cholesterol level and triglyceride levels in the same order.

A higher abdominal adiposity in Thai people was also significantly correlated with insulin sensitivity [41,42]. While in Philipino women, the prevalence of diabetes was higher at every level of visceral adipose tissue compared to white. However, visceral adipose tissue did not explain their elevated diabetes risk [24].

## 4. General discussion

Evidence showed that the high prevalence of metabolic disease in Asia was partly explained by an unfavourable body composition. However, there is a lack of understanding of the ethnic-specific nature of the association between the various components of body composition and morbidity sequelae [17]. For example, in contrast with Caucasians, the higher BMI, body fat percentage, visceral fat and intramyocellular lipid in Asian Indians did not correlate with insulin sensitivity [13], but waist to hip ratio did [13,37,38]. Increased abdominal adiposity and reduced appendicular skeletal muscle may be more important risk factors than total body fat in Asian Indians [17].

Body composition is determined by complex phenotypes for which multiple genetic and non-genetic factors are expected to be involved [43]. Results from genetic correlation analysis revealed some evidence of common genetic pathways underlying certain aspects of growth and adult health outcomes, including body composition and blood pressure variables [44]. Environmental factors are important, however they cannot account for all the characteristic of the epidemic in Asia [3]. Genetic [3,8] and intra-uterine development [8] may also play an important role. This was supported by several studies in Asian children and adolescents, which found that the unfavourable body composition was present from young age onwards. Since body composition consists of two major compartments, fat-free mass and fat mass, the discussion below is focussed on these two major body compartments.

Asian Indian babies were reported as lighter and smaller compared to UK babies but the subscapular skinfold thickness was larger [45]. The follow up study at 4 years of age, observed that the skinfold thickness of Asian Indian children was larger whereas all other anthropometric measurements were smaller [46], suggesting that the thin-fat phenotype is present from childhood onwards [46]. South Asian adolescents had a higher percentage of body fat and waist to hip ratio compared to white European. In addition, they had lower insulin sensitivity even though the effect of ethnicity was no longer seen when body fat was included as a covariate [47].

East Asian girls and boys were reported to have a lower appendicular skeletal muscle mass [48] and lower gynoid fat [49] than Caucasian girls and boys respectively. The difference in body fat percentage of Asian and Caucasian girls varied by BMI for age, with excess body fatness of Asians evident only among relatively thin children [50]. Sampei et al. [51] found no difference in body fat between Japanese and Caucasian boys, but Japanese boys had a statistically lower fat-free mass. Interestingly, the gain in fat free-mass and the loss in body fat when attaining maturation were greater in Caucasian boys. Singaporean boys and girls were also shorter, lighter, had a lower BMI but a higher sum of skinfold thickness and predicted body fat percentage than Dutch Caucasians [52].

It can be concluded that in general Asian whether observed in South Asian adults [16,17] or in East Asian adolescents [48,51] had a lower lean body mass/skeletal muscle mass compared to Caucasian. Based on the interesting finding that the gain in fat free-mass when attaining maturation was greater in Caucasians [51], it is most likely that this was genetically determined. A genome wide scan study on the variation in lean body mass was first reported by Liu et al. [53]. The study, which was replicated in three independent populations, two US Caucasian and one Chinese, reported the association between a polymorphism in the thyrotropin-releasing hormone receptor (TRHR) gene and variations in lean body mass. This receptor is known to have physiological relevance to the hypothalamic-pituitary-thyroid axis (HPTA) and the growth hormone-insuline-like growth factor-I (GH-IGF I) axis, which are responsible for the development of vertebrae skeletal muscle and muscle protein balance respectively [53].

Several studies found a significant correlation between fetal programming, growing during infancy and childhood, and adult body composition. It was consistently reported that birth weight was positively correlated with height [54–56] and higher fat-free mass in later life, both in Caucasians [54,56–58] and Asian Indians [59]. The genetic variation in lean body mass and the high correlation between fat-free mass and birth weight suggest that the intra-uterine environment might modify the effect of genes acting on lean body mass development and therefore body composition in later life, since lean body mass accounts for ∼60% or more of body weight [60]. The association between birth weight and later fatness was weaker both in Caucasians [54,61] and Asian Indians [59]. In addition, the association with fat distribution remains controversial and requires confirmation using more sophisticated methodology [61]. Others suggest that infancy [58,62] and early childhood [62] are critical periods, which have a large impact on body size and body composition in later life. Breast feeding during infancy [58] or dietary patterns and a sedentary life style during childhood might be the explanation but the causal effect still needs to be demonstrated [62]. Campbell et al. [63] reported that the stability of body composition indicators from childhood into adulthood was moderately high but measures of adipose tissue distribution were somewhat lower. While, Peeters et al. [64] found that subcutaneous fat distribution during adolescence was predominantly explained by genetic factors.

Several candidate genes associated with adiposity and fat distribution have been found across populations, among them, the FTO (fat mass and obesity related) gene may be one of the worldwide obesity-risk genes [65]. FTO gene variants were associated with adiposity both in Caucasian [66–70] and Asian populations [65,71–73]. Interestingly, the action of this gene becomes evident only after 7 years of age [74], is strengthened during childhood and adolescence, peaked at age 20 and weakened during adulthood [75]. Fatness induced by FTO polymorphisms in early childhood is sustained until early adulthood, where further weight gain may occur [76]. Taken together all these findings suggest that the action of this gene is strongly influenced by environmental factors such as physical activity and dietary patterns. This was supported by several studies which reported that an increase in BMI across FTO genotypes was found in those who had a high fat diet [77] and low physical activity both in the Caucasian [78–80] and Chinese and Malay population [72]. This might also explain the weaker association between birth weight and body fatness in later life due to the higher influence of postnatal exposure to the environment on the action of the FTO gene.

Different variants of this gene appeared to affect obesity and BMI in European and non-European populations [81]. In addition, the way the FTO gene works may also influence the susceptibility to diabetes in European and other populations [73]. The action of the FTO gene is possibly related to how it affects fat cell lipolysis [82]. Since there is heterogeneity in regional lipolysis in humans [83], it may lead to differences in fat deposition. This might be one of the possible explanations for the difference in fat distribution towards the central fat depot in Asians [13,14,17,20,30,31]. It was also supported by the fact that FTO gene variants were significantly associated with subcutaneous fat and a trend for liver fat content, non-visceral adipose tissue and visceral fat in Caucasians [68] and with waist circumference in Chinese and Malay [72].

In South Asian Indian however, FTO gene variants predisposed to diabetes but did not entirely do so through their influence on BMI, general and central adiposity [73]. Since Chandalia et al. [14] reported that insulin sensitivity in Indian correlated with a higher subcutaneous abdominal fat depot due to lipodistrophy (large adipocyte size). Another gene affecting lypolitic capacity such as the hormone-sensitive lipase (HSL) gene may also play a role. HSL was reported to have a significant correlation with fat cell size [84] and reduced activity of HSL in the abdominal subcutaneous fat depot led to a greater fat accumulation due to a lower fat mobilization [85]. However, polymorphisms in the HSL gene were reported to result in different adiposity phenotypes dependent on the race, gender and insulin level [85]. In addition, a polygenic approach found that diabetes susceptibility can be modulated by genetic variation in insulin action or insulin secretion depending on the level of obesity [86]. Thus, gene-gene interaction might play a role in the susceptibility to diabetes. This suggests a different possible mechanism, mediated by body composition and fat distribution, in the development of diabetes, in European and South Asian or other Asian populations that needs to be further investigated.

## 5. Conclusion

The difference in body fat percentage between Asians and Caucasians is dependent on the region/ethnicity. It is most pronounced in South (Indians), followed by Southeast (Malay) and than East Asian (Chinese/Japanese). In general, Asians tend to store more fat in abdominal regions.

Genetic variation in lean body mass and fat mass may predispose individuals in different ethnicities to a different muscularity and adiposity. The interaction with other genes or the environment, both prenatal and postnatal, as well as during the life course may modify the effect of genes on body composition, fat distribution and the associated metabolic profiles.

## Contributors

As the first author, Siti Wulan is responsible for most of the writing of the manuscript.

Klaas Westerterp and Guy Plasqui, as supervisors of Ms. Siti Wulan, have contributed by discussing the content of the paper, as well as reviewing and correcting the manuscript.

## Competing interests

The authors have no conflicts of interest.

## Provenance and peer review

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