

Adult height and diabetes control: is there an association?

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Background: Obesity is commonly associated with diabetes mellitus (DM). The most frequent anthropometric index utilised to assess obesity is the body mass index (BMI), which uses height and weight as variables, but eliminates height as an independent analytical variable. Currently there are no data available on the relationship between adult height and glycaemic control in patients living with diabetes (PLWD) within the context of HIV infection.

Objectives: This study aimed to determine an association between final adult height and glycaemic control in an HIV endemic area.

Methods: Standardised clinic sheets were used from the DM clinic at Edendale Hospital, Pietermaritzburg, South Africa, from January 1, 2019 to December 31, 2019. Statistical analysis was done.

Results: This study had 957 PLWD. In the height categories of < 1.40 m, 1.40–1.49 m, 1.50–1.59 m, 1.60–1.69 m, 1.70–1.79 m, 1.80–1.89 m and ≥ 1.90 m, there were 11, 60, 321, 343, 121, 26 and 2 patients respectively (with 73 patients having no height recorded). Taller patients had smaller waist circumferences and had poorer glycaemic control. In the lowest vs. highest height (< 1.40 m vs ≥ 1.90 m) categories, the HbA1c values were 8.49% vs. 12.45%, respectively, $p = 0.019$. Height had a strong positive association with diastolic blood pressure (DBP) ($p = 0.001$). Those PLWD in the 1.80–1.89 m height cohort had higher triglyceride levels and lower high-density lipoprotein (HDL) levels when compared with the other height categories. Shorter PLWD with uncontrolled glycaemic control had significantly elevated systolic blood pressure. Gender and HIV infection had a non-significant role on height categories in PLWD.

Conclusion: Taller height categories had poorer glycaemic control. Increasing height was strongly associated with increasing DBP. A higher DBP and triglyceride level with lower HDL level places these PLWD in a higher cardiovascular risk category. Strong emphasis needs to be placed on the monitoring of lipids and blood pressure in PLWD, this more especially in taller patients.

Keywords: adult height, diabetes mellitus, diastolic blood pressure, glycaemic control, HbA1c

Introduction

Obesity, as well as weight gain, is commonly associated with type 2 diabetes mellitus (T2DM), with a large proportion (80–90%) of these patients being overweight or obese.¹ The most common anthropometric index employed to assess obesity is the body mass index (BMI), which uses height and weight as variables but eliminates height as an independent analytical variable.² The mass of the patient is proportional to the BMI while height (which remains constant in adults) is a fixed denominator. Globally, there are 463 million patients living with DM (PLWD), with more than 19 million patients living in Africa.³ Estimates predict that by 2045 there will be approximately 47 million PLWD in Africa alone.³

Many global studies have suggested that short adult height is generally associated with an increased risk of development of T2DM.⁴ Relationships have been described between BMI and glycaemic control, but no studies were found, to our knowledge, on the association between adult height and glycaemic control in PLWD. In Soweto, South Africa (SA), Khoza *et al.*⁵ assessed the effect of HIV on glycaemia and renal function in patients with T2DM; however, no mention was made of any relationship between glycaemic control and patient height. Erasmus *et al.*⁶ assessed DM and metabolic syndrome in Cape Town, but also made no mention of any associations between

height and glycaemic control. Glycaemic control in PLWD and HIV (PLWDH) has been shown to be suboptimal in SA.⁵ Within the PLWDH cohort this can occur in those who are antiretroviral therapy (ART) naive, those on ART, as well as in those with a cluster of differentiation (CD4) level < 200 cell/ μ l.⁵ Approximately 15% of patients living with HIV infection (PLWH) have co-morbid DM (PLWHD).⁷ Pillay *et al.* found that PLWHD had significantly poorer blood sugar control than in those PLWD alone.⁸

Our study aimed to determine a relationship between adult height and glycaemic control in PLWD in an HIV-endemic area within SA, a country with the highest prevalence of HIV (13%).⁹

Anthropometry provides a portable, universally acceptable, inexpensive and non-invasive technique to measure height.¹⁰ Public primary health care (PHC) in SA is available within 5 km to more than 90% of the population.¹¹ Considering that financial costs hinder adequate health care in SA¹² as well as the large percentage of South African citizens who rely on public health institutions (71,5%),¹³ optimising resources should be done routinely. Knowledge of associations between adult height and glycaemic control may be useful in risk stratifying PLWD when formal tests are unavailable, this especially in under-resourced peripheral healthcare facilities.

Methods

A retrospective, analytical cohort study was performed using data collected from patients who attend a specialised diabetes clinic at Edendale Hospital (EDH), Pietermaritzburg, KwaZulu-Natal. Clinicians used a standardised, comprehensive clinic sheet for all patients consulted in this clinic that has been approved by the University of KwaZulu-Natal Biomedical Research and Ethics Committee (BREC)—BCA 194/15. The data for this study included all patients 18 years or older who attended the diabetes clinic at EDH between January 1, 2019 and December 31, 2019.

Patient demographics, height, mean HbA1c %, random blood glucose (mmol/l), HIV status and type of DM were recorded in addition to other variables from the datasheet. Missing or incomplete or incorrectly completed data were not considered. Patients' height was not measured when patients were in wheelchairs or on stretchers. Height was measured in centimetres to the nearest centimetre.

Good glycaemic control was defined as HbA1c value < 7%.¹ The Bio-Rad D-10 machine (Bio-Rad, Hercules, CA, USA) was used for analysing the HbA1c values at the laboratory. Both the laboratory and the machines are National Glycohemoglobin Standardization Program (NGSP) accredited to maintain standardisation of HbA1c results while the random glucose measurement (mmol/L) was determined using an Accu-Chek® glucometer (Roche, Basel, Switzerland). BMI was calculated by dividing mass (in kilograms) by height (in metres) squared.¹⁴

Statistical analysis

Statistical analysis was conducted with numerical data using ANOVA, whilst categorical data relationships were determined using either chi-square or Fisher's exact tests. A *p*-value < 0.05 was used as indicator of significance. Data were analysed by the Statistical Package for the Social Sciences (SPSS) version 25 for Windows (IBM Corp, Armonk, NY, USA).

Table 1: Association between height and mean HbA1c levels

Height (m)	Count	Mean HbA1c (%) ±SD
< 1.40	11	8.49 (1.94)
1.40–1.49	60	8.98 (2.30)
1.50–1.59	321	9.76 (2.29)
1.60–1.69	343	9.43 (2.23)
1.70–1.79	121	9.62 (2.19)
1.80–1.89	26	9.59 (1.89)
1.90+	2	12.45 (1.20)

Table 2: Association between type of diabetes, height and mean HbA1c levels

Height (m)	Type 1 DM		Type 2 DM		<i>p</i> -value
	Count	Mean HbA1c (%) ±SD	Count	Mean HbA1c (%) ±SD	
< 1.40	1	9.30 (0)	10	8.40 (2.04)	0.684
1.40–1.49	5	8.44 (2.05)	55	9.03 (2.33)	0.587
1.50–1.59	33	10.48 (2.10)	286	9.66 (2.31)	0.052
1.60–1.69	61	9.80 (2.34)	281	9.34 (2.20)	0.144
1.70–1.79	27	10.37 (1.20)	97	9.40 (2.36)	0.042
1.80–1.89	2	10.00 (0)	24	9.58 (1.93)	0.765
1.90+	0	0	2	12.45 (1.20)	-

Results

(A) Epidemiology

Data of 957 PLWD were used for this study. When height was stratified into the < 1.40 m, 1.40–1.49 m, 1.50–1.59 m, 1.60–1.69 m, 1.70–1.79 m, 1.80–1.89 m and ≥ 1.90 m categories, there were 11, 60, 321, 343, 121, 26 and 2 patients respectively (73 PLWD didn't have their height recorded). A significant proportion of the patient cohort comprised T2DM (822, 86.2%) while 132 (13.8%) of PLWD had T1DM (PLWT1DM) (3 PLWD had no documentation of type of DM). In addition, just under one-sixth of the cohort had an HIV infection (146, 15.3%). Of this HIV-infected cohort with DM, 84 (57.5%) were on a fixed-dose combination (FDC) of antiretroviral treatment (ART), while the other 62 (42.5%) patients were either not initiated on ART or were using an alternative treatment regimen.

(B) Height and HbA1c

Table 1 demonstrates that taller patients had poorer glycaemic control. PLWD in the 1.40–1.49 m vs. 1.50–1.59 m category had substantially lower HbA1c levels (8.98% vs. 9.76%, *p* = 0.016). When comparing the lowest vs. highest height (<1.40 m vs ≥ 1.90 m) categories, we demonstrated that there were significantly lower HbA1c values (8.49% vs. 12.45% respectively, *p* = 0.019) in the shorter PLWD. This significant trend was also observed when the second lowest height category (1.40–1.49 m) was compared with the ≥ 1.90 m category, (8.98% vs. 12.45%, *p* = 0.039, respectively).

(C) Type of diabetes

Table 2 shows that PLWT1DM generally had poorer glycaemic control when compared with those PLWT2DM. Statistically significant elevated HbA1c levels occurred in those with height between 1.70 m and 1.79 m with a mean HbA1c of 10.37% vs. 9.40%, type 1 vs. type 2 respectively, *p* = 0.042. PLWT1DM were taller than PLWT2DM with a mean height of 162.8 cm vs. 160.5 cm, respectively (*p* = 0.031).

(D) HIV infection

PLWDH had lower mean HbA1c levels than HIV-uninfected patients in all height categories. In the 1.60–1.69 m cohort, the mean HbA1c between HIV-infected and HIV-uninfected patients was 8.87 vs. 9.53, respectively (*p* = 0.052) (Table 3). There were no statistically significant differences between the height categories and those on FDC vs. those not on FDC in PLWDH (*p* ≥ 0.088 for all categories).

(E) Anthropometry

Height had an inverse relationship with waist circumference (Table 4). Each 1 cm increase in height resulted in a decrease of waist circumference by 0.208 cm.

Table 3: Association between HIV, height and mean HbA1c levels

Height (m)	HIV-uninfected		HIV-infected		p-value
	Count	Mean HbA1c (%) \pm SD	Count	Mean HbA1c (%) \pm SD	
< 1.40	10	8.49 (1.94)	1	-	-
1.40–1.49	51	9.04 (2.23)	9	8.65 (2.79)	0.643
1.50–1.59	274	9.79 (2.27)	47	9.55 (2.41)	0.507
1.60–1.69	292	9.53 (2.25)	51	8.87 (2.08)	0.052
1.70–1.79	94	9.76 (2.15)	27	9.07 (2.28)	0.150
1.80–1.89	25	9.63 (1.92)	1	8.70 (0)	0.639
1.90+	1	13.30 (0)	1	11.60 (0)	0.950

Table 4: Association between waist circumference and height

Height (metres)	Count	Waist circumference (cm) (\pm SD)
< 1.40	11	110.55 (25.87)
1.40–1.49	60	102.61 (12.23)
1.50–1.59	321	107.38 (17.29)
1.60–1.69	343	104.94 (17.56)
1.70–1.79	121	97.76 (19.02)
1.80–1.89	26	100.13 (16.55)
1.90+	2	87.50 (2.12)

Table 5: Associations between BMI and glycaemic control

BMI	Count	Mean HbA1c (%) \pm SD
< 18.5	15	11.34 (2.36)
18.5–24.9	136	10.06 (2.13)
25.0–29.9	192	9.67 (2.30)
30.0–34.9	218	9.60 (2.29)
35.0–39.9	161	9.15 (1.99)
40.0+	153	9.05 (2.22)

Table 6: Associations among type of DM, BMI and HbA1c

BMI	T1DM		T2DM		p-value
	Count	Mean HbA1c (%) \pm SD	Count	Mean HbA1c (%) \pm SD	
< 18.5	6	11.58 (2.04)	9	11.17 (2.71)	0.758
18.5–24.9	53	10.83 (1.70)	83	9.55 (2.23)	0.001
25.0–29.9	32	9.89 (1.95)	160	9.62 (2.37)	0.546
30.0–34.9	18	9.03 (2.18)	200	9.65 (2.30)	0.273
35.0–39.9	11	8.52 (2.48)	149	9.18 (1.95)	0.29
40.0+	8	8.76 (1.76)	143	9.04 (2.25)	0.73

Table 7: Associations among SBP, height and HbA1c

Height (metres)	HbA1c < 7		HbA1c \geq 7		p-value
	Count	Systolic blood pressure (mmHg) (\pm SD)	Count	Systolic blood pressure (mmHg) (\pm SD)	
< 1.40	3	105.00 (24.88)	7	146.86 (23.97)	0.037
1.40–1.49	13	133.69 (15.76)	43	142.74 (31.92)	0.330
1.50–1.59	36	143.19 (26.40)	262	138.09 (25.53)	0.264
1.60–1.69	49	133.94 (23.45)	277	135.91 (25.99)	0.620
1.70–1.79	20	135.65 (22.82)	89	129.97 (20.90)	0.283
1.80–1.89	3	125.33 (24.11)	22	136.27 (25.78)	0.495
1.90+	0	-	2	127.50 (3.54)	-

Between the 1.50–1.59 m and the 1.70–1.79 m categories the waist circumference was 107.38 cm vs. 97.76 cm, respectively ($p < 0.001$). A similar finding occurred between the 1.60–1.69 m and the 1.70–1.79 m categories, which had a mean waist circumference of 104.94 cm vs. 97.76 cm, respectively $p < 0.001$.

Table 5 shows that BMI had a negative correlation with mean HbA1c levels. A comparison between BMI categories of < 18.5 and \geq 40 showed significantly lower mean HbA1c levels of 11.34 vs. 9.05, respectively ($p < 0.001$). When factoring in the type of DM, a similar finding occurred. In PLWT1DM and PLWT2DM there were significant p -values of $p = 0.017$ and $p = 0.007$, respectively.

Table 6 further breaks down the associations between BMI and mean HbA1c, taking into account the type of DM. Again, patients with BMI < 18.5 had the highest mean HbA1c in both T1DM and T2DM categories. Most PLWT1DM had a normal BMI (18.5–24.9), with significantly higher mean HbA1c being found in PLWT1DM compared with PLWT2DM (10.83% vs. 9.55%), $p = 0.001$. Although not statistically significant, obese (BMI > 30) PLWT2DM had poorer glycaemic control. In addition to this, PLWT2DM had higher mean BMI than PLWT1DM (33.20 vs. 26.72, respectively, $p < 0.001$).

(F) Blood pressure and height

In the cohort of patients with HbA1c \geq 7%, height had a negative correlation with mean systolic blood pressure (SBP). There was a statistically significant difference between those in the 1.50–1.59 m vs. 1.70–1.79 m categories in terms of SBP (138.09 vs. 129.97, $p=0.007$). Furthermore, in patients $<$ 1.40 m with an HbA1c $<$ 7% there was statistically significant lower SBP (105.00 vs. 146.86, $p=0.037$) (Table 7).

Height had a positive association with diastolic blood pressure (DBP) ($p=0.001$). For each 1 cm increase in height, the DBP increased by 0.139 mmHg (Table 8).

(G) Dyslipidaemia

Patients with heights between 1.80 m and 1.89 m had decreased HDL levels compared with the other height categories. A comparison between the 1.80–1.89 m and the 1.60–1.69 m category showed a decreasing level of HDL-cholesterol, 1.06 vs. 1.25 ($p=0.007$). Furthermore, the 1.80–1.89 m category had substantially higher triglyceride levels. A comparison between the 1.80–1.89 m and the 1.40–1.49 m categories showed significantly increasing triglyceride levels of 2.15 vs. 1.62, $p=0.042$ (Table 9).

(H) Gender

No statistically significant differences were found in the different height categories when comparing HbA1c levels for gender ($p > 0.05$ for all height categories).

Discussion

Height appears to have an impact on glycaemic control in PLWD. Our study found that taller patients had higher mean HbA1c levels than those in the shorter height categories. This contrasted with other studies on glycaemic control. Rehunen *et al.* assessed height and 2-hour plasma glucose levels and found that a taller height had improved glucose than shorter people, for those with a BMI of 35 (kg/m²) or less.¹⁵ Our study found that height was

negatively associated with waist circumference. When factoring in BMI, we discovered that higher BMI values were associated with lower mean HbA1c. This suggested that, in our study, patients who were taller and thinner had poorer glycaemia than the shorter, heavier patients. This was unexpected as obesity is a risk factor for diabetes and leads to insulin resistance.¹⁶ Sisodia *et al.* concurred and found that obesity is associated with poor glycaemic control.¹⁷ We postulate that these finding occurred due to the type of diabetes. In our study, PLWT1DM had significantly poorer glycaemia and were taller than PLWT2DM. These PLWT1DM also had significantly lower BMI levels. Chetty *et al.* suggested that genetics (especially in patients with T1DM) plays a significant role on glycaemia.¹⁸ This suggests that the type of DM may have a greater influence on the glycaemia than was previously described.

We found that blood pressure was affected by the different height categories. One of the major findings from the United Kingdom Prospective Diabetes Study (UKPDS) was that tight blood pressure control is essential to decrease both micro- and macro-vascular diabetes-related complications.¹⁹ We showed in our study that in shorter patients ($<$ 1.40 m) with elevated HbA1c values, elevated SBPs were recorded. This contrasted with those who were shorter with normal HbA1c values, who demonstrated lower SBP. This suggested that shorter patients with good glucose control are more likely also to control their blood pressure, while shorter patients with poorer glycaemia are likely to have poorer blood pressure readings. PLWT2DM have a 200–400% increased risk of dying from cardiovascular disease (CVD).²⁰ When hypertension coexists with DM, the risk of CVD increases by a further 75%.²¹ Our study also found that height was positively associated with DBP. Bourgeois *et al.* also found that height was associated with elevated DBP in patients, occurring after the third decade of life.²² Isolated diastolic hypertension has been noted to be a substantially underrated risk factor for cardiovascular mortality.²³ This is problematic as it suggests that taller PLWD may have an additional risk factor for CVD when compared with shorter patients.

When compared with the other categories of height, the 1.80–1.89 m cohort had elevated triglycerides and lower HDL-cholesterol levels. Miselli *et al.* found that there was a direct association between mean triglycerides levels and long-term total mortality risk in older adult type 2 diabetic outpatients.²⁴ In addition, Alexopoulos *et al.* highlighted that lowering triglycerides may reduce residual cardiovascular risk, especially in high-risk patients with diabetes and dyslipidemia.²⁵ These studies illustrate the significance of hypertriglyceridemia and the importance of lowering it in PLWD. It has also been shown that a low level of HDL-cholesterol is associated with increased risk of cardiovascular outcomes and death.²⁶ In addition to CVD,

Table 8: Association between DBP and height

Height (metres)	Counts	Diastolic blood pressure (mmHg) (\pm SD)
$<$ 1.40	11	74.91 (10.27)
1.40–1.49	60	76.62 (19.80)
1.50–1.59	321	78.02 (12.93)
1.60–1.69	343	79.35 (13.80)
1.70–1.79	121	80.67 (12.97)
1.80–1.89	26	85.00 (13.66)
1.90+	2	86.50 (17.68)

Table 9: Associations among height, triglycerides, HDL and LDL cholesterol

Height (metres)	Count	Triglycerides (\pm SD)	HDL (\pm SD)	LDL (\pm SD)
$<$ 1.40	11	1.82 (1.36)	1.26 (0.33)	2.08 (0.45)
1.40–1.49	60	1.62 (1.00)	1.35 (0.36)	2.40 (0.97)
1.50–1.59	321	1.84 (1.05)	1.23 (0.37)	2.61 (1.07)
1.60–1.69	343	1.85 (1.56)	1.25 (0.35)	2.46 (0.96)
1.70–1.79	121	1.86 (1.32)	1.19 (0.38)	2.35 (1.05)
1.80–1.89	26	2.15 (1.28)	1.06 (0.30)	2.37 (0.98)
1.90+	2	1.31 (0.85)	1.58 (0.11)	0.97 (0)

HDL: high density lipoprotein; LDL: low density lipoprotein.

low levels of HDL also increase cancer mortality risk.²⁷ We showed that tall PLWD had increased levels of triglycerides with low levels of HDL cholesterol, placing them at increased risk of cardiovascular morbidity and mortality.

Limitations

Not all patients had all results filled in on their datasheets.

As this was a retrospective study, no causal relationships could be determined; rather, associations were defined.

Patients who were in wheelchairs and on stretchers did not have their height and weight measured.

Conclusion

Different height categories in PLWD were found to be associated with different levels of glycaemia achieved. Taller height categories had smaller waist circumferences with poorer glycaemia than those in the shorter height categories. Increasing height was strongly associated with increasing diastolic blood pressures. Those in the 1.80–1.89 m height category had higher triglyceride levels and lower HDL levels than the other height categories. Monitoring of triglyceride and HDL levels, and blood pressure (both systolic and diastolic) needs to be continually stressed at all levels of health care, this more importantly in taller patients.

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