Original Article

Central hemodynamics and arterial stiffness in Gujarati diabetics not receiving any antihypertensive: A case–control study based on oscillometric pulse wave analysis

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Abstract

Introduction: Diabetes is a modern epidemic imposing significant cardiovascular risk. Immediate and discrete parameters such as arterial stiffness and central hemodynamics are studied scarcely. Pulse wave analysis (PWA) offers noninvasive measurement of the same and we performed that in diabetics. **Materials and Methods:** We performed a case–control study on 148 treated diabetic not on antihypertensive and 148 nondiabetic normotensive controls. Oscillometric PWA was performed by Mobil-O-Graph (IEM). Parameters were further analyzed for effect of gender, physical activity, body mass index (BMI; cut-off 23), glycemic control, and disease duration (cut-off 4 years). Multiple linear regressions were used to find significant predictors. $P<0.05$ was taken as statistical significance. **Results:** Cases had significantly raised brachial hemodynamics (blood pressure, heart rate, rate pressure product), arterial stiffness (augmentation pressure, augmentation index, pulse wave velocity, total arterial stiffness, pulse pressure amplification), and central hemodynamics (central blood pressure, cardiac output, stroke work) than controls. In the case group, female gender, BMI ≥ 23, and physical inactivity were the significant factors affecting results (arterial stiffness more than central hemodynamics); glycemic control and duration were not. Heart rate was the major predictor of study parameters. Brachial pressure parameters were not significant predictors of corresponding central pressure parameters. **Conclusion:** Gujarati diabetics not using any antihypertensive had adverse profile of beyond brachial blood pressure discrete cardiovascular parameters, independent of duration and glycemic control, related to gender, BMI, and physical activity, indicating vascular progeria in the absence of hypertension. This baseline study suggests further work on these potential parameters.

Keywords: Arterial stiffness, blood pressure, diabetic hypertensive, hemodynamic, pulse wave analysis

Introduction

Diabetes is on rise,[1] imposing a significant risk of cardiovascular morbidity and mortality.[2] In a majority, hypertension coexists and protective pharmacotherapy is used[3] that offers cardioprotection as published by us. Nonhypertensive diabetics are monitored for brachial blood pressure (bBP) and not offered cardioprotective pharmacotherapy.[4,5] Hence, progression of cardiovascular aging continues in them adding to suboptimum glycemic control. There are limitations of bBP measurement. Aortic blood pressure, central hemodynamics, and arterial stiffness overcome these limitations.[6,7] Pulse wave analysis (PWA)–based devices like Mobil-O-Graph provide an opportunity to measure the same. We performed PWA study in type 2 diabetics not receiving antihypertensive medication.

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Materials and Methods

Study design

Study protocol was first approved by the institutional review board of our college. We conducted a case–control study on patients of medicine outdoor patient department of a tertiary

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care teaching government hospital affiliated to a government medical college.

Study participants

The sample size was calculated by Raosoft software (free online software; Raosoft, Inc., Seattle, WA, USA). To have 95% confidence level, 5% precision, considering diabetes prevalence of 7%, a sample size of 148 was adequate for a city with a population of 6 lakhs. We included apparently healthy, nonathletic, type 2 diabetics taking antidiabetics regularly since at least 6 months, not taking any antihypertensives, age ≤65 years, of either sex, nonsmoking, nonalcoholic, not known to have any acute or chronic systemic disease, and ready for written informed consent. We screened and enrolled 208 diabetics by simple random sampling. We excluded 9 irregular diabetics, 19 with use of life style modification, 4 owing to irregular pulse wave recording, 24 with body mass index (BMI) that cannot be matched with any healthy control, and 4 due to arm circumference beyond available cuff size. Hence, the case group finally had 148 cases. For comparison, we selected 148 apparently healthy, nondiabetic normotensive subjects from the available pool of 1226 healthy controls.

Subject assessment and definitions

All participants were interviewed personally regarding general features, demographic characteristics, risk factors; self-reported moderate physical activity, and relevant disease history. Detailed history of pharmacotherapy used was elicited from each and regularity was confirmed by patient's case report chart. Systolic blood pressure (SBP) ≥140 mmHg and diastolic blood pressure (DBP) ≥90 mmHg or use of antihypertensive medication was defined as hypertension. SBP < 140 mmHg and DBP <90 mmHg was taken as blood pressure control. Glycemic control was defined as per American Diabetes Association guidelines 2018[8] based on fasting plasma glucose (FPG < 130 mg/dL) and 2-h plasma glucose (2 hPG < 180 mg/dL).

Instrument used

We used portable, personal computer–attached, calibrated, and validated instrument Mobil-O-Graph (IEM GMBH, Stolberg, Germany) of the physiology department to record brachial pulse wave. It undergoes oscillometric pressure PWA as per the protocol designed by the European Society of Hypertension. Pressure oscillations are generated by brachial arterial pulsation which are transmitted to bBP cuff and measured by transducer to be fed into the microprocessor. Computerized software records pulse wave of brachial artery and by validation a generalized transfer factor derives central aortic pulse wave. It further undergoes point- and area-based analysis by a computer to derive various cardiovascular parameters.[9]

Measurement protocol

A blood pressure cuff of appropriate size (mid arm circumference: 20–24 cm = small size, 24–32 cm = medium size, 32–38 cm = large size) was chosen based on measured mid arm circumference and applied to left arm using standard protocol. All readings were taken after rest for 10 min, in the postabsorptive phase with the subjects avoiding smoking or alcohol for 12 h before measurement, in a calm room without external influences or avoiding arm movement.[9]

Parameters measured

1) Heart rate (HR), BMI, body surface area (BSA)
2) bBP – systolic (bSBP), diastolic (bDBP), pulse (bPP), and mean (bMBP)
3) Central blood pressure (cBP) – systolic (cSBP), diastolic (cDBP), pulse (cPP)
4) Central hemodynamics – cardiac output (CO), cardiac index (CI), peripheral resistance (PR)
5) Arterial stiffness – augmentation pressure (AP), augmentation index at HR 75/min, reflection magnitude percentage (Ref %), aortic pulse wave velocity.

Parameters derived

1) Rate pressure product – (HR per minute) × (SBP) × 10^{-2}
2) Stroke volume (SV) – CO/HR
3) Stroke volume index (SVI) – SV/BSA
4) Stroke work (SW) – (pulse pressure) × (SV) × 0.0144
5) Total arterial stiffness (TAS) – pulse pressure/SV
6) Pulse pressure index – pulse pressure/SBP
7) Pulse pressure amplification – brachial pulse pressure/aortic pulse pressure.

Results

The case and control groups (n = 148 each) had comparable age, sex distribution, anthropometry, and physical activity status. Cases (mean diabetes duration 4.32 years, 35% glycemic control) were significantly shorter than controls. Cases showed significantly higher brachial hemodynamics (all), arterial stiffness (only PWV and TAS), and central hemodynamics (CO and PR) than controls [Table 1]. In the case group, we further compared males (n = 73) and females (n = 75). They were comparable for age, weight, BMI, duration, and glycemic control. Females had significantly shorter stature, smaller BSA, and lesser prevalence of physical activity. HR and arterial stiffness (except PWV) were significantly higher while SV was significantly lower in females than males, while parameters of brachial hemodynamics (except DBP, MBP), arterial stiffness (except PWV), and other central hemodynamics (only CO and CI) were comparable between females and males [Table 1].

Physically active cases had significantly better profile of PWA parameters than matched and comparable physically inactive cases, with statistical significance for most brachial, cBPs, arterial stiffness parameters, and SW. When compared with cases with BMI < 23, cases with BMI ≥ 23 had significantly higher values of arterial stiffness and PR. The former group had insignificantly higher brachial and cBP than the latter group [Table 2].

Table 1: Compassion of baseline and study parameters between cases and matched controls, and male cases versus female cases

Parameter, unit	Cases (*n*=148)	Controls (*n*=148)	*P*	Male cases (*n*=73)	Female cases (*n*=75)	*P*
Age, years	52.75±7.29	52.42±7.78	0.63	52.84±7.78	52.67±6.82	0.99
Male, no. (%)	73 (52%)	73 (59%)	1.000	-	-	-
Height, cm	160.83±6.24	162.56±6.48	**0.0013***	163.15±5.31	158.57±6.28	**<0.0001***
Weight, kg	63.82±9.47	63.36±8.27	0.21	65.33±9.60	62.36±9.17	0.08
BMI, kg/m^2	24.66±3.05	24.37±3.11	0.29	24.52±3.25	24.80±2.86	0.45
BSA, m^2	1.68±0.16	1.69±0.13	0.49	1.72±0.16	1.65±0.16	0.0172*
P A, no. (%)	28 (32%)	24 (17%)	0.65	19 (32%)	9 (17%)	0.0362*
Duration, years	4.32±4.51	-	-	4.78±4.81	3.86±4.18	0.11
FPG, mg/dl	159.23±61.22	-	-	150.22±52.66	168.00±67.74	0.18
2 hPG, mg/dl	228.93±88.17	-	-	219.38±77.25	238.21±97.26	0.41
G C, no (%)	53 (35%)	-	-	29 (35%)	24 (36%)	0.39
bBP (mmHg)						
SBP	134.55±17.26	127.66±17.07	**0.0001***	134.26±17.86	134.82±16.76	0.84
DBP	86.26±10.18	84.51±11.82	**0.18***	86.93±10.66	85.63±9.72	0.43
MBP	108.22±12.26	104.20±13.03	**0.0021***	108.29±13.75	108.16±11.85	0.95
PP	48.40±12.83	43.15±12.29	**<0.0001***	47.56±13.26	49.23±12.43	0.43
PPI	0.36±0.06	0.33±0.07	**0.0058***	0.35±0.07	0.36±0.06	0.28
HR, bpm	93.64±13.31	88.30±14.10	**0.0009***	91.19±14.13	96.01±12.10	**0.0272***
RPP, mmHg.bpm	125.63±13.31	112.53±22.85	<**0.0001***	121.62±27.39	129.53±23.49	**0.06**
Art stiffneAP, mmHg						
Ref (%)	9.59±5.75	8.75±5.27	0.17	7.92±4.98	11.24±6.00	**<0.0001*0.0259***
AIx@75 (%)	65.52±7.55	64.95±5.98	0.48	64.12±7.16	66.88±7.72	**<0.0001***0.66
PWV, m/s	34.31±11.75	32.02±11.31	0.20	29.18±10.25	39.31±10.98	**0.0245***
TAS, mL/mmHg	7.84±1.09	7.52±1.17	**0.0139***	7.88±1.15	7.80±1.05	**0.0355***
PPA	0.86±0.20	0.77±0.20	**<0.0001***	0.82±0.23	0.90±0.16	
	1.34±0.15	1.32±0.14	0.13	1.32±0.12	1.35±0.18	
c BP (mmHg)						
cSBP	124.47±15.93	118.78±15.70	**0.0004***	123.66±16.43	125.25±15.49	0.43
cDBP	87.90±10.56	85.99±11.73	0.14	88.51±10.82	87.31±10.39	0.49
cPP	36.68±10.60	33.09±10.70	**0.0005***	35.62±10.44	37.71±10.72	0.23
cPP ≥40, no. (%)	55 (35%)	27 (13%)	**0.0005***	23 (62%)	32 (78%)	0.18
Central hemodynamics	5.26±0.81	4.89±0.70	<**0.0001***	5.32±0.90	5.20±0.72	0.39
CO, L/min	1.25±0.13	1.29±0.15	**0.0043***	1.24±0.16	1.26±0.10	0.41
PR, mm Hg/mL	3.13±0.55	2.90±0.43	**<0.0001***	3.09±0.61	3.17±0.49	0.50
CI, L/min/m^2	56.80±10.20	56.62±10.99	0.90	58.80±12.12	54.84±8.99	**0.0252***
SV, mL/beat	34.05±7.12	33.57±6.48	0.44	34.62±8.12	33.49±6.00	0.34
SVI, mL/m^2/beat	117.88±34.43	105.55±30.66	0.07	115.34±33.55	107.94±28.61	0.16
SW, g/beat						

Bold values: Statistically significant with *P*<0.05. BMI: body mass index; PA: physical activity; FPG: fasting plasma glucose; 2 hPG: 2-h plasma glucose; GC: glycemic control; bBP: brachial blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; MBP: mean blood pressure; PP: pulse pressure; PPI: pulse pressure index; HR: heart rate RPP: rate pressure product; AP: augmentation pressure; Ref: reflection percentage; AIx@75: augmentation index at heart rate 75 beats/min; PWV: pulse wave velocity; TAS: total arterial stiffness; PPA: pulse pressure amplification; cSBP: central systolic blood pressure; cDBP: central diastolic blood pressure; cPP: central pulse pressure; CO: cardiac output; PR: peripheral resistance; CI: cardiac index; SV: stroke volume; SVI: stroke volume index; SW: stroke work '*' indicates statistical significance. Bold data indicates statistically significant with *P*<0.05

Good glycemics and poor glycemics were comparable for baseline and PWA parameters. Cases with disease duration of >4 years had no significantly different profile of study parameters when compared with those with a duration of ≤4 years [Table 3].

By multiple linear regression models, we tested for predictors of major PWA parameters (dependent parameters) from independent study parameters. HR was the consistent predictor of arterial stiffness (except for PWV) and central hemodynamics (except cPP). Age was a major positive predictor only for PWV. bMBP and bPP were significant predictors but not for all dependent parameters. Duration was a significant negative predictor for PWV, cSBP, and cPP, and positive predictor for SW. Height, weight, BMI, SBP (except for cDBP), DBP, FPG, and two hPGs were not significant predictors. Most bBPs were not significant predictors of corresponding cBPs [Table 4].

Discussion

This is by far the first Mobil-O-graph-based study on urban Indian diabetics. Oscillometric PWA using generalized transfer factor provides details of cardiovascular health and aging, beyond routinely and subjectively measured bBP.[10,11] We included diabetics not receiving any antihypertensive therapy that allowed us to study the effect of diabetes before there is incident hypertension or its correction. We compared treated diabetics

Table 2: Comparison of baseline and study parameters between subgroups of cases based on physical activity (present or absent) and BMI (cut-off 23)

Parameter, unit	PA+ (*n*=28)	PA− (*n*=28)	*P*	BMI<23 (*n*==42)	BMI≥23 (*n*==42)	*P*
Age, years	52.36±6.77	52.54±8.45	0.94	52.93±7.71	52.79±7.81	0.93
Male, no. (%)	19 (52%)	19 (59%)	1.00	23 (52%)	23 (59%)	1.00
Height, cm	161.39±6.21	161.79±5.97	0.81	160.64±6.46	161.14±5.85	0.71
Weight, kg	64.79±9.60	64.54±9.20	0.95	54.95±5.16	65.26±6.19	**<0.0001***
BMI, kg/m^2	24.89±3.56	24.62±2.77	0.76	21.28±1.26	25.21±1.71	**<0.0001***
BSA, m^2	1.69±0.19	1.70±0.14	0.82	1.57±0.12	1.71±0.13	**<0.0001***
P A, no. (%)	-	-	-	6 (32%)	8 (17%)	0.77
Duration, years	3.83±3.73	4.66±4.41	0.47	3.40±3.15	4.33±4.10	0.29
FPG, mg/dL	159.04±61.79	168.89±72.12	0.52	147.31±39.58	148.55±55.10	0.54
2 hPG, mg/dL	230.39±92.23	233.03±75.59	0.64	212.5±76.70	216.48±81.69	0.88
G C, no. (%)	13 (35%)	8 (36%)	0.27	15 (35%)	19 (36%)	0.51
bBP (mmHg)						
SBP	126.50±12.85	137.79±21.57	**<0.0209***	136.57±18.33	132.62±18.34	0.63
DBP	83.89±8.81	84.93±14.00	0.74	88.38±8.28	84.81±10.49	0.13
MBP	102.57±8.86	109.18±16.45	**0.0447***	110.26±11.83	106.67±13.27	0.55
PP	43.21±10.08	52.68±13.88	**0.0044***	48.19±14.29	47.81±12.00	0.90
PPI	0.34±0.06	0.38±0.07	**0.0158***	0.35±0.06	0.36±0.05	0.45
HR, bpm	92.68±14.77	93.54±12.04	0.81	92.17±12.98	93.76±12.13	0.56
RPP, mmHg.bpm	117.56±24.51	128.51±25.12	0.0963	124.65±29.52	123.97±21.80	0.90
Art stiffness						
AP, mmHg	6.39±3.41	10.79±6.38	**0.0022***	8.92±6.99	12.23±7.34	**<0.0001*0.0006***
Ref (%)	63.54±7.05	66.43±7.72	0.15	64.27±7.98	67.30±7.21	**<0.0001*0.74<0.0001***
AIx@75 (%)	28.82±11.62	35.25±13.43	**0.0374***	29.85±11.47	35.91±10.95	**0.0031***
PWV, m/s	7.31±1.08	7.9±1.18	**0.0183***	7.90±1.08	7.49±1.06	
TAS, mL/mmHg	0.79±0.18	0.91±0.20	**0.0304***	0.78±0.23	6.84±0.22	
PPA	1.40±0.13	1.30±0.12	**0.0072***	1.37±0.19	1.33±0.16	
cBP (mmHg)						
cSBP	116.00±11.07	127.82±19.28	**0.0068***	126.45±16.13	122.09±17.25	0.24
cDBP	85.07±8.87	86.93±14.39	0.56	90.45±8.51	86.31±11.33	0.13
cPP	31.11±7.26	40.89±11.31	**0.0003***	36.00±11.68	35.43±10.05	0.81
cPP ≥40, no. (%)	2 (35%)	14 (13%)	**0.0008***	15 (62%)	13 (78%)	0.82
Central hemodynamics	5.03±0.68	5.44±1.02	0.08	5.26±0.91	5.29±0.74	0.44
CO, L/min	1.24±0.12	1.22±0.15	0.54	1.28±0.13	1.22±0.15	**0.0076***
PR, mmHg/mL	2.96±0.47	3.20±0.59	0.09	3.36±0.61	3.07±0.50	0.07
CI, L/min/m^2	55.17±9.31	59.05±13.35	0.21	57.17±13.16	57.14±9.58	0.99
SV, mL/beat	33.15±6.96	34.75±8.00	0.43	36.58±8.66	33.61±6.06	0.07
SVI, mL/m^2/beat	101.24±22.99	119.89±40.05	**0.0371***	114.41±38.41	110.77±29.66	0.63
SW, g/beat						

PA+: physical activity present; PA−: physical activity absent; the remaining abbreviations are the same as Table 1. Bold data indicates statistically significant with $P<0.05$

with controls from the same setup using the same recording device with proven reproducibility.

Cases showed higher brachial, central hemodynamics, and arterial stiffness than controls despite antidiabetic therapy and absence of hypertension. Higher results in diabetics can also be explained by poor glycemic control despite therapy which is the feature of our diabetics.[12] Such results are in line with a study done elsewhere.[13] It can also be due to (1) unavailability of HbA1c that gives better inference about glycemic control, (2) higher prevalence of physical inactivity, (3) poor blood pressure control, (4) ethnic predisposition, (5) delayed diagnosis, and (6) lack of life style modification. Diabetes and hypertension are interrelated,[14] and we found the same in treated diabetics in whom cardiovascular aging is not prevented by use of drugs such as beta blocker[5] or drugs affecting renin–angiotensin aldosterone system.[4] This accelerated cardiovascular profile indicates the increase in work load on heart that can produce adverse effect on itself and other target organ damages.[15] Raised arterial stiffness indicates future risk of hypertension that is a very common aftermath of diabetes.[14]

Females had significantly higher values of PWA parameters mainly arterial stiffness, in line with our previous studies on normotensives[10,16] and hypertensives[11] in middle-aged group. The mean age of 52 years explains female disadvantage of postmenopausal age in most of the female cases.[17] Apart from gender-specific and sex hormone–specific differences, these results can be viewed in light of shorter stature, higher physical inactivity, and higher mean HR in females. Raised stiffness and

Table 3: Comparison of baseline and study parameters between subgroups of cases based on blood pressure control (present or absent) and duration (cut-off 5)

Parameter, unit	GC+ (*n*=48)	GC− (*n*=48)	*P*	Dn ≤4 years (*n*=88)	Dn >4 years (*n*=60)	*P*
Age, years	51.46±6.69	51.46±6.44	0.84	51.54±7.08	54.52±7.29	**0.0118***
Male, no. (%)	25 (52%)	25 (59%)	1.00	40	33	0.31
Height, cm	161.98±5.25	160.54±7.16	0.27	160.22±5.95	161.73±6.60	0.25
Weight, kg	64.83±10.42	64.04±9.50	0.65	63.32±9.96	64.57±8.72	0.17
BMI, kg/m^2	24.75±3.60	24.80±2.81	0.81	24.64±3.35	24.70±2.58	0.38
BSA, m^2	1.71±0.17	1.68±0.15	0.30	1.67±0.17	1.71±0.15	0.13
P A, no. (%)	11 (32%)	6 (17%)	0.28	19 (32%)	9 (17%)	0.39
Duration, years	4.51±4.34	4.69±5.35	0.84	1.56±1.00	8.35±4.63	**<0.0001***
FPG, mg/dL	108.79±10.79	180.23±46.58	**<0.0001***	158.88±60.93	159.75±62.16	0.81
2 hPG, mg/dL	150.94±16.68	255.25±82.66	**<0.0001***	228.49±90.47	204.69±87.04	**0.0322***
G C, no. (%)	48 (35%)	0 (36%)	-	29 (35%)	24 (36%)	0.39
bBP (mmHg)						
SBP	134.10±17.82	134.98±17.49	0.80	133.80±18.73	135.65±14.91	0.52
DBP	85.81±9.69	86.85±9.79	0.60	86.69±11.25	85.62±8.44	0.53
MBP	107.69±11.94	108.88±11.89	0.63	108.06±13.74	108.45±9.80	0.39
PP	48.65±12.67	48.13±14.16	0.85	47.31±12.54	50.01±13.19	0.15
PPI	0.36±0.06	0.35±0.07	0.58	0.35±0.06	0.36±0.07	0.17
HR, bpm	91.04±13.29	93.85±13.58	0.31	93.24±12.81	94.22±14.12	0.66
RPP, mmHg.bpm	120.47±25.45	126.98±26.51	0.22	124.13±27.08	127.83±23.61	0.39
Art stiffness						
AP, mmHg	9.29±5.60	9.83±5.67	0.55	9.56±5.68	9.63±5.90	0.99
Ref (%)	65.21±7.77	66.25±8.84	0.54	65.55±7.78	65.48±7.26	0.68
AIx@75 (%)	33.31±9.25	35.46±14.16	0.20	34.70±12.12	33.73±12.26	0.62
PWV, m/s	7.66±1.06	7.73±1.00	0.72	7.74±1.10	7.98±1.09	0.20
TAS, mL/mmHg	0.86±0.22	0.84±0.20	0.96	0.85±0.20	0.87±0.21	0.54
PPA	1.35±0.14	1.33±0.17	0.84	1.32±0.12	1.36±0.18	0.06
cBP (mmHg)						
cSBP	123.58±15.49	129.85±16.28	0.70	124.48±17.38	124.45±13.66	0.70
cDBP	86.75±10.22	88.69±10.05	0.35	88.14±11.79	87.55±8.52	0.35
cPP	36.46±10.14	36.90±11.57	0.84	36.22±10.75	37.35±10.43	0.84
Cpp ≥40, no. (%)	17 (35%)	20 (13%)	0.68	31 (62%)	24 (78%)	0.68
Central h						
emodynamics	5.23±0.79	5.28±0.92	0.75	5.20±0.87	5.30±0.73	0.09
CO, L/min	1.25±0.14	1.25±0.19	0.98	1.26±0.14	1.22±0.11	0.18
PR, mmHg/mL	3.06±0.60	3.15±0.57	0.48	3.11±0.59	3.17±0.48	0.30
CI, L/min/m^2	57.55±11.03	57.31±12.52	0.92	56.00±10.24	57.97±11.56	0.28
SV, mL/beat	34.09±8.06	34.36±7.62	0.87	33.91±6.88	34.24±7.52	0.78
SVI, mL/m^2/beat	112.87±33.25	112.91±34.24	>0.99	109.70±32.81	111.38±30.29	0.38
SW, g/beat						

GC+: glycemic control present; GC−: glycemic control absent; Dn: duration; the remaining abbreviations are the same as Table 1. Bold data indicates statistically significant with $P<0.05$

accelerated hemodynamics indicate beyond aging cardiovascular risk in postmenopausal females compared with premenopausal women.

Self-reported moderate physical activity and controlled BMI had significant positive impact on PWA results in line with a previous study.[18] This indicates the importance of obesity and its correction by physical activity as a potential to explore in diabetics without incident hypertension. These two are modifiable risk factors that must be corrected by all. Adiposity is one of the factors affecting vascular aging, hence PWA parameters.[19]

Hyperglycemia accelerates cardiovascular aging that manifests as raised stiffness, reduced compliance, and loss of elasticity.[20] And diagnosis and treatment of the same is supposed to benefit these parameters as published previously. Contrastingly, lack of impact glycemic control was found. It can be explained by ethnicity risk, lack of HbA1c result, and poor glycemic control (40%) in most cases. Our results are similar to Gordin[21] *et al.* and Chang[22] *et al.* In previous studies, we found that arterial stiffness was significantly raised in young first-degree relatives of diabetic[6] or hypertensive[7] parents and so the vascular change may precede the incident diabetes or hypertension. It supports the idea that diabetes is more a disease affecting cardiovascular health with hyperglycemia being a late manifestation. We did not find significant difference between new or old cases and with duration less than or more than 4 years with respect to PWA parameters, in line with our previous studies in diabetics with different cardiovascular parameters.[12,23-26] It indicates the importance of presence of disease, early diagnosis, physical

Table 4: Calculation of predictors for dependent variables by multiple linear regression (rpartial values) in case group

Parameters	AP	AIx@75	aPWV	TAS	cSBP	cDBP	cPP	CO	SW
Age	0.05	0.10	**0.11****	0.00	0.05	0.02	0.00	−0.01	−0.21
Height	0.18	−0.43	0.03	−0.00	−0.11	0.08	−0.11	0.02	0.21
Weight	0.07	0.26	−0.04	0.00	0.05	−0.10	0.09	−0.02	−0.13
BMI	−0.19	−0.95	0.08	−0.01	0.02	0.13	−0.00	0.06	0.49
SBP	−0.73	−1.85	0.05	−0.02	0.44	**0.84****	−0.31	0.09	2.51
DBP	−0.08	0.01	0.01	0.00	0.06	0.09	0.01	0.00	−0.10
MBP	**0.82***	**1.88***	−0.03	0.01	0.50	0.08	0.33	−0.06	−0.94
HR	**−0.05***	**0.44****	−0.00	**0.01****	**−0.04***	**0.02***	−0.04	**0.01***	**−0.85****
PP	0.63	1.25	−0.01	**0.02***	0.17	**−0.82****	**0.91***	−0.02	−0.46
Duration	−0.13	−0.27	**−0.02***	0.00	**−0.19***	−0.00	**−0.17***	0.02	**0.54***
FPG	0.01	0.01	0.00	0.00	0.01	0.00	0.01	−0.00	−0.02*
2hPG	−0.00	−0.01	0.00	−0.00	−0.01	0.00	0.00	0.00	0.01

BMI: body mass index; PA: physical activity; FPG: fasting plasma glucose; 2 hPG: 2-h plasma glucose; GC: glycemic control; bBP: brachial blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; MBP: mean blood pressure; PP: pulse pressure; PPI: pulse pressure index; HR: heart rate RPP: rate pressure product; AP: augmentation pressure; Ref: reflection percentage; AIx@75: augmentation index at heart rate 75 beats/min; PWV: pulse wave velocity; TAS: total arterial stiffness; PPA: pulse pressure amplification; cSBP: central systolic blood pressure; cDBP: central diastolic blood pressure; cPP: central pulse pressure; CO: cardiac output; PR: peripheral resistance; CI: cardiac index; SV: stroke volume; SVI: stroke volume index; SW: stroke work '*' indicates statistical significance. Bold data indicates statistically significant with $P<0.05$

activity, and prompt treatment more than further chronicity or glycemic control.

We studied predictors of the major study parameters by multiple linear regressions. The pattern of predictors was similar to our previous PWA studies.[6,7,10,11,16,27] The major points were as follows: (1) most outcome parameters were not significantly predicted by age (except PWV), height, weight, and BMI; (2) most of these were independent of bBPs pointing toward superiority of these parameters to complement routinely measured objective bBP; (3) HR proved to be the most consistent predictor which normally one can infer from pulse examination and proves the potential of details that can be obtained by arterial pulse examination; and (4) cBPs were not predicted significantly by the corresponding brachial artery values showing its importance beyond bBP.

Hypertension with coexisting or causative type 2 diabetes is one of the frequent encounters to a family physician. Routine bBP sometimes do not infer to more direct cardiovascular parameters. Physician can take advantage of PWA that offers better understanding of cardiovascular aging. We have established trends, association, and predictors of PWA parameters for our population. Central hemodynamics and arterial stiffness are stable, reliable, reproducible, objective, direct, discrete parameters. With availability of devices like Mobil-O-graph, it can be offered on large-scale and even at primary care level. This baseline work asks for further vertical and interventional studies to reinforce our results and to ascertain role of other risk factors not studied as limitations of our study.

There were few limitations of our study like cross-sectional nature, moderate sample size, lack of baseline data or follow-up, and absence of biochemical investigations.

Conclusion

Oscillometric PWA shows adverse profile of beyond bBP direct and discrete cardiovascular parameters in Gujarati diabetics not using any antihypertensive medication. This vascular progeria in the absence of hypertension and antihypertensive use was independent of duration and glycemic control, related to gender, BMI, and physical activity. This baseline study suggests further work on these potential parameters.

Study association

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Conflicts of interest

There are no conflicts of interest.

References

1. Zheng Y, Ley SH, Hu FB. Global aetiology and epidemiology of type 2 diabetes mellitus and its complications. Nat Rev Endocrinol 2018;14:88-98.
2. Einarson TR, Acs A, Ludwig C, Panton UH. Prevalence of cardiovascular disease in type 2 diabetes: A systematic literature review of scientific evidence from across the world in 2007–2017. Cardiovasc Diabetol 2018;17:83.
3. Solanki JD, Makwana AH, Mehta HB, Gokhale PA, Shah CJ. Hypertension in type 2 diabetes mellitus: Effect of the disease and treatment on development of peripheral artery disease. Int J Diabetes Dev Ctries 2015;35(Suppl 3):S380-4.
4. Solanki JD, Mehta HB, Panjwani SJ, Munshi HB, Shah CJ. Effect of antihypertensive pharmacotherapy on oscillometric pulse wave analysis parameters in treated Gujarati hypertensives: A cross-sectional study. J Pharmacol Pharmacother 2018;9:153-9.
5. Solanki JD, Mehta HB, Panjwani SJ, Munshi HB, Shah CJ. Impact of concomitant use of beta blocker, statin, aspirin, and metformin on central hemodynamics and arterial stiffness in hypertension. J Pharmacol Pharmacother 2018;9:167-73.
6. Solanki JD, Mehta HB, Shah CJ. Pulse wave analysed

cardiovascular parameters in young first degree relatives of type 2 diabetics – A cross-sectional study. Indian Heart J 2018;70:341-5.

7. Solanki JD, Mehta HB, Shah CJ. Pulse wave analyzed cardiovascular parameters in young first degree relatives of hypertensives. J Res Med Sci 2018;23:72.
8. American Diabetes Association. 2. Classification and diagnosis of diabetes: Standards of medical care in diabetes – 2018. Diab Care 2018;41(Suppl 1):S13-27.
9. Weiss W, Gohlisch C, Harsch-Gladisch C, Tölle M, Zidek W, van der Giet M. Oscillometric estimation of central blood pressure: Validation of the Mobil-O-Graph in comparison with the SphygmoCor device. Blood Press Monit 2012;17:128-31.
10. Solanki JD, Mehta HB, Shah CJ. Aortic pulse wave velocity and augmentation index@75 measured by oscillometric pulse wave analysis in Gujarati nonhypertensives. Vasc Invest Ther 2018;1:50-5.
11. Solanki JD, Mehta HB, Shah CJ. Oscillometric pulse wave analysis in newly diagnosed never treated Gujarati hypertensives. Vasc Invest Ther 2018;1:62-7.
12. Solanki JD, Gadhavi BP, Makwana AH, Mehta HB, Shah CJ, Gokhale PA. QTc interval in young Gujarati hypertensives: Effect of disease, antihypertensive monotherapy, and coexisting risk factors. J Pharmacol Pharmacother 2016;7:165-70.
13. Ben-Shlomo Y, Spears M, Boustred C, May M, Anderson SG, Benjamin EJ, *et al.* Aortic pulse wave velocity improves cardiovascular event prediction: An individual participant meta-analysis of prospective observational data from 17,635 subjects. J Am Coll Cardiol 2014;63:636-46.
14. Nilsson PM. Blood glucose and hypertension development: The hen and egg controversy. J Hypertens 2019;37:11-2.
15. Strain WD, Paldánius PM. Diabetes, cardiovascular disease and the microcirculation. Cardiovasc Diabetol 2018;17:57.
16. Solanki JD, Mehta HB, Shah CJ. Aortic blood pressure and central hemodynamics measured by noninvasive pulse wave analysis in Gujarati normotensives. Int J Clin Exp Physiol 2018;5:75-80.
17. Colafella KM, Denton KM. Sex-specific differences in hypertension and associated cardiovascular disease. Nat Rev Nephrol 2018;14:185-201.
18. Metsämarttila E, Rodilla E, Jokelainen J, Herrala S, Leppäluoto J, Keinänen-Kiukaanniemi S, *et al.* Effect of physical activity on pulse wave velocity in elderly subjects with normal glucose, prediabetes or Type 2 diabetes. Sci Rep 2018;8:8045.
19. Zachariah JP, Rong J, Larson MG, Hamburg NM, Benjamin EJ, Vasan RS, *et al.* Metabolic predictors of change in vascular function: Associations from a community-based cohort. Hypertens 2018;71:237-42.
20. Petrie JR, Guzik TJ, Touyz RM. Diabetes, hypertension, and cardiovascular disease: Clinical insights and vascular mechanisms. Can J Cardiol 2018;34:575-84.
21. Gordin D, Saraheimo M, Tuomikangas J, Soro-Paavonen A, Forsblom C, Paavonen K, *et al.* Influence of postprandial hyperglycemic conditions on arterial stiffness in patients with type 2 diabetes. J Clin Endocrinol Metab 2016;101:1134-43.
22. Chang S, Kim J, Sohn T, Son H, Lee J. Effects of glucose control on arterial stiffness in patients with type 2 diabetes mellitus and hypertension: An observational study. J Int Med Res 2018;46:284-92.
23. Solanki JD, Makwana AH, Mehta HB, Gokhale PA, Shah CJ. Evaluating glycemic control and its correlation with peripheral artery disease in ambulatory type 2 diabetic patients of an urban area of Gujarat, India. Int J Clin Exp Physiol 2014;1:221-5.
24. Solanki JD, Basida SD, Mehta HB, Panjwani SJ, Gadhavi BP, Patel P. Impact of disease control and co-existing risk factors on heart rate variability in Gujarati type 2 diabetics: An observational study. J Family Med Prim Care 2016;5:393-8.
25. Solanki JD, Patel KJ, Lalwani N, Mehta HB, Shah CJ, Lakhtaria MN. QT corrected for heart rate and qtc dispersion in Gujarati type 2 diabetics predominantly using preventive pharmacotherapy and with very low electrocardiogram left ventricular hypertrophy. J Diabetol 2017;8:86-91.
26. Solanki JD, Basida SD, Mehta HB, Panjwani SJ, Gadhavi BP. Comparative study of cardiac autonomic status by heart rate variability between under-treatment normotensive and hypertensive known type 2 diabetics. Indian Heart J 2017;69:52-6.
27. Solanki JD, Munshi HB, Shah CJ. Pulse wave analysis in Gujarati type 1 diabetics: A case control study. Natl J Integr Res Med 2018;9:59-65.