


Assessing a new hip index as a risk predictor for diabetes mellitus

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Keywords

A new hip index, Diabetes mellitus, Ethnic specificities

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J Diabetes Investig 2018; 9: 799–805

doi: 10.1111/jdi.12756

ABSTRACT

Aims/Introduction: Recently, a new anthropometric parameter (a new hip index [HI]) was developed, and the HI shows a U-shaped relationship to mortality in the USA population. It is well known that there is an inverse relationship between hip circumference (HC) and the risk of diabetes mellitus. Accordingly, the study sought to investigate whether HI could predict future diabetes mellitus, as compared with HC and the waist-to-hip ratio (WHR), in a general Chinese population.

Materials and Methods: In 2007, we carried out a health examination of 687 participants (mean age 48.1 ± 6.2 years, male 58.1%). Development of diabetes mellitus by the 2007 examination was studied in relation to data from a baseline health examination carried out in 1992.

Results: During the follow up, 74 participants were diagnosed with diabetes mellitus. Across the quintiles of baseline HI, the incidence rates of diabetes mellitus were 12.4, 12.4, 9.9, 7.8 and 11.3% in quintile (Q)1, Q2, Q3, Q4 and Q5, respectively ($P = 0.698$). With the lowest quintile (Q1) as reference, univariate and multivariate Cox regression analyses showed that HI was not associated with diabetes mellitus. In contrast, HC and WHR could predict future diabetes mellitus. Furthermore, WHR had the best discriminatory power for diabetes mellitus (area under the receiver operating characteristic curve 0.691, 95% confidence interval 0.621–0.761), followed by HC (area under the receiver operating characteristic curve 0.623, 95% confidence interval 0.558–0.689) and HI (area under the receiver operating characteristic curve 0.464, 95% confidence interval 0.396–0.531).

Conclusions: Compared with HC and WHR, HI was not an independent risk factor for diabetes mellitus in the Chinese population. More studies are required to delineate the limits of the utility of HI.

INTRODUCTION

The global prevalence and incidence of diabetes mellitus have risen steadily. The number of adults with diabetes mellitus worldwide was estimated at 415 million in 2015, and is projected to reach 552 million by 2030¹ and 642 million by 2040². Inevitably, diabetes mellitus will be a major public health issue throughout the world. If we can identify the individuals who are at high risk of developing the new onset of diabetes mellitus, preventive actions could be used. Currently, many clinical practices have recommended anthropometric parameters for predicting future diabetes mellitus^{3–5}.

Recently, Krakauer *et al.*⁶ developed a new anthropometric parameter (a new hip index [HI]) based on hip circumference

(HC), height and weight. The normalized value of the HI is independent of height, body mass index (BMI) and a body shape index (ABSI), and the HI shows a U-shaped relationship to mortality in the USA population⁶. Furthermore, it is well known that there is an inverse relationship between HC and the risk of diabetes mellitus^{4,7–9}. However, it is unclear whether the new HC-based parameter, namely HI, is associated with diabetes mellitus in the Chinese population. In the present study, we sought to investigate whether HI could predict future diabetes mellitus, as compared with HC and the waist-to-hip ratio (WHR), in a general Chinese population during 15 years of follow up.

METHODS

Participants and Study Design

In 2007, health examinations were carried out on 711 individuals in an urban community located in Chengdu, Sichuan

Received 20 March 2017; revised 16 August 2017; accepted 25 September 2017

Province, China. These participants also accepted health examinations in 1992; therefore, we picked up the data. The two examinations were supported by a project from China's eighth national 5-year research plan and a megaproject of science research for China's 11th 5-year plan. Detailed information on these studies has been reported elsewhere^{10–12}. As 24 participants had diabetes mellitus in 1992, the remaining 687 participants were included for the present analysis. This study was approved by the Ministry of Health of the People's Republic of China and the Ethics Committee of Fuwai Hospital of the Chinese Academy of Medical Sciences, as well as by the Ethics Committee of West China Hospital of Sichuan University. All participants gave informed written consent.

Related Definitions

HC was measured at the maximum protrusion of the gluteal region (accuracy 0.5 cm), and waist circumference (WC) was measured at the midpoint between the lower rib and the upper margin of the iliac crest at the end of a normal exhalation (accuracy 0.5 cm). Height without shoes was measured in centimeters (accuracy 1.0 cm), and weight in light clothing was measured in kilograms (accuracy 0.2 kg). BMI was calculated as weight (kg)/height (m)², and WHR was defined as WC (cm)/HC (cm). HI was defined as $HC (H/[H])^{0.310} (W/[W])^{0.482}$, where height (H) = 166 cm and weight (W) = 73 kg were average values⁶.

ABSI was defined as $WC/(BMI^{2/3} \text{height}^{1/2})$, expressing WC and height in m¹³. The z -score was calculated as $(\text{Parameter} - \text{Parameter}_{\text{mean}})/\text{Parameter}_{\text{SD}}$ ($\text{Parameter}_{\text{mean}}$, mean values of the present study population; $\text{Parameter}_{\text{SD}}$, standard deviation of the present study population), and the $\text{Parameter}_{\text{mean}}$ and $\text{Parameter}_{\text{SD}}$ were derived from the present study population. Diabetes mellitus was defined by self-reported history or a fasting plasma glucose ≥ 7.0 mmol/L.

Statistical Analysis

Continuous variables are presented as mean \pm standard deviation and median with interquartile range where appropriate, and categorical variables as frequencies (n) and percentages (%). Comparisons of baseline characteristics between diabetes patients and non-diabetic participants were carried out by independent t -test and non-parametric Mann–Whitney U -test where appropriate. Interactions between categorical variables were evaluated with the χ^2 -test. Correlations between different variables were determined using Pearson's or Spearman's analysis. To quantify in a simple form the relationship between HI and diabetes mellitus, the participants were divided into five groups according to the baseline HI, which were categorized separately as follows: the first quintile ($Q1 < 96.6$ cm), the second quintile ($96.6 \text{ cm} \leq Q2 < 99.2$ cm), the third quintile ($99.2 \text{ cm} \leq Q3 < 101.4$ cm), the fourth quintile

Table 1 | Baseline characteristics

Variable	Subsequent diabetes patients ($n = 74$)	Subsequent non-diabetic participants ($n = 613$)	P -value
Age (years)	49.8 \pm 5.7	47.9 \pm 6.2	0.013
Male sex	48 (64.9)	351 (57.3)	0.210
SBP (mm Hg)	119.5 (106.8–129.3)	110.0 (104.0–120.0)	0.021
DBP (mm Hg)	75.7 \pm 9.6	72.0 (70.0–80.0)	0.095
FPG (mmol/L)	4.6 \pm 0.8	4.0 (3.8–4.7)	<0.001
TC (mmol/L)	4.7 \pm 0.7	4.3 (3.9–5.0)	0.023
TG (mmol/L)	2.6 \pm 1.2	1.8 (1.5–2.3)	<0.001
LDL-C (mmol/L)	2.3 \pm 0.9	2.3 \pm 0.8	0.776
HDL-C (mmol/L)	1.2 \pm 0.2	1.2 (1.1–1.4)	0.007
HI (cm)	99.8 \pm 4.2	100.3 \pm 4.1	0.341
HC (cm)	94.9 \pm 7.1	91.9 \pm 5.6	<0.001
WHR	0.86 \pm 0.05	0.82 (0.78–0.87)	<0.001
BMI (kg/m ²)	25.1 \pm 3.3	23.2 \pm 2.7	<0.001
WC (cm)	82.0 \pm 8.4	75.9 \pm 7.6	<0.001
Height (cm)	160.7 \pm 8.4	160.9 \pm 7.6	0.801
Weight (kg)	64.9 \pm 10.5	60.1 \pm 8.5	<0.001
ABSI (m ^{11/6} kg ^{-2/3})	0.0757 \pm 0.0041	0.0737 \pm 0.0044	<0.001
Hypertension	16 (21.6)	88 (14.4)	0.099
Family history of DM	6 (8.1)	20 (3.3)	0.039
Exercise	14 (18.9)	132 (21.5)	0.604

Data are presented as mean \pm standard deviation or median with interquartile range, or number (percentage). ABSI, a body shape index; BMI, body mass index; DBP, diastolic blood pressure; DM, diabetes mellitus; FPG, fasting plasma glucose; HC, hip circumference; HDL-C, high-density lipoprotein cholesterol; HI, hip index; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; WC, waist circumference; WHR, waist-to-hip ratio.

Table 2 | Correlations between body size and shape

	HI	HC	WHR	BMI	WC	Height	Weight	ABSI
HI	1	0.284	−0.533	−0.135	−0.180	−0.445	−0.377	0.092
HC	0.325	1	0.190	0.769	0.730	0.145	0.728	0.171
WHR	−0.533	0.190	1	0.367	0.786	0.360	0.527	0.746
BMI	−0.131	0.782	0.367	1	0.725	−0.085	0.757	−0.040*
WC	−0.180	0.730	0.786	0.725	1	0.324	0.808	0.611
Height	−0.455	0.145	0.360	−0.085	0.324	1	0.571	0.283
Weight	−0.377	0.733	0.527	0.757	0.808	0.571	1	0.155
ABSI	0.092	0.162	0.746	−0.040*	0.611	0.283	0.155	1

Correlation coefficients between hip index (HI), hip circumference (HC), waist-to-hip ratio (WHR), body mass index (BMI), waist circumference (WC), height, weight and a body shape index (ABSI) among the participants (all P -values <0.05 , if not otherwise indicated; * $P > 0.05$). Right side (above diagonal) shows the correlations of the raw values; left side (below diagonal) shows the correlations of the z -scores.

(101.4 cm \leq Q4 $<$ 103.7 cm) and the fifth quintile (103.7 cm \leq Q5). The cumulative probability of diabetes mellitus by HI subgroups was graphically displayed according to the method of Kaplan and Meier, with comparison of groups by the log-rank test. To assess the impact of the variables on the incidence rate of diabetes mellitus over the follow-up period, Cox proportional hazards models were used. Area under the receiver operating characteristic curve (AROC) was used to examine the discriminatory power of anthropometric parameters for diabetes mellitus. All analyses were carried out with Spss (version 17.0; SPSS, Chicago, Illinois, USA), and statistical significance was defined as $P < 0.05$.

RESULTS

In the present study, the age distribution of the 687 participants was 48.1 ± 6.2 years (male 58.1%), and the mean/variance of HI, HC, height and weight were 100.2 ± 4.2 cm, 92.2 ± 5.8 cm, 160.9 ± 7.7 cm and 60.6 ± 8.9 kg, respectively. The baseline data showed HI and height did not differ between the subsequent diabetes patients or subsequent non-diabetes patients, and other anthropometric parameters were significantly greater in the subsequent diabetes patients (Table 1). Correlation coefficients of HI/HI z -score with other anthropometric parameters are shown in Table 2. HI/HI z -score had a mild-to-moderate correlation with other anthropometric parameters except ABSI.

During the follow up from 1992 to 2007, 74 participants were diagnosed with diabetes mellitus (incidence rate 10.8%). The participants were divided into five groups by the quintiles of baseline HI, and there were 129 participants in Q1, 145 participants in Q2, 131 participants in Q3, 141 participants in Q4 and 141 participants in Q5, respectively. Across the quintiles, 16, 18, 13, 11 and 16 diabetes patients were received in Q1, Q2, Q3, Q4 and Q5, respectively. The crude incidence rates of diabetes mellitus were 12.4, 12.4, 9.9, 7.8 and 11.3% in Q1, Q2, Q3, Q4 and Q5, respectively ($P = 0.698$). The cumulative probability of diabetes mellitus evaluated by a Kaplan–Meier analysis

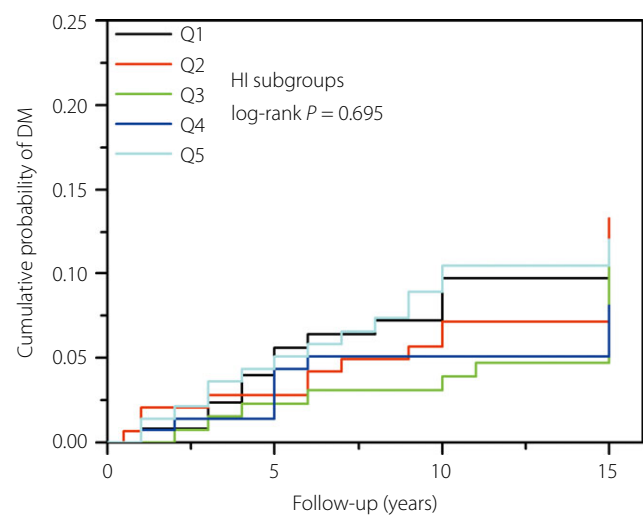


Figure 1 | Cumulative probability of diabetes mellitus by hip index (HI) subgroups. DM, diabetes mellitus; Q, quintile.

were similar across the quintiles of HI (log-rank $P = 0.695$; [Figure 1]).

Among the anthropometric parameters shown in Table 1, univariate Cox regression analysis showed that HI and height were not significant predictors of diabetes mellitus, and many other variables could predict future diabetes mellitus (Table 3). After adjusting for confounders, HI could still not predict future diabetes mellitus (Table 4). Consistent with these findings, multivariate analysis showed that HI z -score was not significantly related to the new onset of diabetes mellitus (data not shown). Although, HC and WHR could predict future diabetes mellitus (Tables 3 and 4). Furthermore, a cubic spline smoothing technique was used to study the shape of the relationship of HI as well as HC and WHR with the logarithm of the relative risk of diabetes mellitus, and the results showed that there might be a linear approximation for the three variables. We also analyzed multivariate Cox models with HI/HC/WHR as linear continuous predictors. After adjusting for confounding

Table 3 | Univariate Cox regression analysis of diabetes mellitus

Variable	Change	HR	95% CI	P-value
Age	Per 1-year increase	1.05	1.01–1.09	0.017
Female sex	Yes vs no	0.75	0.46–1.20	0.229
SBP	Per 1-mmHg increase	1.02	1.00–1.03	0.011
DBP	Per 1-mmHg increase	1.02	1.00–1.05	0.055
FPG	Per 1-mmol/L increase	1.79	1.35–2.37	<0.001
TC	Per 1-mmol/L increase	1.32	1.01–1.73	0.042
TG	Per 1-mmol/L increase	1.34	1.17–1.53	<0.001
LDL-C	Per 1-mmol/L increase	1.04	0.79–1.37	0.763
HDL-C	Per 1-mmol/L increase	0.26	0.09–0.74	0.011
HI				
Q1		1		
Q2		0.99	0.50–1.94	0.970
Q3		0.78	0.37–1.61	0.497
Q4		0.61	0.29–1.32	0.213
Q5		0.92	0.46–1.84	0.815
HC	Per 1-cm increase	1.09	1.05–1.14	<0.001
WHR	Per 0.01 increase	1.10	1.06–1.14	<0.001
BMI	Per 1-kg/m ² increase	1.26	1.17–1.37	<0.001
WC	Per 1-cm increase	1.10	1.07–1.13	<0.001
Height	Per 1-cm increase	1.00	0.97–1.03	0.808
Weight	Per 1-kg increase	1.06	1.03–1.09	<0.001
ABSI	Per 0.001-m ^{11/6} kg ^{-2/3} increase	1.08	1.04–1.13	<0.001
Hypertension	Yes vs no	1.58	0.91–2.75	0.105
Family history of DM	Yes vs no	2.40	1.04–5.54	0.040
Exercise	Yes vs no	0.87	0.49–1.56	0.642

ABSI, a body shape index; BMI, body mass index; DBP, diastolic blood pressure; DM, diabetes mellitus; FPG, fasting plasma glucose; HC, hip circumference; HDL-C, high-density lipoprotein cholesterol; HI, hip index; LDL-C, low-density lipoprotein cholesterol; Q, quintile; SBP, systolic blood pressure; TC, total cholesterol; TG, triglyceride; WC, waist circumference; WHR, waist-to-hip ratio.

Table 4 | Multivariate Cox regression analysis of diabetes mellitus

Quintile	Hazard ratios (95% CI)					
	HI [†]	P-value	HC [‡]	P-value	WHR [§]	P-value
1 (lowest)	1	NA	1	NA	1	NA
2	1.30 (0.65–2.60)	0.460	0.53 (0.20–1.36)	0.185	2.69 (0.55–13.05)	0.220
3	1.14 (0.53–2.44)	0.745	0.31 (0.11–0.88)	0.027	5.65 (1.26–25.27)	0.023
4	1.25 (0.52–3.02)	0.619	0.39 (0.14–1.07)	0.067	5.03 (1.12–22.67)	0.036
5 (highest)	1.63 (0.68–3.90)	0.273	0.21 (0.06–0.69)	0.010	6.64 (1.45–30.51)	0.015

[†]From Cox regression model with adjustment for sex, age, systolic blood pressure (SBP), fasting plasma glucose (FPG), total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), waist circumference (WC) and history of diabetes mellitus in family. [‡]From Cox regression model with adjustment for sex, age, SBP, FPG, TC, TG, HDL-C, body mass index (BMI), WC and history of diabetes mellitus in family. [§]From Cox regression model with adjustment for sex, age, SBP, FPG, TC, TG, HDL-C, BMI and history of diabetes mellitus in family. Hazard ratios are relative to the lowest quintile in each case. The between-quintile cut points are 103.7, 101.4, 99.2 and 96.6 cm for hip index (HI); 97, 94, 91 and 87 cm for hip circumference (HC); 0.88, 0.84, 0.81 and 0.78 for waist-to-hip ratio (WHR). CI, confidence interval; NA, not available.

variables, only WHR reached both statistical and clinical significance, and the risk of diabetes mellitus was 1.42 (95% confidence interval [CI] 1.08–1.88, $P = 0.013$) for a per-standard deviation change in WHR. The risk of diabetes mellitus was 1.02 (95% CI: 0.76–1.36, $P = 0.904$) and 0.76 (95% CI: 0.51–1.12, $P = 0.160$) for HI and HC, respectively. In addition,

WHR had the best discriminatory power for diabetes mellitus (AROC 0.691, 95% CI: 0.621–0.761; Figure 2).

We also used a supplementary set of multivariate Cox models that omitted the laboratory measurements as covariates (Table 5), which might answer the public health question of whether/how anthropometry could identify people at risk for

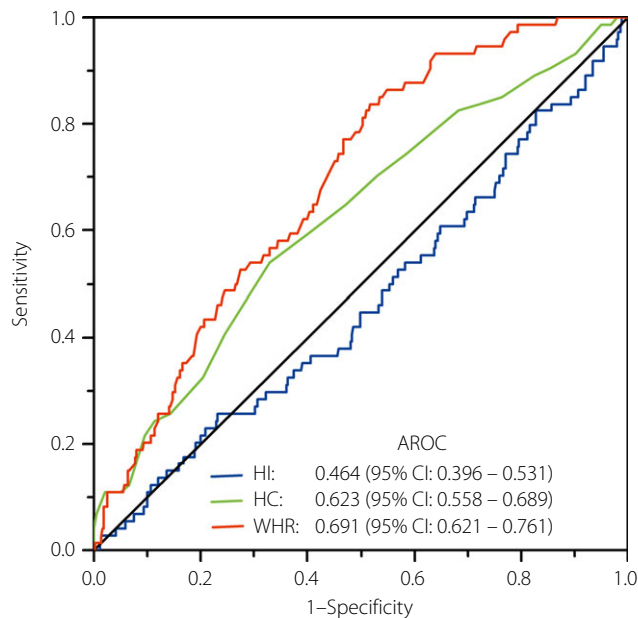


Figure 2 | A receiver operating characteristic curve of hip index (HI) to predict diabetes mellitus. AROC, area under the receiver operating characteristic curve; CI, confidence interval; HC, hip circumference; WHR, waist-to-hip ratio.

diabetes mellitus without regular universal laboratory testing. The results showed anthropometric parameters could identify people at risk for diabetes mellitus independently (Table 5), similar to the findings as shown in Table 4.

DISCUSSION

The main aims of the present study were to assess whether HI could predict future diabetes mellitus, as compared with HC and WHR, in a general Chinese population during 15 years of follow up. The results suggested that HI was not an independent risk factor for diabetes mellitus in the Chinese population, and further studies are required to explore the specificities of HI in different populations.

Some studies^{4,9} have shown that WHR is positively associated with the risk of diabetes mellitus, and the present study also showed similar results. Like some previous findings^{7,8,14}, HC showed an inverse association with the risk of diabetes mellitus. Although the exact mechanisms for the negative effects of HC on the risk of diabetes mellitus are not entirely clear, some studies have reported that more peripheral fat accumulation in the hips might be associated with a more favorable metabolic profile⁷. More studies are required to expand our understanding of the metabolism and function of adipocytes located at different sites of the body⁹. However, HC and WHR are highly correlated to BMI or WC, and several studies have failed to show added value of HC-based indicators compared with those only based on height, weight and WC^{15,16}. To avoid these drawbacks, a new anthropometric parameter, namely HI, has emerged, which is based on HC, height and weight⁶. In the original research, the normalized value of HI is independent of height, BMI and ABSI, and the researchers believe that HI can be understood as the HC of a given person normalized to a standard height and weight. In the original research, HI showed a U-shaped relationship to mortality in USA populations⁶. Nevertheless, whether the same coefficients could be used to properly standardize HC for weight and height in populations that might not have the same pattern of body size and shape is unknown, as well as the usefulness of HI for prediction of diabetes mellitus.

Although the relationship between HI and mortality has been shown in USA populations, there are no data regarding the relationship between HI and diabetes mellitus. To the best of our knowledge, we are the first to examine the specific relationship between HI and diabetes mellitus, and the results showed that HI had no significant association with diabetes mellitus in the general Chinese population. Currently, a comprehensive understanding of the weak association between HI and diabetes mellitus is not yet available; however, some speculations can be made. First, a possible explanation for the contrasting findings between our data and Krakauer *et al.*⁶ is the end-point variable, namely diabetes mellitus vs mortality.

Table 5 | Multivariate Cox regression analysis of diabetes mellitus that omits the laboratory measurements as covariates

Quintile	Hazard ratios (95% CI)					
	HI [†]	P-value	HC [‡]	P-value	WHR [§]	P-value
1 (lowest)	1	NA	1	NA	1	NA
2	1.18 (0.60–2.33)	0.639	0.49 (0.19–1.26)	0.136	3.07 (0.63–14.84)	0.164
3	0.91 (0.43–1.93)	0.797	0.34 (0.13–0.94)	0.037	7.19 (1.62–31.93)	0.010
4	0.92 (0.39–2.17)	0.848	0.34 (0.12–0.92)	0.034	6.51 (1.45–29.21)	0.014
5 (highest)	1.10 (0.47–2.57)	0.829	0.18 (0.06–0.59)	0.005	8.75 (1.93–39.70)	0.005

[†]From Cox regression model with adjustment for sex, age, systolic blood pressure (SBP), waist circumference (WC) and family history of diabetes mellitus.

[‡]From Cox regression model with adjustment for sex, age, SBP, body mass index (BMI), WC and family history of diabetes mellitus. [§]From Cox regression model with adjustment for sex, age, SBP, BMI and family history of diabetes mellitus. Hazard ratios are relative to the lowest quintile in each case. The between-quintile cut points are 103.7, 101.4, 99.2 and 96.6 cm for hip index (HI); 97, 94, 91 and 87 cm for hip circumference (HC); 0.88, 0.84, 0.81 and 0.78 for waist-to-hip ratio (WHR).

Second, the coefficients of HI formula are derived from a USA population of the third National Health and Nutrition Examination Survey (NHANES III; mainly including black and Mexican American people)¹⁷, and the coefficients might not be suitable for the Chinese population. For example, our study population had approximately the same HI values as the original research (100 vs 100 cm), but surprisingly the present study population had a lower HC (92 vs 99 cm), height (161 vs 166 cm) and weight (61 vs 73 kg). In addition, these z-scores for HI, height, BMI and ABSI were found, in both NHANES III and the Atherosclerosis Risk in Communities study, to indeed be mutually almost uncorrelated in the original research⁶; however, in the present study, the HI z-score was only independent of ABSI (Table 2). It is likely that the NHANES III-derived HI should be modified for application to non-USA populations¹⁸. Although the use of the same index has the advantage for international comparison, it incurs a cost of not being optimal in a local population. Researchers should balance these two concerns in their analysis. Third, a greater muscle mass in the gluteofemoral region might be associated with a lower risk of diabetes mellitus¹⁹, and a number of studies have also reported that more peripheral fat accumulation in the hips and thighs for a given amount of abdominal fat might be associated with a more favorable metabolic profile^{20,21}. Larger HC means more muscle and fat tissues in the gluteofemoral region; therefore, it should be associated with a lower risk of developing diabetes mellitus. In the present study population, the HC values were lower than in the NHANES III population⁶, and this might also be a possible reason.

Certain limitations need to be considered in the present study. First, because the study was based on retrospective data, it was probable that not all the factors related to diabetes mellitus were included in the analysis. Second, some participants with diabetes mellitus might be missed for the absence of an oral glucose tolerance test, raising the possibility of some bias in the estimated risks. Third, the results of the present study might have limited statistical power for the relatively small sample size; but we still could obtain some clues. Fourth, the participants included in the study were from a single center and the findings could not be generalized. Further studies are required and warranted.

In conclusion, the new anthropometric parameter, namely HI, could not predict future diabetes mellitus compared with HC and WHR in the general Chinese population. More studies are required to determine whether the findings of the current study can be generalized to other populations.

ACKNOWLEDGMENTS

This study was supported by a project from China's eighth national 5-year research plan (grant no: 85-915-01-02), megaprojects of science research for China's 11th 5-year plan (grant no: 2006BAI01A01) and the National Natural Science Foundation of China (grant number: 81600299).

DISCLOSURE

The authors declare no conflict of interest.

REFERENCES

- Whiting DR, Guariguata L, Weil C, et al. IDF diabetes atlas: global estimates of the prevalence of diabetes for 2011 and 2030. *Diabetes Res Clin Pract* 2011; 94: 311–321.
- Quan J, Li TK, Pang H, et al. Diabetes incidence and prevalence in Hong Kong, China during 2006–2014. *Diabet Med* 2017; 34: 902–908.
- Alperet DJ, Lim WY, Mok-Kwee Heng D, et al. Optimal anthropometric measures and thresholds to identify undiagnosed type 2 diabetes in three major Asian ethnic groups. *Obesity (Silver Spring)* 2016; 24: 2185–2193.
- Cameron AJ, Magliano DJ, Soderberg S. A systematic review of the impact of including both waist and hip circumference in risk models for cardiovascular diseases, diabetes and mortality. *Obes Rev* 2013; 14: 86–94.
- Kumanyika SK, Obarzanek E, Stettler N, et al. Population-based prevention of obesity: the need for comprehensive promotion of healthful eating, physical activity, and energy balance: a scientific statement from American Heart Association Council on Epidemiology and Prevention, Interdisciplinary Committee for Prevention (formerly the expert panel on population and prevention science). *Circulation* 2008; 118: 428–464.
- Krakauer NY, Krakauer JC. An anthropometric risk index based on combining height, weight, waist, and hip measurements. *J Obes* 2016; 2016: 8094275.
- Janghorbani M, Momeni F, Dehghani M. Hip circumference, height and risk of type 2 diabetes: systematic review and meta-analysis. *Obes Rev* 2012; 13: 1172–1181.
- Conway B, Xiang YB, Villegas R, et al. Hip circumference and the risk of type 2 diabetes in middle-aged and elderly men and women: the Shanghai women and Shanghai men's health studies. *Ann Epidemiol* 2011; 21: 358–366.
- Parker ED, Pereira MA, Stevens J, et al. Association of hip circumference with incident diabetes and coronary heart disease: the Atherosclerosis Risk in Communities study. *Am J Epidemiol* 2009; 169: 837–847.
- He S, Chen X. Could the new body shape index predict the new onset of diabetes mellitus in the Chinese population? *PLoS One* 2013; 8: e50573.
- Ren J, Grundy SM, Liu J, et al. Long-term coronary heart disease risk associated with very-low-density lipoprotein cholesterol in Chinese: the results of a 15-year Chinese Multi-Provincial Cohort Study (CMCS). *Atherosclerosis* 2010; 211: 327–332.
- Liu J, Hong Y, D'Agostino RB Sr, et al. Predictive value for the Chinese population of the Framingham CHD risk assessment tool compared with the Chinese Multi-Provincial Cohort Study. *JAMA* 2004; 291: 2591–2599.

13. Krakauer NY, Krakauer JC. A new body shape index predicts mortality hazard independently of body mass index. *PLoS One* 2012; 7: e39504.
14. Bozorgmanesh M, Hadaegh F, Zabetian A, *et al.* Impact of hip circumference and height on incident diabetes: results from 6-year follow-up in the Tehran Lipid and Glucose Study. *Diabet Med* 2011; 28: 1330–1336.
15. Song X, Jousilahti P, Stehouwer CD, *et al.* Comparison of various surrogate obesity indicators as predictors of cardiovascular mortality in four European populations. *Eur J Clin Nutr* 2013; 67: 1298–1302.
16. Czernichow S, Kengne AP, Stamatakis E, *et al.* Body mass index, waist circumference and waist-hip ratio: which is the better discriminator of cardiovascular disease mortality risk?: evidence from an individual-participant meta-analysis of 82 864 participants from nine cohort studies. *Obes Rev* 2011; 12: 680–687.
17. Ezzati TM, Massey JT, Waksberg J, *et al.* Sample design: Third National Health and Nutrition Examination Survey. *Vital Health Stat* 1992; 2: 1–35.
18. Cheung YB. “A Body Shape Index” in middle-age and older Indonesian population: scaling exponents and association with incident hypertension. *PLoS One* 2014; 9: e85421.
19. Manolopoulos KN, Karpe F, Frayn KN. Gluteofemoral body fat as a determinant of metabolic health. *Int J Obes (Lond)* 2010; 34: 949–959.
20. Snijder MB, Dekker JM, Visser M, *et al.* Trunk fat and leg fat have independent and opposite associations with fasting and postload glucose levels: the Hoorn study. *Diabetes Care* 2004; 27: 372–377.
21. Tanko LB, Bagger YZ, Alexandersen P, *et al.* Peripheral adiposity exhibits an independent dominant antiatherogenic effect in elderly women. *Circulation* 2003; 107: 1626–1631.