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Articles

The association between components of adult height and Type II diabetes and insulin resistance: British Women's Heart and Health Study

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Abstract

Aims/hypothesis. The aim of this study was to investigate the associations between components of adult height (leg length, trunk length, ratio of leg to trunk length) and Type II (non-insulin-dependent) diabetes mellitus and insulin resistance.
Methods. A cross sectional study was carried out on 4286 women of age 60 to 79 years from 23 towns across England, Scotland and Wales.
Results. Total height was weakly and inversely associated with diabetes but this masked differences in the association with leg and trunk length. Leg length was inversely associated with Type II diabetes [age adjusted odds ratio (95% CI) for diabetes for each standard deviation (4.3 cm) increase in leg length: 0.81 (0.73, 0.90)] whereas trunk length was not associated with diabetes [age adjusted odds ratio (95% CI) for diabetes for each standard deviation (3.6 cm) increase in trunk length: 1.05 (0.94, 1.18)]. Adjustment for potential confounding factors attenuated but did not remove the inverse association between leg length and the prevalence of diabetes: fully adjusted odds ratio (95% CI) per standard deviation increase in leg length was 0.87 (0.77, 0.98) and that per standard deviation increase in the ratio of leg to trunk length was 0.88 (0.78, 0.99). In non-diabetic women leg length was inversely associated with insulin resistance, whereas trunk length was positively associated with insulin resistance.
Conclusion/interpretation. Leg length is an indicator of early childhood environmental circumstances, in particular of infant nutrition. These results suggest that poor infant nutrition is an important causal factor in the development of Type II diabetes and insulin resistance in later life. [Diabetologia (2002) 45: 1097–1106]

Keywords Type II diabetes mellitus, insulin resistance, stature, leg length, trunk length, childhood environment, epidemiology.

A number of studies have found that short stature is associated with increased risk of glucose intolerance, Type II (non-insulin-dependent) diabetes mellitus and gestational diabetes [1, 2, 3, 4, 5]. The underlying mechanisms for this association, and therefore its relevance to the aetiology and prevention of diabetes, is not understood. Reverse causality could be important since diabetes is associated with osteoporosis [6], which results in reduced stature due to vertebral collapse. It has also been postulated that greater age-related reductions in height could occur in people with chronic diseases compared to those who are disease free and that this could explain the association between short stature and chronic diseases, such as coronary heart disease and diabetes [7]. Assuming the association is not due to bias or reverse causality, genetic factors with pleiotropic effects that influence both growth and glucose intolerance could explain the association; alternatively, intra-uterine or childhood environmental factors could be important [8].

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One way of exploring the underlying mechanism for the association between short stature and diabetes is to look at the association between components of height and diabetes. The interruption of growth at any time during the life course, but particularly during childhood, results in a relatively long torso and short legs [9, 10, 11]. Adult short-leg length, relative to trunk length, is a useful indication of poor childhood environmental conditions, in particular poor infant feeding [11]. Osteoporotic shrinkage will have a minimal effect on leg length and differential shrinkage due to chronic disease is not likely to have a marked effect on leg length relative to trunk length.

A recent study has shown that leg length is the component of height that underlies the association between adult stature and coronary heart disease [12]. Leg length, but not trunk length, in this study, was inversely associated with coronary heart disease risk and with components of the insulin resistance syndrome [12].

Our aim was to investigate the associations between components of adult height and Type II diabetes and insulin resistance.

Subjects and methods

Participants. The British Women's Heart and Health Study is a sample of women aged 60 to 79 years randomly selected from general practitioner lists from 23 towns across England, Scotland and Wales. The selection of towns, general practitioners and participants was based on the methods used for the British Regional Heart Study of men [13]. A total of 4286 women (60% of those invited) participated and baseline data were collected between April 1999 and March 2001. Participants completed a questionnaire requesting information on a wide range of risk factors, and attended a local health centre where a research nurse interview, physical examination and blood sampling were undertaken. General practitioner medical records were also reviewed for each participant and details (including date of diagnosis) of diagnoses of cardiovascular disease, diabetes and cancer extracted.

Measurements. Standing and seated height were measured, without shoes, using a Harpenden Stadiometer (Critikon Service Centre, Berkshire, UK) recording to the nearest millimetre. Trunk length was calculated as the seated height minus the height of the stool. Leg length was taken as the standing height minus the trunk length. Diabetes was defined according to the World Health Organisation (WHO) criteria as any woman with a doctor diagnosis of diabetes and/or with a fasting glucose concentration of more than or equal to 7 mmol/l [14]. Type II diabetes was defined on the basis of age at diagnosis. All women who were diagnosed at age 30 or older were considered to have Type II diabetes.

Blood samples were taken after a 12-h fast. Glucose and insulin were measured on fasting venous plasma samples. Insulin was measured with a specific ELISA assay which does not cross-react with proinsulin [15]. Insulin resistance was estimated according to the homeostasis model assessment (HOMA) [16] as the product of fasting plasma glucose and insulin concentrations divided by the constant 22.5. HOMA scores were not calculated for diabetic women.

Total cholesterol, high density lipoprotein cholesterol (HDL_c) and triglycerides were measured on frozen serum samples using an Hitachi 747 analyser (Hitachi, Tokyo, Japan) and standard reagents. Low density lipoprotein cholesterol (LDL_c) was estimated using the Friedwald equation: LDL_c = total cholesterol minus (HDL_c + triglycerides*0.45) [17].

Weight was measured in light clothing without shoes to the nearest 0.1 kg using Soenhle portable scales (Critikon Service Centre, Berkshire, UK). Waist circumference was taken as the midpoint between the lower rib and the iliac crest. Hip circumference was taken as the largest circumference below the waist. In all analyses two measurements of both waist and hip circumference were taken to the nearest millimetre using a flexible metal tape and the mean of these two used.

A Dinamap 1846SX (GE Clinical Services, Northampton, UK) vital signs monitor was used to measure blood pressure. Arm circumference was measured and the appropriate cuff size was used. Seated blood pressure was taken twice in succession, using the right arm, supported on a cushion and the mean of the two measurements used in all analyses.

Adult social class was defined on the basis of the longest held occupation of her husband for married women and her own longest held occupation for single women. Childhood social class was defined on the basis of the longest held occupation of the woman's father.

Full ethics committee approval for the study was obtained from Local Ethics Committees in each of the 23 participating towns and informed consent to review their general practice medical records was obtained from each participant included in the study.

Statistical analysis. To illustrate the direction and shape of any associations between the four height components – leg length, trunk length, total height and leg to trunk ratio – and other variables, quartiles were used. Age-adjusted means and prevalence of each variable were assessed for these quartiles using linear regression and logistic regression models. Multiple logistic regression was used to assess the association between each component of height and diabetes prevalence and multiple linear regression to assess the association between components of height and insulin resistance. In these models age, systolic blood pressure, diastolic blood pressure, high density lipoprotein cholesterol, low density lipoprotein cholesterol, triglycerides (logged), weight and waist-to-hip ratio were entered as continuous variables. Adult and childhood social class (I, II, III non-manual, III manual, IV, V), and smoking (never-smoked, ex-smoker, current-smoker) were entered as categorical variables, together with two dummy variables representing those for whom adult social class or childhood social class was not available (425 and 544 subjects respectively). HOMA scores and triglyceride concentrations were log normal: geometric means are shown and the natural log of the concentrations were used in the regression models.

Results

Of the 4286 women 218 had a doctor's diagnosis of diabetes. Of these, five had been diagnosed at 30 years of age or younger (age range 18–28). For 13 women data on age at diagnosis was not available; of these women four were using insulin to control their diabetes. These four together with the five diagnosed at age 30 or younger (all of whom used insulin to control their diabetes) were all assumed to have Type I (insulin-dependent) diabetes mellitus and were ex-

Table 1. Age standardised mean or prevalence (95% CI) of diabetes, insulin resistance and other characteristics by components of height

	Leg length quartile (range of leg length cm)				Difference per SD leg length[a] (1SD=4.3 cm)	*p* trend
	1 (34.6–73.1)	2 (73.2–75.7)	3 (75.8–78.3)	4 (78.4–100.7)		
Age (years)	69.1 (68.8, 69.5)	68.9 (68.6, 69.2)	68.7 (68.4, 69.1)	68.4 (68.1, 68.8)	–0.33 (–0.50, –0.16)	0.02
Diabetes (%)	10.5 (8.7, 12.6)	10.8 (9.0, 13.0)	7.4 (5.9, 9.3)	6.8 (5.4, 8.6)	0.81 (0.73, 0.90)	<0.001
Insulin resistance (HOMA)[b]	1.72 (1.65, 1.79)	1.66 (1.59, 1.73)	1.62 (1.56, 1.73)	1.51 (1.45, 1.57)	–0.04 (–0.06, –0.02)	<0.001
Systolic blood pressure (mmHg)	149.3 (147.8,150.8)	147.4 (145.9,148.9)	146.9 (145.4,148.4)	145.4 (143.9,146.9)	–0.98 (–1.73, –0.22)	<0.001
Diastolic blood pressure (mmHg)	79.7 (79.0, 80.4)	79.4 (78.6, 80.1)	79.7 (79.0, 80.4)	79.1 (78.4, 79.9)	–0.04 (–0.40, 0.32)	0.83
High density lipoprotein cholesterol (mmol/l)	1.63 (1.60, 1.65)	1.66 (1.63, 1.69)	1.65 (1.62, 1.68)	1.68 (1.65, 1.71)	0.02 (0.01, 0.04)	0.02
Low density lipoprotein cholesterol (mmol/l)	4.17 (4.10, 4.25)	4.10 (4.03, 4.17)	4.15 (4.09, 4.23)	4.15 (4.08, 4.22)	–0.01 (–0.05, 0.02)	0.52
Triglyceride (mmol/l)[b]	1.72 (1.67, 1.77)	1.69 (1.64, 1.74)	1.65 (1.60, 1.70)	1.61 (1.56, 1.65)	–0.03 (–0.04, –0.01)	<0.001
BMI (kg/m^2)	29.0 (28.7, 29.3)	27.7 (27.4, 28.0)	27.3 (27.0, 27.6)	26.4 (26.1, 26.7)	–1.14 (–1.29, –0.99)	<0.001
Waist:hip ratio	0.82 (0.81, 0.82)	0.82 (0.82, 0.83)	0.82 (0.82, 0.83)	0.82 (0.81, 0.82)	0.00 (–0.00, 0.00)	>0.70
Current smoker (%)	11.7 (9.9, 12.9)	12.0 (10.1, 14.2)	8.6 (7.0, 10.5)	11.4 (9.5, 13.5)	0.97 (0.88, 1.07)	0.20
Non-manual social class (%)	39.7 (36.3, 43.2)	46.1 (42.7, 49.6)	51.6 (48.1, 55.1)	52.1 (48.6, 55.5)	1.18 (1.10, 1.27)	<0.001
Father non-manual social class (%)	15.8 (13.5, 18.4)	23.9 (21.2, 26.9)	24.1 (21.3, 27.1)	30.5 (27.5, 33.6)	1.36 (1.25, 1.48)	<0.001
	Trunk length quartile (range of trunk length cm)				**Difference per SD trunk length[a] (1SD=3.6 cm)**	***p* trend**
	1 (64.9–80.7)	2 (80.8–83.0)	3 (83.1–85.4)	4 (85.5–112.0)		
Age (years)	70.9 (70.6, 71.3)	69.4 (69.0, 69.7)	68.0 (67.7, 68.4)	66.8 (66.5, 67.1)	–1.58 (–1.74, –1.42)	<0.001
Diabetes (%)	9.8 (8.0, 11.8)	7.8 (6.3, 9.7)	8.6 (7.0, 10.5)	9.4 (7.7, 11.5)	1.05 (0.93, 1.17)	0.44
Insulin resistance (HOMA)[b]	1.57 (1.50, 1.63)	1.62 (1.55, 1.69)	1.67 (1.61, 1.74)	1.65 (1.58, 1.73)	0.03 (0.01, 0.05)	0.01
Systolic blood pressure (mmHg)	148.4 (146.9,150.0)	147.6 (146.1, 149.1)	147.1 (145.6,148.6)	145.8 (144.3,147.4)	–1.11 (–1.89, –0.32)	0.02
Diastolic blood pressure (mmHg)	80.0 (79.3, 80.8)	79.7 (78.9, 80.4)	79.4 (78.7, 80.1)	78.8 (78.0, 79.5)	–0.49 (–0.87, –0.12)	0.01
High density lipoprotein cholesterol (mmol/l)	1.70 (1.67, 1.73)	1.66 (1.63, 1.69)	1.63 (1.60, 1.66)	1.62 (1.59, 1.66)	–0.03 (–0.05, –0.02)	<0.001

Table 1. (continued)

	Trunk length quartile (range of trunk length cm)				Difference per SD trunk length[a] (1SD=3.6 cm)	*p* trend
	1 (64.9–80.7)	2 (80.8–83.0)	3 (83.1–85.4)	4 (85.5–112.0)		
Low density lipoprotein cholesterol (mmol/l)	4.17 (4.10, 4.24)	4.12 (4.05, 4.19)	4.13 (4.06, 4.20)	4.16 (4.09, 4.23)	0.00 (–0.04, 0.04)	0.98
Triglyceride (mmol/l)[b]	1.65 (1.61, 1.71)	1.66 (1.62, 1.72)	1.68 (1.63, 1.72)	1.67 (1.62, 1.72)	0.01 (–0.01, 0.02)	0.40
BMI (kg/m^2)	27.4 (27.1, 27.7)	27.6 (27.3, 27.9)	27.7 (27.4, 28.0)	27.7 (27.4, 28.1)	0.18 (0.01, 0.34)	0.15
Waist:hip ratio	0.83 (0.82, 0.83)	0.82 (0.81, 0.82)	0.82 (0.81, 0.82)	0.81 (0.81, 0.82)	–0.01 (–0.01, –0.00)	0.04
Current smoker (%)	12.5 (10.6, 14.68)	11.6 (9.8, 13.8)	10.4 (8.7, 12.4)	8.9 (7.2, 10.8)	0.81 (0.73, 0.90)	<0.001
Non-manual social class (%)	43.2 (39.8, 46.8)	46.8 (43.2, 50.2)	49.1 (45.6, 52.5)	50.5 (47.0, 54.0)	1.13 (1.05, 1.22)	0.001
Father non-manual social class (%)	20.9 (18.3, 23.8)	>22.5 (19.8, 25.4)	26.3 (23.5, 29.3)	24.5 (21.7, 27.6)	>1.13 (1.04, 1.22)	0.01
	Height quartile (range of height cm)				Difference per SD height[a] (1SD=6.4 cm)	*p* trend
	1 (115.2–154.7)	2 (154.8–158.7)	3 (158.8–162.8)	4 (162.9–189.9)		
Age (years)	70.3 (69.9, 70.6)	69.1 (68.8, 69.5)	68.1 (68.1, 68.8)	67.3 (67.0, 67.6)	–1.07 (–1.24, –0.90)	<0.001
Diabetes (%)	10.7 (8.9, 12.8)	9.1 (7.4, 11.0)	8.3 (6.7, 10.2)	7.6 (6.0, 9.4)	0.89 (0.80, 0.99)	0.04
Insulin resistance (HOMA)[b]	1.65 (1.58, 1.72)	1.71 (1.64, 1.79)	1.59 (1.52, 1.65)	1.56 (1.50, 1.65)	–0.03 (–0.05, –0.01)	0.02
Systolic blood pressure (mmHg)	148.6 (147.1, 150.1)	149.1 (147.6,150.6)	145.9 (144.4,147.4)	145.3 (143.8, 146.9)	–1.27 (–2.04, –0.50)	<0.001
Diastolic blood pressure (mmHg)	79.9 (79.1, 80.6)	79.7 (78.9, 80.4)	79.4 (78.7, 80.1)	79.0 (78.2, 79.7)	–0.31 (–0.68, 0.06)	0.10
High density lipoprotein cholesterol (mmol/l)	1.65 (1.63, 1.68)	1.66 (1.63, 1.69)	1.65 (1.62, 1.67)	1.66 (1.63, 1.69)	0.00 (–0.01, 0.02)	0.64
Low density lipoprotein cholesterol (mmol/l)	4.21 (4.14, 4.28)	4.07 (4.00, 4.14)	4.15 (4.08, 4.22)	4.15 (4.08, 4.23)	–0.02 (–0.06, 0.02)	0.26
Triglyceride (mmol/l)[b]	1.70 (1.65, 1.75)	1.68 (1.64, 1.73)	1.66 (1.62, 1.71)	1.61 (1.57, 1.66)	–0.02 (–0.03, –0.01)	0.01
BMI (kg/m^2)	28.3 (28.0, 28.6)	27.9 (27.6, 28.2)	27.3 (27.0, 27.6)	26.9 (26.5, 27.2)	–0.63 (–0.78, –0.47)	<0.001
Waist:hip ratio	0.82 (0.82, 0.83)	0.82 (0.82, 0.83)	0.82 (0.81, 0.82)	0.82 (0.81, 0.82)	–0.00 (–0.01, –0.00)	0.09
Current smoker (%)	13.4 (11.4, 15.6)	10.8 (9.0, 12.8)	9.3 (7.6, 11.2)	10.0 (8.3, 12.1)	0.88 (0.80, 0.97)	
Non-manual social class (%)	39.6 (36.1, 43.1)	46.2 (42.7, 49.6)	49.1 (45.6, 52.5)	54.3 (50.8, 57.7)	1.23 (1.14, 1.33)	<0.001

Table 1. (continued)

	Leg to trunk ratio quartiles (range leg to trunk ratio)				Difference per SD leg:trunk[a]	p trend
	1 (0.37–0.87)	2 (0.88–0.91)	3 (0.92–0.95)	4 (0.96–1.37)		
Father non-manual social class (%)	17.6 (15.2, 20.3)	22.7 (20.1, 25.7)	23.5 (20.8, 26.4)	30.3 (27.3, 33.5)	1.32 (1.21, 1.44)	<0.001
Age (years)	67.6 (67.3, 67.9)	68.6 (68.2, 68.9)	69.0 (68.7, 69.3)	70.1 (69.7, 70.4)	0.03 (0.02, 0.03)	<0.001
Diabetes (%)	11.4 (9.6, 13.5)	9.0 (7.4, 11.0)	8.5 (6.9, 10.4)	6.5 (5.1, 8.2)	0.79 (0.71, 0.88)	<0.001
Insulin resistance (HOMA)[b]	1.76 (1.68, 1.83)	1.65 (1.58, 1.72)	1.64 (1.57, 1.70)	1.49 (1.43, 1.55)	–0.06 (–0.08, –0.04)	<0.001
Systolic blood pressure (mmHg)	148.1 (146.6,149.6)	146.6 (145.0, 148.1)	147.1 (145.6,148.6)	147.2 (145.7, 148.7)	–0.16 (–0.93, 0.61)	0.68
Diastolic blood pressure (mmHg)	79.0 (78.3, 79.7)	79.5 (78.8, 80.2)	79.6 (78.9, 80.4)	79.7 (79.0, 80.5)	0.31 (–0.06, 0.68)	0.10
High density lipoprotein cholesterol (mmol/l)	1.60 (1.58, 1.64)	1.64 (1.61, 1.67)	1.65 (1.62, 1.68)	1.72 (1.68, 1.75)	0.04 (0.03, 0.06)	<0.001
Low density lipoprotein cholesterol (mmol/l)	4.13 (4.07, 4.20)	4.17 (4.10, 4.24)	4.16 (4.09, 4.22)	4.13 (4.06, 4.20)	–0.01 (–0.05, 0.03)	0.58
Triglyceride (mmol/l)[b]	1.70 (1.67, 1.75)	1.67 (1.63, 1.73)	1.68 (1.64, 1.73)	1.59 (1.55, 1.64)	–0.03 (–0.04, –0.02)	<0.001
BMI (kg/m^2)	29.1 (28.8, 29.4)	27.8 (27.5, 28.1)	27.2 (26.9, 27.5)	26.3 (26.0, 26.7)	–1.21 (–1.36, –1.05)	<0.001
Waist:hip ratio	0.82 (0.81, 0.82)	0.82 (0.81, 0.82)	0.82 (0.82, 0.82)	0.82 (0.82, 0.83)	0.01 (0.00, 0.01)	0.002
Current smoker (%)	11.0 (9.2, 13.1)	9.6 (7.9, 11.6)	10.6 (8.8, 12.7)	12.5 (10.5, 14.7)	1.12 (1.01, 1.24)	0.04
Non-manual social class (%)	42.0 (38.6, 45.4)	47.9 (44.4, 51.4)	50.8 (47.3, 54.2)	49.0 (45.5, 52.5)	1.07 (1.00, 1.15)	0.01
Father non-manual social class (%)	18.9 (16.4, 21.7)	22.3 (19.6, 25.2)	25.9 (23.1, 29.0)	27.2 (24.4, 30.3)	1.22 (1.12, 1.33)	<0.001

[a] Difference per SD (Standard deviation) of components of height: age standardised regression coefficients for continuous variables and odds ratios per standard deviation of height component for binary variables

[b] Geometric mean and logged regression coefficient for one standard deviation increase in height component
All means and prevalences age adjusted (except for age)

cluded from any further analysis. In addition to the 209 women with a doctor's diagnosis of Type II diabetes 168 women (of 3824 with fasting glucose data) had fasting glucose concentrations of more than or equal to 7 mmol/l. The total number of women with WHO defined Type II diabetes was therefore 375 and the prevalence in this cohort of older women was 8.97% (95% CI 8.08, 9.92).

Diabetes prevalence, mean HOMA score and other risk factors and demographic data are shown according to quartiles of anthropometric measures (Table 1). Both diabetes prevalence and insulin resistance, in women without diabetes, were inversely associated with leg length, total height and leg to trunk ratio. Trunk length was not associated with diabetes prevalence and was positively associated with insulin resistance. Systolic blood pressure was inversely associated with both leg length and trunk length and diastolic blood pressure was inversely associated with trunk length. High density lipoprotein cholesterol was posi-

Table 2. Odds ratios for Type II diabetes prevalence for increase in one standard deviation of leg length, trunk length, height and leg to trunk length ratio

Variables in model	Leg length		
	Number of women with full data on all variables considered	Age adjusted odds ratio (95% CI) for increase of 1 SD (4.3 cm) in leg length	Fully adjusted odds ratio (95% CI) for increase of 1 SD (4.3 cm) in leg length
Model 1 Metabolic and diabetic risk factors[a]	3660	0.80 (0.71, 0.89)	0.87 (0.77, 0.97)
Model 2 Adult and childhood social class	3790	0.81 (0.73, 0.90)	0.81 (0.73, 0.90)
Model 3 All listed variables[b]	3660	0.80 (0.71, 0.89)	0.87 (0.77, 0.97)
Variables in model	Trunk length		
	Number of women with full data on all variables considered	Age adjusted odds ratio variables considered SD (3.6 cm) in trunk length	Fully adjusted odds ratio (95% CI) for increase of 1 SD (3.6 cm) in trunk
Model 1 Metabolic and diabetic risk factors[a]	3660	1.00 (0.89, 1.12)	1.00 (0.88, 1.14)
Model 2 Adult and childhood social class	3793	1.05 (0.93, 1.17)	1.05 (0.94, 1.18)
Model 3 All listed variables[b]	3660	1.00 (0.89, 1.13)	1.00 (0.88, 1.14)
Variables in model	Height		
	Number of women with full data on all variables considered	Age adjusted odds ratio (95% CI) for increase of 1 SD (6.4 cm) in height	Fully adjusted odds ratio (95% CI) for increase of 1 SD (6.4 cm) in height
Model 1 Metabolic and diabetic risk factors[a]	3660	0.86 (0.77, 0.97)	0.91 (0.80, 1.03)
Model 2 Adult and childhood social class	3793	0.89 (0.80, 0.99)	0.89 (0.80, 1.00)
Model 3 All listed variables[b]	3660	0.86 (0.77, 0.97)	0.91 (0.80, 1.03)
Variables in model	Leg to trunk length ratio		
	Number of women with full data on all variables considered	Age adjusted odds ratio (95% CI) for increase of 1 SD in leg:trunk (0.06)	Fully adjusted odds ratio (95% CI) for increase of 1 SD in leg:trunk (0.06)
Model 1 Metabolic and diabetic risk factors[a]	3660	0.80 (0.72, 0.90)	0.87 (0.77, 0.98)
Model 2 Adult and childhood social class	3793	0.79 (0.71, 0.88)	0.80 (0.72, 0.89)
Model 3 All listed variables[b]	3660	0.80 (0.72, 0.90)	0.87 (0.77, 0.98)

[a] Metabolic and diabetic risk factors: systolic blood pressure, diastolic blood pressure, HDL, LDL, logged triglycerides, weight, waist-to-hip ratio, smoking

[b] All listed variables: systolic blood pressure, diastolic blood pressure, HDL, LDL, logged triglycerides, weight, waist-to-hip ratio, smoking, adult social class and childhood social class

Table 3. Regression coefficient of logged HOMA score (insulin resistance) for increase in one standard deviation of leg length, trunk length, height and leg to trunk length ratio

	Leg length		
	Number of women with full data on all variables considered	Age regression coefficient (95% CI) for increase of 1 SD (4.3 cm) in leg length	Fully adjusted regression coefficient (95% CI) for increase of 1 SD (4.3 cm) in leg length
Model 1 Metabolic and diabetic risk factors[a]	3155	–0.04 (–0.06, 0.02)	–0.07 (–0.08, –0.05)
Model 2 Adult and childhood social class	3250	–0.04 (–0.06, –0.02)	–0.04 (–0.06, –0.02)
Model 3 All listed variables[b]	3155	–0.04 (–0.06, 0.02)	–0.07 (–0.08, –0.05)
	Trunk length		
	Number of women with full data on all variables considered	Age adjusted regression coefficient (95% CI) for increase of 1 SD (3.6 cm) in trunk length	Fully adjusted regression coefficient (95% CI) for increase of 1 SD (3.6 cm) in trunk length
Model 1 Metabolic and diabetic risk factors[a]	3155	0.03 (0.01, 0.05)	0.04 (0.02, 0.06)
Model 2 Adult and childhood social class	3250	0.03 (0.01, 0.05)	0.03 (0.01, 0.05)
Model 3 All listed variables[b]	3155	0.03 (0.01, 0.05)	0.04 (0.02, 0.06)
	Height		
	Number of women with full data on all variables considered	Age adjusted regression coefficient (95% CI) for increase of 1 SD (6.4 cm) in height	Fully adjusted regression in coefficient (95% CI) for crease of 1 SD (6.4 cm) in height
Model 1 Metabolic and diabetic risk factors[a]	3155	–0.02 (–0.04, –0.002)	–0.01 (–0.03, 0.01)
Model 2 Adult and childhood social class	3250	–0.03 (–0.05, –0.01)	–0.02 (–0.04, –0.002)
Model 3 All listed variables[b]	3155	–0.02 (–0.04, –0.002)	–0.01 (–0.03, 0.01)
	Leg to trunk length ratio		
	Number of women with full data on all variables considered	Age adjusted regression coefficient (95% CI) for increase of 1 SD in leg:trunk (0.06)	Fully adjusted regression coefficient (95% CI) for increase of 1 SD in leg:trunk (0.06)
Model 1 Metabolic and diabetic risk factors[a]	3155	–0.06 (–0.08, –0.04)	–0.08 (–0.10, –0.06)
Model 2 Adult and childhood social class	3250	–0.06 (–0.08, –0.04)	–0.06 (–0.08, –0.04)
Model 3 All listed variables[b]	3155	–0.06 (–0.08, –0.04)	–0.08 (–0.01, –0.06)

[a] Metabolic and diabetic risk factors: systolic blood pressure, diastolic blood pressure, HDL, LDL, logged triglycerides, weight, waist-to-hip ratio, smoking

[b] All listed variables: systolic blood pressure, diastolic blood pressure, HDL, LDL, logged triglycerides, weight, waist-to-hip ratio, smoking, adult social class and childhood social class

tively associated with leg length and inversely associated with trunk length. Triglyceride concentrations were inversely associated with leg length but not with trunk length and low density lipoprotein cholesterol was not associated with either leg or trunk length. BMI was inversely associated with leg length but not with trunk length, whereas waist-to-hip ratio was not associated with leg length but was associated with trunk length. Cigarette smoking was not associated with leg length but was positively associated with trunk length. All anthropometric measures were associated with adult and childhood occupational social class, with those from lower social classes in adulthood or childhood having shorter leg and trunk lengths.

Odds ratios of prevalent diabetes in relation to the anthropometric measures are shown in Table 2. Greater leg length was associated with reduced risk of diabetes and this association was independent of diabetes risk factors including generalised obesity, central obesity, smoking, social class and other components of the metabolic syndrome. After full adjustment, the odds ratio (95% CI) per standard deviation (4.3 cm) increase in leg length was 0.87 (0.77, 0.98) and that per standard deviation (0.06) increase in the ratio of leg-to-trunk length was 0.88 (0.78, 0.99). Trunk length was not associated with diabetes prevalence.

The regression coefficients of log HOMA score (insulin resistance) per standard deviation increase in each anthropometric measure in women who did not have diabetes are shown in Table 3 . Leg length was inversely associated with insulin resistance – age adjusted regression coefficient (95% CI) –0.04 (–0.06, –0.02) of log HOMA per standard deviation (4.3 cm) increase in leg length – whereas trunk length was positively associated with insulin resistance 0.03 (0.01, 0.05) per standard deviation (3.6 cm) increase in trunk length. Adjustment for potential confounding factors increased the association with leg length and did not substantially alter any of the other associations between components of height and insulin resistance in women without diabetes.

Of the 4286 participants 1419 (33%) provided details of their birth weight. There were no differences in prevalent diabetes, insulin resistance or other metabolic risk factors between women who provided details of their birth weight and those who did not (all p values >0.1). The age adjusted Pearson's correlation coefficients (95% CI) for the association between self-reported birth weight and current height (0.25; 0.19, 0.30) weight (0.12; 0.06, 0.17), BMI (0.02; –0.04, 0.07) and waist-to-hip ratio (–0.04; –0.09, 0.02) in those with self-reported birth weights were all in the same direction and of a similar magnitude to those reported in studies comparing birth weights from hospital records to adult anthropometric measurements in western populations [18, 19]. Self-reported birth weight was also positively associated with both leg length and trunk length–age adjusted Pearson's correlation coefficient for the association between birth weight and leg length 0.15 (0.11, 0.19) and between birth weight and trunk length 0.16 (0.11, 0.02). In this sub-group of women with data on birth weights the associations between components of height and diabetes prevalence were not altered after adjustment for birth weight. The fully adjusted (but without inclusion of birth weight) odds ratio for diabetes per one standard deviation increase in leg length was 0.86 (0.70, 1.05); when birth weight was included in the model this became 0.87 (0.70, 1.05). Similar results for one standard deviation increase in trunk length were 0.94 (0.77, 1.16) and 0.95 (0.78, 1.17). Adjustment for birth weight did not influence the association between components of height and insulin resistance. The fully adjusted (but without inclusion of birth weight) regression coefficient of log HOMA score per one standard deviation increase in leg length was –0.05 (–0.09, –0.02), when birth weight was included in the model this increased slightly to –0.06 (–0.09, –0.03). Similar results for one standard deviation increase in trunk length were 0.05 (0.02, 0.09) and 0.04 (0.01, 0.08).

Discussion

Height has been found to be inversely associated with diabetes and glucose intolerance in several studies [1, 2, 3, 4, 5] but the underlying mechanism for this association have not been understood. We have shown that leg length is the component of height that is inversely associated with diabetes whereas trunk length is not associated with diabetes. Furthermore, in women who do not have diabetes, leg length is inversely associated with insulin resistance whereas trunk length is positively associated with insulin resistance. These associations remain after control for potential confounding factors such as smoking, central and generalised obesity and adult and childhood social class. They are also independent of other metabolic risk factors.

It has been suggested that the association between height and adult chronic disease is merely a reflection of the well documented association between birth weight and adult chronic disease since adult height is correlated to birth weight. However, correlations between birth weight and the two components of height (leg and trunk length) are similar [12, 20] and therefore if impaired foetal growth underlay the height-diabetes association it would be expected that both components of height would have similar associations with diabetes. In women in this cohort, with data on self-reported birth weights, there was no effect of adjustment for birth weight on the associations between components of height and diabetes or insulin resistance.

Total adult height and both trunk and leg length are likely to be influenced by genetic factors but an important determinant of leg length and leg length relative to trunk length is the early childhood environment, in particular infant nutrition [9, 10, 11]. Adult leg length is, therefore, a useful indicator of infant nutrition and early childhood environmental circumstances. No previous studies have assessed the associations between components of adult height and diabetes though one study has investigated these associations with respect to coronary heart disease and insulin resistance [12]. This was a study of middle aged men that found similar associations to those found in our study of women, between components of height and insulin resistance. It was also found that the risk of coronary heart disease was inversely related to leg length but showed little association with trunk length [12]. In this study of men [12] and in our study the association between leg length and insulin resistance and that between trunk length and insulin resistance were in opposite directions. Whilst increasing insulin resistance with decreasing leg length most likely reflects adverse childhood environmental circumstances, in particular poor nutrition, the positive association between trunk length and insulin resistance is harder to explain. This is not likely to be a chance finding, having been found in two independent studies. Trunk length is possibly more strongly associated with pubertal growth, and therefore growth hormone and IGF surges, that could result in long-term effects on insulin resistance and explain the positive association between trunk length and insulin resistance.

Study limitations. Our response (60%) is moderate but consistent with other baseline data collection in large epidemiological surveys including that for the Health Survey for England in which participants were visited in their own homes [21]. Mean cholesterol concentrations, systolic blood pressure, smoking prevalence and doctor diagnosed diabetes prevalence for women in our study are similar to those for older women in the Health Survey for England [21]. The social class distribution of the British Women's Heart and Health Study is similar to that found for the 1991 census (52% manual social class in British Women's Heart and Health Study vs, 55% older adults in the 1991 census). Response bias is, therefore, not likely to have had an important effect on our results. Nearly all (99.8%) participants in this study were Caucasian; the results are therefore not necessarily generalisable to other ethnic groups.

Implications. Leg length is an indicator of early childhood environmental circumstances, in particular of infant nutrition. These results suggest that poor infant nutrition is an important aetiological factor in the development of Type II diabetes and insulin resistance in later life and explain the well documented association between stature and diabetes.

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