

Gestational Diabetes

Is there a relationship between leg length and glucose tolerance?

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OBJECTIVE— To assess the relationship between leg length and glucose tolerance in pregnancy.

RESEARCH DESIGN AND METHODS— The leg length and leg-to-height percentage were prospectively determined on 161 glucose-tolerant women during pregnancy and 61 women with gestational diabetes mellitus (GDM).

RESULTS— Women with GDM were a mean of 2.8 cm shorter than women who were glucose tolerant, due entirely to their leg lengths being a mean of 3.2 cm shorter. With respect to the 2-h result on the glucose tolerance test (GTT), there were negative correlations for height ($r = -0.161$, $P = 0.017$), leg length ($r = -0.266$, $P < 0.0005$), and the leg-to-height percentage ($r = -0.294$, $P < 0.0005$). The correlation between the leg-to-height percentage and the 2-h result on the GTT remained significant after adjustment for age ($r = -0.252$, $P < 0.0005$) and for age and BMI ($r = -0.224$, $P = 0.001$).

CONCLUSIONS— Women with GDM are shorter than glucose-tolerant women and have a lower leg-to-height percentage. Consideration of short stature as a risk factor for GDM is not valid without taking into account the leg-to-height percentage.

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Gestational diabetes mellitus (GDM) is carbohydrate intolerance of variable severity with onset or first recognition during the current pregnancy (1). Women with GDM have been found to be shorter than women who are glucose tolerant in most (2–7) but not all studies (8). People with impaired glucose tolerance (IGT) are shorter than people who are glucose tolerant (9), and women with type 2 diabetes are shorter than women who are glucose tolerant (10). In the British Women's Heart and Health Study, the women with type 2 diabetes were shorter because their legs were shorter (10). Women with GDM are very likely to develop IGT and type 2 diabetes in future years (11) and hence may be shorter because their legs are shorter.

The aims of this study were to determine whether there were any differences in leg length for women with GDM com-

pared with women who were glucose tolerant and to determine the relationship between the leg-to-height percentage and the results of the glucose tolerance test (GTT).

RESEARCH DESIGN AND METHODS

This study was conducted in Wollongong, NSW, Australia. In this Health Area, it has been local policy for all pregnant women to be tested for GDM. There is >90% compliance with this advice (12). Unless otherwise indicated, all women are tested at the beginning of the third trimester with a 75-g oral GTT administered in the morning after an overnight fast. No preliminary challenge test is used. According to the Australasian Diabetes in Pregnancy Society (ADIPS) recommendations (13), GDM is diagnosed if the fasting glucose is ≥ 5.5 mmol/l (100 mg%) and/or the 2-h glucose

is ≥ 8.0 mmol/l (145 mg%). On occasions the fasting level was omitted.

The subjects for this study were recruited from two sources over a 3-month period, May to June 2003. Women with GDM were attending the private practice of one of the investigators (R.G.M.) for the medical management of their GDM. The referral sources were the antenatal clinics at the two public hospitals in the region, general practitioners, and specialist obstetricians. All women approached agreed to have the measurements carried out.

Glucose-tolerant women were recruited from consecutive women attending the Antenatal Clinic on 2 weekdays at one of the public hospitals in the region (Wollongong Hospital). Women with an abnormal GTT were excluded from this group. All women approached agreed to have the measurements taken.

Data recorded included maternal age, parity, the number of weeks of gestation when the measurements were taken, prepregnancy weight by recall, and a measure of current weight. Height was measured with a stadiometer to the nearest 0.5 cm with the subject standing and also while sitting on a stool. The stadiometer and stool height were standardized for the two sites.

Trunk length was calculated by deducting the stool height from the measured sitting height. Leg length was calculated by deducting the trunk height from the measured standing height. BMI was calculated in the standard way using the prepregnancy weight by recall.

In addition, the data of all women who had delivered at Wollongong Hospital during 2002 and who had had a GTT were considered. Fetal length, sex, and weeks of gestation were obtained from the obstetric database. The data from women with multiple deliveries were not considered.

All statistics were carried out using SPSS version 11.5 for PC. The analyses were standard procedures. Tests for differences in means were carried out using independent Student's *t* tests; correlations using Pearson's correlation supplemented by partial correlation procedures when

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Abbreviations: GDM, gestational diabetes mellitus; GTT, glucose tolerance test; IGT, impaired glucose tolerance.

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adjusting for other variables. Unless otherwise stated, results have been expressed as the means \pm 1 SD. Results were considered significant if $P < 0.05$. There were some small variations in the sample sizes for different analyses because of missing data on some variables. This study was reviewed by the University of Wollongong/Illawarra Area Health Service Human Research Ethics Committee.

RESULTS— Data were available for 61 women with GDM and 161 glucose-tolerant women. The results are shown in Table 1. As could be anticipated, women with GDM were older, shorter, and had a higher preconception BMI than women who were glucose tolerant. Women with GDM were a mean of 2.8 cm shorter than women who were glucose tolerant. This was due entirely to their leg lengths being a mean of 3.2 cm shorter.

There were significant positive correlations between the fasting glucose level on the GTT and age ($r = 0.303$, $P < 0.0005$, $n = 185$), prepregnancy weight ($r = 0.231$, $P < 0.002$, $n = 186$), and prepregnancy BMI ($r = 0.270$, $P < 0.0005$, $n = 186$). However, there were no significant correlations between the fasting glucose level and total height, trunk length, and leg length either before or after adjustment for age and BMI.

There were significant positive correlations between the 2-h result on the GTT and age ($r = 0.302$, $P < 0.0005$, $n = 220$), prepregnancy weight ($r = 0.235$, $P < 0.0005$, $n = 219$), and prepregnancy BMI ($r = 0.310$, $P < 0.0005$, $n = 219$), and there were negative correlations for height ($r = -0.161$, $P = 0.017$, $n = 220$), leg length ($r = -0.266$, $P < 0.0005$, $n = 220$), and leg-to-height percentage ($r = -0.294$, $P < 0.0005$). The significant negative correlation between the leg-to-height percentage and the 2-h result on the GTT remained after adjustment for age ($r = -0.252$, $P < 0.0005$, $n = 217$) and for age and BMI ($r = -0.224$, $P = 0.001$, $n = 215$).

The equation that models the change in GTT at 2 h is given by $GTT_2 = 188.238 + 0.1 \times \text{pregnancy BMI} + 0.079 \times \text{age} - 7.546 \times \text{leg-to-height percentage} + 0.76 \times (\text{leg-to-height percentage})^2$. With this equation, for women aged between 20 and 40 years with a prepregnancy BMI between 17 and 33 kg/m², it is very likely that only those women with a leg-to-height percentage of <48

Table 1—Patients demographics and selected anthropometry

	Normal	GDM	P
n	161	61	
Age (years)	26.9 \pm 5.3	30.7 \pm 5.5	<0.0005
Glucose (mmol/l) at fasting GTT	4.2 \pm 0.4	5.2 \pm 0.9	<0.0005
Glucose (mmol/l) at 2-h GTT	5.4 \pm 1.0	8.7 \pm 1.7	<0.0005
Prepregnancy weight (kg)	63.8 \pm 13.7	70.9 \pm 15.8	<0.001
Height (cm)	164.9 \pm 6.3	162.1 \pm 6.9	<0.005
BMI (kg/m ²)	23.4 \pm 4.6	27.0 \pm 6.0	<0.0005
Trunk length (cm)	85.8 \pm 3.8	86.0 \pm 3.4	0.363
Leg length (cm)	79.3 \pm 4.4	76.1 \pm 5.0	<0.0005
Current weight (kg)	78.4 \pm 14.7	81.3 \pm 14.6	0.191
Leg-to-height percentage	48.1 \pm 1.5	46.9 \pm 1.6	0.001

Data are means \pm SD.

will have an elevated 2-h glucose on the GTT.

Data were available for the length at birth of 1,850 fetuses. There were no significant correlations between fetal length at birth and the result of either the fasting ($r = -0.017$, $P = 0.593$, $n = 966$) or the 2-h glucose on the GTT ($r = 0.022$, $P = 0.349$, $n = 1,850$). There were also no significant correlations between fetal length and the results of the GTT when adjusted for sex, gestational age, and birth weight. However, after adjusting for these three variables, women with GDM compared with glucose-tolerant women had fetuses that were slightly shorter by 0.331 cm ($P = 0.047$).

CONCLUSIONS— There have been four reports (4–7) specifically examining the height of women during pregnancy and the relationship of height to glucose tolerance. In relatively homogeneous populations in Korea (4) and Greece (5) and heterogeneous populations in Brazil (6) and England (7), women with GDM were shorter than glucose-tolerant women. There was also a negative correlation between height and the nonfasting results of the GTT.

In the study herein reported, we have also found that women with GDM were shorter than women who were glucose tolerant. Women with GDM also had a lower leg-to-height percentage. Given that women with GDM are very likely to develop type 2 diabetes, these findings are in accord with the results of the British Women's Heart and Health Study (10).

We did not record the racial or ethnic background of the women in this study. However, in our Health Area, because $>90\%$ of pregnant women are of Cauca-

sian origin, we did not feel that the inclusion of a small number of women from racial groups with either longer or shorter legs would have influenced the results. It also must be acknowledged that leg length, being derived from two measurements, is likely to have a greater degree of error than the measurement of either height or sitting height alone.

As with other studies (4–7), we have found that various height parameters, including the leg-to-height percentage, were correlated with the 2-h result on the GTT but not with the fasting level. The reason for this is not immediately apparent and will require further research. Data are becoming available suggesting that the metabolic associates of impaired fasting glucose are different from those of IGT (14,15). Although the conclusions from these data are by no means concordant, it is possible that deficits of insulin secretion may play a major part in determining the fasting glucose level, whereas insulin resistance may play a major role in determining the postprandial glucose responses. Maternal anthropometrics may be influencing the physiological increase in insulin resistance found in pregnancy.

In the speculation about why women who are shorter should be more likely to develop glucose intolerance, there have been two broad themes. One has considered environmental influences either operating in utero or as a result of adverse childhood socioeconomic circumstances. The other has focused on pleiotropic genetic factors influencing, in general terms, both growth and insulin resistance. To these speculations must now be added the confounding variable of leg length rather than actual height.

Because the offspring of women with

GDM are very likely themselves to develop type 2 diabetes, we also examined fetal length in relation to maternal glucose tolerance. The fetal leg length was not routinely measured, and thus the total length had to be considered. Women with GDM, after correction for variables, had a mean fetal length that was slightly shorter than the fetal length from women who were glucose tolerant, suggesting that some intrauterine factors may be operative.

It could be hypothesized that people born with shorter legs are more likely to develop type 2 diabetes. This could come about because having a relatively larger trunk means they are more likely to have more insulin-resistant fat cells. It also could be related to, and be in combination with, a relative reduction in muscle mass with their shorter legs.

Why people should have short legs is undoubtedly related to a combination of factors, both genetic and environmental. In addition, environmental factors may also influence the genetically determined phenotype. For example, adult leg length is influenced by various factors, including diet in early childhood (16).

The clinical implications of these observations are unlikely to be of major importance. Clearly, short stature alone, without consideration of the leg-to-height percentage, cannot be added to the risk factors in pregnancy that might be used to conduct selective testing for GDM. Although women with a BMI between 17 and 33 kg/m², an age between 20 and 40 years, and a leg-to-height percentage ≥ 48 are very unlikely to develop GDM, this does not offer much in terms of discrimination.

However, the general observation about leg-to-height percentage may stimulate further research. The validity of BMI has been questioned for populations with both long and short legs (17). The rela-

tionship of body anthropometrics to insulin resistance, and the disorders for which insulin resistance is a surrogate, may further help to define risk factors.

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