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Original Article

Cardiovascular Responses to Squatting Postural Stress among Non-Diabetic and Type-2 Diabetic Nigerian Black Africans

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Abstract

Background:A change in posture brings about a significant alteration in cardiovascular functions. The squat test has been used to study autonomic function in White Europeans but not Black Africans. The aim of this study is to determine the cardiovascular effects of postural stress in Black African non-diabetics and Type-2 diabetics.
Method: Blood pressure (BP) and heart rate (HR) was measured in 40 non-diabetics and 40Type-2 diabetics in sitting, standing from sitting, squatting and standing from squatting positions Difference in BP and HR between consecutive positions was tested using 2- way mixed ANOVA. Proportions of those who showed orthostatic hypotension and hypertension were compared with Fishers exact test. Significance was set at $p < 0.05$.
mmHg: Δ: BP and HR changes evoked by standing from sitting were not different, however squatting evoked greater increase in BP in diabetics(change (Δ) SBP: 5.85±9.95 vs 17.40±13.75mmHg: Δ DBP: 0.15 ± 6.89 vs 5.10 ± 7.59 mmHg:Δ MABP:2.02 ± 6.98 vs 8.63 ± 9.34 mmHg ,$p < 0.05$) and standing from squatting evoked greater fall BP in diabetics (ΔSBP: -9.80±13.89 vs -24.35±16.03 mmHg; Δ MABP:-2.02±6.98 vs -8.63±9.34 mmHg: Δ PP: -2.28 ±15.35 vs -14.50 ±11.96 mmHg, $p < 0.05$) while Δ HR did not differ. A higher proportion of diabetics showed SBP and DBP orthostatic hypertension.
Conclusion: Relative to the non-diabetics, diabetics showed greater BP but not HR responses to postural stress.
Keywords: Squat; Postural Stress; Blood Pressure; Heart Rate; Black African; Diabetics.

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Introduction

A change in posture brings about significant alterations in cardiovascular function. Standing is accompanied by gravitational pooling of 0.5 litre to 1 litre of blood from thorax to the legs and splanchnic vessels leading to reduced venous return to the heart, reduced stroke volume (SV)and cardiac output (CO) with subsequent fall in blood pressure (BP). The fall in blood pressure (BP)unloads the cardiopulmonary baroreceptors and triggers baroreceptor mediated reflex which increases sympathetic nervous outflow to the heart and blood vessels and decreases cardiac vagal nerve activity. These cause increase in vascular tone, heart rate (HR) as well as cardiac contractility and restores BP to normal. On the other hand, squatting from standing position results in mobilization of peripheral venous pool leading to increase in venous return to the heart, increase in CO and subsequent increase in BP. The rise in BP triggers baroreceptor mediated reflex which increases parasympathetic nervous outflow to the heart and decreases sympathetic nerve activity causing reduction in heart rate.

It is known that following orthostatic stress, the baroreceptor reflex usually initiates correction of BP back to normal within 30 seconds with reflex tachycardia. However in some disease conditions such as diabetes mellitus, arterial stiffness can lead to blunted baroreceptor sensitivity and dysfunction resulting in prolongation of the time for restoration of BP, the blood pressure may not returned to normal or BP responses become exaggerated and heart changes are blunted.

A fall in SBP of not more than 20 mmHg within 3 minutes of standing is considered a normal response. However, in some subjects an exaggerated fall in SBP of more than 20 mmHg occurs (orthostatic hypotension) while in others, an increase in SBP of more than 10 mmHg BP occurs (orthostatic hypertension).In addition, a fall in DBP of less than 10mmHg is considered normal while a fall in DBP of 10 mmHg or more is referred to as orthostatic hypotension and an increase in DBP of more than 10 mmHg is referred to as orthostatic hypertension. Orthostatic hypotension has been associated with autonomic dysfunction arising from failure to achieve adequate compensatory vasoconstriction and heart rate increase after standing. Conversely, orthostatic hypertension arises from overcompensation for an excessive initial fall in BP with an exaggerated sympathetic nervous activity and vasoconstriction. Thus, an assessment of hemodynamic responses to standing from sitting or from squatting positions can provide useful measure of autonomic control of BP.

Given that hemodynamic responses to postural stress can be used to assess autonomic function, the use of the squat test rather than the sophisticated electric tilt table has been proposed as an alternative for those in developing countries where the tilt table is unavailable. Although, the squat test has been used to determine cardiac autonomic function in Asians and in White European (WE) adults and diabetics, the usefulness of the squat stress test has not been tested in Black Africans (Bas) and whether the previous findings are generalizable to black African diabetics is not known.

The aim of this study was to determine the blood pressure and heart rate responses to postural stress in Black African diabetic and non-diabetic adults.

Objectives

The specific objectives were to determine changes in blood pressure evoked by change in position from sitting to standing, from standing to squatting and from squatting to standing; to determine changes in heart rate evoked by changes in position from sitting to standing, from standing to squatting and from squatting to standing and to assess effect of diabetic status on the magnitude of change in blood pressure and heart rate during change of position.

The study was conducted based on the following null hypothesis:

Standing from sitting and standing from squatting will not evoke decrease in BP with increase in HR while squatting from standing will not evoke increase in BP with decrease in HR in the diabetic and non-diabetic BA adults.

The diabetics will show not greater fall in BP and blunted HR responses during standing relative to the non-diabetics.

Diabetics will not show greater increases in BP and blunted HR responses during squatting relative to the non-diabetics.

Larger proportion of diabetics will not show orthostatic hypotension during standing and orthostatic hypertension during squatting relative to non-diabetics.

The corresponding Alternate hypotheses were:
Standing from sitting and standing from squatting will each evoke decrease in BP with increase in HR while squatting from standing will evoke increase in BP with decrease in HR in the diabetic and non-diabetic BA adults.

The diabetics will show greater fall in BP with blunted HR responses during standing relative to the non-diabetics.

Diabetics will show greater increases in BP with blunted HR responses during squatting relative to the non-diabetics.

Larger proportion of diabetics will show orthostatic hypotension during standing and orthostatic hypertension during squatting relative to non-diabetics.

Materials and method

The required sample size to have an 80% chance of detecting a significant5 mmHg difference in BP between squatting and standing position between diabetics and non-diabetics, at two-sided 5% level, with standard deviation of change in SBP of 10.8 mmHg was 37 individuals per group. Anticipating a 10% attrition rate, the sample size was increased to forty per group.

A cross sectional study was done on forty healthy non-diabetics recruited from local community and 40 Type-2 diabetics recruited from the Endocrinology clinic at University College Hospital, Ibadan using convenience sampling method. Ethical approval was obtained from the University of Ibadan/University College Hospital Ethical review committee.

Exclusion criteria included the presence of Type-1 Diabetes mellitus, pregnancy, stroke, inability to squat or history of smoking. Experiments on diabetics were done at the Endocrinology clinic, University College Hospital Ibadan. Non-diabetic subjects were experimented on at the Department of Physiology of University of Ibadan, Nigeria.

A questionnaire was administered to collect information on participants' sociodemographic characteristics such as age, sex, marital status, and medical history. Anthropometric measurements were taken, height (in meters, m) was measured by using stadiometer and weight (in kilograms, kg) was measured using a weighing scale. Body mass index (BMI) was calculated as weight /height^2. An automated BP monitoring device (Omron MX2, Omron healthcare, UK) was used to measure BP and HR.

After subjects had rested for 10minutes (mins) in sitting position, measurement of BP and HR were taken as baseline values. Using the squat test protocol from previous studies, each individual stood upright for 3 mins (pre-squat standing), squatted for 2 mins (squat) and stood upright for 1 minute (post-squat standing) Systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) measurements were taken in the last minute of standing was used as pre-squat standing values, measurements taken immediately squatting position was assumed as were used as squatting values. Lastly, measurement taken immediately subject assumed upright position from squatting position was used as post-squat standing values. Mean arterial blood pressure (MABP) was calculated using the formula (1/3 pulse pressure (PP) + DBP) and pulse pressure was calculated using the formula; SBP-DBP.

Data analysis

Mean values were presented with standard deviation (SD). Absolute values of systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial blood pressure(MABP), pulse pressure (PP) and heart rate (HR) in sitting and standing positions were compared with independent Student's t test.The changes (Δ)in SBP, DBP, MABP, PP and HR between sitting and pre-squat standing positions were determined as measures of response to standing from sitting position. The changes (Δ) in BP and HR between squatting and pre-squat stand were determined as measures of response to squatting. In addition, the changes (Δ) in BP and HR between post-squat stand and squatting were determined as measures of response to standing from squatting position. Statistical analyses were performed using SPSS version 22.0 (IBM Corp, 2013). Two-way mixed ANOVA was done with posture as the within subjects' factor (3 levels) and diabetic status as the between subjects' factor (diabetic and non-diabetic). Significance level was set at $p<0.05$.

A fall in SBP was categorized as normal (1-19 mmHg) and postural hypotension (≥20 mmHg). Increase in SBP was categorized as normal (1-9 mmHg) and postural hypertension (≥ 10 mmHg). A fall in DBP was categorized as normal (1-9mmHg), orthostatic (≥10mmHg), while increase in DBP was categorized as normal (1-9 mmHg) and orthostatic hypertension (≥10 mmHg). Proportion In each category was presented as numbers (n) and percentage (%), association between diabetic status and responses were determined by Fishers exact test. Significance was set at $p < 0.05$.

Results

Diabetics were older than non–diabetics ($p= 0.001$). Height, weight, and body mass index were similar between the two groups (Table 1). At baseline in sitting position, absolute SBP, PP and HR but not DBP or MABP were higher in the diabetics relative to the non-diabetics (Table 2). In pre-squat standing position, absolute SBP, MABP, PP and HR but not DBP were higher in the diabetics relative to the non-diabetics (Table 3).

Change in Blood Pressure and Heart Rate in the non-diabetics and the diabetics in the 3 positions.

Change in Systolic Blood Pressure
During pre-squat standing, there was no significant difference in Δ SBP in non-diabetics vs the diabetics($F(1,78) = 0.046$, $\eta 2 = 0.001$, $p = 0.832$).In the diabetics relative to the non-diabetics, there was significantly higher increase in SBP during squatting ($F(1,78) = 18.52$, $\eta 2 = 0.192$, $p = 0.000$) as well as greater fall in SBP during post squat standing ($F(1,78) = 18.82$, $\eta 2 = 0.194$, $p = 0.000$), see Table 4 .

Change in Diastolic Blood Pressure
Relative to the non-diabetics, the diabetics had significantly higher increase in DBP during squatting ($F(1,78) = 9.33$, $\eta 2 = 0.107$, $p = 0.003$), however during pre-squat and post-squat standing, there were no significant differences ($F(1,78) = 3.35$, $\eta 2 = 0.041$, $p = 0.071$; $F(1,78) = 1.77$, $\eta 2 = 0.022$, $p = 0.187$ respectively, see Table 4).

Change in Mean Arterial Blood Pressure
During pre-squat standing, there was no significant difference between diabetics and non-diabetics ($F(1,78) = 1.63$, $\eta 2 = 0.020$, $p = 0.205$). However relative to the non-diabetics, the diabetics had significantly greater increase in MABP during squatting ($F(1,78) = 12.87$, $\eta 2 = 0.142$, $p = 0.001$), and greater fall in MABP during post squat standing ($F(1,78) = 12.12$, $\eta 2 = 0.134$, $p = 0.002$) (Table 4).
Change in Pulse Pressure
Relative to the non-diabetics, the diabetics had significantly higher increase in PP during squatting ($F(1,78) = 9.33$, $\eta 2 = 0.107$, $p = 0.003$), however, during pre-squat standing and squatting the differences were not significant ($F(1,78) = 1.85$, $\eta 2 = 0.023$, $p = 0.177$): $F(1,78) = 2.77$, $\eta 2 = 0.034$, $p = 0.100$ respectively).

Change in Heart Rate
There was no significant main effect of diabetic status on HR ($F(1,101) = 0.20$, $\eta 2 = 0.002$, $p = 0.660$), although there was significant main effect of position on HR ($F(1,101) = 10.04$, $\eta 2 = 0.114$, $p = 0.001$). The difference between pre-squat standing and squatting as well as between squatting and post squat standing were significant ($p = 0.000$, 0.008 respectively). There was no significant difference in Δ HR between pre-squat and post-squat standing ($p = 1.00$).

Orthostatic hypotension or hypertension
Pre-squat standing
There was no significant difference between the proportion of non-diabetic's vs diabetics who showed SBP orthostatic hypotension (0 % vs 2.5%) or orthostatic hypertension SBP (15 % vs 20%), see Table 5.A higher proportion of diabetics showed DBP orthostatic hypertension relative to the non- diabetics (5 % vs 25 %, $p = 0.035$, Table 6).

Squatting
There was no orthostatic hypotension in either the diabetics or non-diabetics, however a higher proportion of the diabetics showed SBP orthostatic hypertension relative to the non-diabetics (65 % vs 37.5 %, $p = 0.020$, Table 5).Considering DBP responses, 2.5 % of the non-diabetics showed DBP orthostatic hypotension, while DBP orthostatic hypertension occurred in 10 % of non-diabetics vs 20 % of diabetics ($p = 0.06$, Table 6).

Post-squat standing
A higher proportion of diabetics showed SBP orthostatic hypotension (30 % vs 57.5%, $p = 0.006$, Table 5). Similar proportions of non-diabetics and diabetics showed orthostatic DBP hypotension (30 % vs 37.5 %, $p = 0.60$, Table 6).

Table 1: Anthropometric characteristics and cardiovascular variables at baseline in sitting position in non-diabetic's vs diabetics.

	Non-diabetics	Diabetics	P value
Age (years)	43.30±6.78	52.56±9.88	<0.001
Male /Female (n, %)	18(45%):22(55%)	11(27.5%):29(72.5%)	0.162
Height (metres, m)	1.64 ± 0.77	1.63 ± 0.072	0.678
Weight (Kilograms, kg)	74.25±14.77	76.18±17.99	0.602
BMI (kg/m^2)	27.66± 5.583	28.80±6.565	0.350

Values are mean ±standard deviation (SD). Analysed with independent Student's T test. Male/females shown in numbers (n) and percentage (%) analyzed with Chi squared test.

Table 2: Cardiovascular variables in sitting position in non-diabetic's vs diabetics.

	Non-diabetics	Diabetics	P value
Systolic blood pressure, SBP(mmHg)	119.53±9.70	130.13±21.16	0.005
Diastolic blood pressure, DBP (mmHg)	75.18±9.46	75.08± 10.77	0.965
Mean arterial pressure, MAP(mmHg)	89.63±9.48	91.93±16.46	0.446
Pulse pressure, PP(mmHg)	44.35±9.19	55.05±15.30	<0.0001
Heart rate, HR (beats per minute, bpm)	73.83±10.44	81.52±10.82	0.002

Values are mean ±standard deviation (SD)of absolute blood pressure and heart rate in non-diabetics and diabetics. Analyzed with independent Student's T-test.

Table 3: Blood pressure and heart rate in pre-squat standing position in non-diabetic's vs diabetics.

	Non-diabetics	Diabetics	P value
Systolic blood pressure, SBP(mmHg)	123.90±13.09	135.73±22.37	0.005
Diastolic blood pressure, DBP (mmHg)	80.23±8.24	82.50±9.27	0.251
Mean arterial pressure, MAP(mmHg)	94.82±8.93	100.81±12.23	0.014
Pulse pressure, PP (mmHg)	43.63±10.17	54.93±18.92	0.001
Heart rate, HR (beats per minute)	79.13±11.64	88.18±11.15	0.001

Values are mean ± standard deviation (SD) of absolute blood pressure and heart rate in non-diabetics and diabetics. Analyzed with independent Student's T-test.

Table 4: Change (Δ) in blood pressure and heart rate in pre-squat, post- squat standing and squatting positions in non-diabetics and diabetics.

		Pre-squat standing	Squat	Post-squat standing
Δ SBP	Non-diabetics	5.05±8.92	5.85±9.95	-9.80±13.89
	Diabetics	4.63±8.90	17.40±13.75***	-24.35±16.03***
Δ DBP	Non-diabetics	4.50±4.41	0.15±6.89	-7.03±10.28
	Diabetics	6.60±5.75	5.10±7.59**	-9.85±8.62
Δ MABP	Non-diabetics	5.02±4.63	2.02±6.98	-8.03±9.24
	Diabetics	7.44±11.09	8.63±9.34**	-15.43±9.77**
Δ PP	Non-diabetics	0.55±9.00	5.75±8.63	-2.28±15.35
	Diabetics	-1.98±7.53	10.60±16.27	-14.50±11.96*
Δ HR	Non-diabetics	4.78±5.67	1.58±10.02	5.55±12.48
	Diabetics	6.95±6.05	-1.40±7.83	7.55±10.68

Values are mean ± SD of changes (Δ)in systolic blood pressure (SBP, mmHg), diastolic blood pressure (DBP, mmHg), mean arterial blood pressure (MABP, mmHg), pulse pressure (PP, mmHg) and heart rate (HR, beats per minute) in non-diabetics vs diabetics during postural stress * p <0.05, **p <0.005, ***p <0.0005. Analysed with 2-way mixed factor ANOVA.

Table 5: Change (Δ) in systolic blood pressure (SBP) in pre-squat and post-squat standing and in squatting positions in non-diabetics and diabetics.

	Pre-squat standing			Squatting			Post-squat standing		
Δ SBP (mmHg)	**Non-Diabetics**	**Diabetics**	**P value**	**Non-Diabetics**	**Diabetics**	**P value**	**Non-Diabetics**	**Diabetics**	**P Value**
< -20	0 (0.0)	1 (2.5)	0.910	0 (0.0)	0 (0.0)	0.020	12 (30.0)	23 (57.5)*	0.006
-20 to -0	13 (32.5)	11 (27.5)		15 (35.0)	4 (10.0)		18 (35.0)	15 (37.5)	
+1 to+10	21 (52.5)	20 (50.0)		11 (27.5)	10 (25.0)		7 (17.5)	0 (0.0)	
> +10	6 (15.0)	8 (20.0)		15 (37.5)	26 (65.0)*		3 (7.5)	2(5.0)	

n) and percentage %. Analyzed with Fishers exact test.

Table 6: Change (Δ) in diastolic blood pressure (DBP) in standing from sitting position and from squatting position in non-diabetics and diabetics.

	Pre-squat standing			Squatting			Post-squat standing		
ΔDBP (mmHg)	**Non-Diabetics**	**Diabetics**	**P value**	Non-Diabetics	Diabetics	**P value**	**Non-Diabetics**	**Diabetics**	**P Value**
< -10	0 (0.0)	0(0.0)	0.035	1 (2.5)	0 (0.0)	0.060	12 (30.0)	15(37.5)	0.600
-10to -1	3 (7.5)	5 (12.5)		3 (7.5)	1 (2.5)		20 (50.0)	21 (52.5)	
0	3(7.5)	1(2.5)		18 (45)	9 (22.5)		2 (5)	0 (0.0)	
+1 to+10	32 (80.0)	24 (60.0)		14 (35)	22 (55.0)		5(12.5)	4 (10.0)	
> +10	2 (5.0)	10 (25.0)		4 (10)	8 (20.0)		1(2.5)	0 (0.0)	

Values are number (n) and percentage %. Analysed with Fishers exact test.

Discussion

The higher resting systolic blood pressure (SBP), pulse pressure (PP) and heart rate (HR) in the diabetics relative to the non-diabetics is consistent with previous reports [23,24]. Diabetes is known to increase the rate of vascular remodeling, leading to an increase in arterial stiffness [25]. Arterial stiffness can be estimated using the pulse pressure. In the present study, the augmentation of PP was due to increase in SBP which may be related to the higher heart rate in the diabetics.

In White Europeans (WEs), assumption of upright posture was associated with a fall in BP and an increase in HR [26]. Although Asians and White Europeans showed decrease in MABP after standing, Black Africans (BAs) showed increase in DBP and MABP[27]. Further, [22] reported that a large proportion of black subjects showed increased SBP during standing. These suggest that BAs show a different cardiovascular pattern reflecting increased peripheral resistance compared to WEs or Asians.

Contrary to the widely accepted concept of a universal fall in BP upon assumption of standing position, there is evidence of a spectrum of SBP changes such that increases and decreases in SBP are known to occur [28]. Consistent with this pattern, BP responses ranged from increases to decreases however, the majority of the BA participants we studied showed increase in BP rather than decrease when the standing position was assumed from sitting position, irrespective of the diabetic status. The increase in BP could be due to increased venoconstriction or vasoconstriction in response to increased sympathetic nervous activity preventing fluid shift and venous pooling [14].

Consistent with previous report, this present study shows that squatting induces a higher increase in the SBP and DBP in diabetics than in non-diabetics[29]. Greater increased DBP during squatting suggests peripheral resistance increased to a greater extent in the diabetics. Although heart rate (HR) was higher in the diabetics than in non-diabetics, the heart rate changes were similar suggesting blunted HR responses in diabetics. Since previous reports show evidence of bradycardia during squatting [16,17], the lack of significant bradycardia in spite of increases in BP in this present study suggests altered baroreceptor function in the diabetics. Further, standing up from the squatting position induced greater decline in SBP, MAP

and PP, in diabetics relative to non-diabetics but not greater increase in HR, suggesting defective baroreceptor regulation of heart rate during postural stress.

Orthostatic hypotension

The usual response to standing has been reported to a reduction of SBP of less than <4 mm Hg and elevation of SBP less than <10 mm Hg[7].Comparing the responses to standing from sitting position with standing from squatting, the latter induced greater fall in BP and is a more effective orthostatic stress in BAs. This is consistent with findings of [30] who showed that reduction in stroke volume and systemic vascular resistance were more pronounced when subjects assumed the upright posture from a squat position. They concluded that significantly greater drop in BP will occur in diabetic patients with autonomic neuropathy. Consistent with this, a larger proportion of the diabetics we studied showed orthostatic hypotension during post squat standing than during standing from sitting position.

Orthostatic hypotension is usually tested by standing from supine or sitting position or with 60% tilt using a tilt table [12]. The squat test has been proposed as an alternative to the use of tilt table and standing from sitting elicited a greater drop in BP in WE diabetics with autonomic neuropathy [21]. We also confirm that among BAs, the squat test is a much more robust postural stress test, however, BA diabetics as well as non-diabetics show some evidence of orthostatic hypotension during post squat standing. We hereby provide the first evidence for squatting induced orthostatic hypotension among BAs and propose that this stress can be adopted for such testing rather than standing from sitting position which tends to elicit orthostatic hypertension.

The diabetics showed higher prevalence of DBP orthostatic hypertension in during pre-squat standing and squatting but not during post-squat standing. Orthostatic hypertension is associated with over activity in sympathetic nervous system with associated increased vasoconstriction and increased peripheral resistance causing DBP to increase [31]. Although previous studies done on WEs have attributed increased in BP during squatting to increased stroke volume and cardiac output [5,32], however the findings of the present study suggests that in diabetic BAs, excessive activation of SNS with increased peripheral resistance leading increased DBP may play a role.

Conclusion

Squatting is associated with net increase in SBP, DBP and MABP without significant bradycardia in adult BAs. Standing from squatting is an effective maneuver that unveils postural hypotension better than standing from sitting position. We present the first report of responses to postural stress using the squat test in BA diabetics. The use of the BP changes during standing from squatting is an easy and useful method for assessing autonomic control of the heart that can be adopted in clinical practice in a developing country where the tilt table is not available.

Limitations

The study was a cross sectional descriptive study, stroke volume and cardiac output during postural stress were not measured and the mechanisms underlying the altered responses were not explored. In addition, continuous recordings of BP, HR and recordings of sympathetic nerve activity could have provided measure of cardiac and vascular baroreceptor sensitivity. These will be explored in further studies.

Highlights

1. Contrary to our alternate hypothesis 1, standing from sitting did not evoke net decrease in BP, however in agreement with the alternate hypothesis 1, standing from squatting evoked net decrease in BP.
2. Contrary to our alternate hypothesis 2, diabetics did not show greater fall in BP relative to non-diabetics during standing from sitting position, however diabetics showed greater fall in BP during standing from squatting position in agreement with the alternate hypothesis.
3. Consistent with our alternate hypothesis 3, diabetics showed greater increases in BP than non- diabetics during squatting.
4. HR changes were similar in the non-diabetics and the diabetics during postural stress.
5. Consistent with our alternate hypothesis 4, a larger proportion of diabetics showed orthostatic hypotension during standing from squatting and orthostatic hypertension during squatting.

References

1. Hill L. The Influence of the Force of Gravity on the Circulation of the Blood. J Physiol, 1895. 18:15-53.
2. Matzen, S., et al., Blood volume distribution during head-up tilt induced central hypovolaemia in man. Clin Physiol, 1991. 11: p. 411-22.
3. Sjostrand T. Volume and distribution of blood and their significance in regulating the circulation. Physiol Rev, 1953. 33: p. 202-28.
4. Rossberg F, Penaz J. Initial cardiovascular response on change of posture from squatting to standing. Eur J Appl Physiol Occup Physiol, 1988. 57: p. 93-7.

5. O'Donnell TV, Ilroy MB. The circulatory effects of squatting. Am Heart J, 1962. 64: p. 347-56.
6. Sharpey-Schafer EP. Effects of squatting on the normal and failing circulation. Br Med J, 1956. 1: p. 1072-4.
7. Borst C, Wieling W, van Brederode JF, Hond A, de Rijk LG, Dunning AJ. Mechanisms of initial heart rate response to postural change. Am J Physiol, 1982;243:H676-81.
8. Philips JC, Marchand M, Scheen AJ. Squatting, a posture test for studying cardiovascular autonomic neuropathy in diabetes. Diabetes Metab 2011; 37:489-96.
9. Philips JC, Marchand M, Scheen AJ. Squatting amplifies pulse pressure increase with disease duration in patients with type 1 diabetes. Diabetes Care 2008.31:322-4.
10. Tabara Y, Igase M, Miki T, Ohyagi Y, Matsuda F, Kohara K; J-SHIPP study group. Orthostatic hypertension as a predisposing factor for masked hypertension: the J-SHIPP study. Hypertens Res 2016;39(9):664-9.
11. Ricci F, De Caterina R, Fedorowski A. Orthostatic Hypotension: Epidemiology, Prognosis, and Treatment. J Am Coll Cardiol, 2015;66:848-860.
12. Freeman R, Wieling W, Axelrod FB, Benditt DG, Benarroch E, Biaggioni I, et al. Consensus statement on the definition of orthostatic hypotension, neurally mediated syncope and the postural tachycardia syndrome. Clin Auton Res 2011;21(2):69-72.
13. Freeman R, Abuzinadah AR, Gibbons C, Jones P, Miglis MG, Sinn DI. Orthostatic Hypotension: JACC State-of-the-Art Review. Journal of the American College of Cardiology 2018;72(11):1294-1309.
14. Magkas N, Tsioufis C, Thomopoulos C, Dilaveris P, Georgiopoulos G, Sanidas E, Papademetriou V, Tousoulis D. Orthostatic hypotension: From pathophysiology to clinical applications and therapeutic considerations. J Clin Hypertens (Greenwich), 2019;21(5):546-554.
15. Fessel J, Robertson D. Orthostatic hypertension: when pressor reflexes overcompensate. Nat Clin Pract Nephrol, 2006;2(8):424-31.
16. Nakagawa M, Shinohara T, Anan F, Yufu K, Takahashi N, Okada N, Hara M, Yoshimatsu H, Saikawa T. New squatting test indices are useful for assessing baroreflex sensitivity in diabetes mellitus. Diabet Med 2008;25(11):1309-15.
17. Scheen AJ, Philips JC. Squatting test: a dynamic postural manoeuvre to study baroreflex sensitivity. Clin Auton Res. 2012;22(1):35-41.
18. Philips JC, Scheen AJ. Squatting test: A posture to study and counteract cardiovascular abnormalities associated with autonomic dysfunction. Auton Neurosci. 2011;162(1-2):3-9.
19. Marfella R, Giugliano D, di Maro G, Acampora R, Giunta R, D'Onofrio F. The squatting test. A useful tool to assess both parasympathetic and sympathetic involvement of the cardiovascular autonomic neuropathy in diabetes. Diabetes. 1994;43(4):607-12.
20. Philips JC, Marchand M, Scheen AJ. Haemodynamic changes during a squat test, pulsatile stress, and indices of cardiovascular autonomic neuropathy in patients with long-duration type 1 diabetes. Diabetes Metab 2012; 38:54-62.
21. Scheen AJ, Marchand M, Philips JC. Relationships between baroreflex gain and pulsatile stress in type 1 diabetic patients. Ann Cardiol Angeiol (Paris) 2012; 61:178-83.
22. Nardo CJ, Chambless LE, Light KC, Rosamond WD, Sharrett AR, Tell GS, Heiss G. Descriptive epidemiology of blood pressure response to change in body position. The ARIC study. Hypertension 1999;33(5):1123-9.
23. Jarrett, R.J., et al., Glucose tolerance and blood pressure in two population samples: their relation to diabetes mellitus and hypertension. Int J Epidemiol, 1978. 7: p. 15-24.
24. Fuller JH. Epidemiology of hypertension associated with diabetes mellitus. Hypertension 1985;7(6part 2):113-7.
25. Spinetti G, Kraenkel N, Emanueli C, Madeddu P. Diabetes and vessel wall remodelling: from mechanistic insights to regenerative therapies. Cardiovasc Res 2008;78(2):265-73.
26. Eşer I, Khorshid L, Güneş UY, Demir Y. The effect of different body positions on blood pressure. J Clin Nurs 2007;16(1):137-40.
27. Goldstein IB, Shapiro D. The cardiovascular response to postural change as a function of race. Biol Psychol, 1995; 39:173-86.
28. Townsend RR, Chang TI, Cohen DL, Cushman WC, Evans GW, Glasser SP, et al., Orthostatic changes in systolic blood pressure among SPRINT participants at baseline. J Am Soc Hypertens 2016;10(11):847-856.
29. Philips JC, Marchand M, Scheen AJ. Pulsatile stress in middle-aged patients with type 1 or type 2 diabetes compared with nondiabetic control subjects. Diabetes Care 2010; 33:2424-9.
30. Scheen AJ, Juchmes J, Pochet T, Marfela R, Di Maro G, Lefebvre PJ. Non invasive beat-to-beat investigation of the effects of posture on arterial blood pressure in diabetic neuropathy. Seminaire International sur les Neuropathies Diabetiques 1990.
31. Kario K. Orthostatic hypertension-a new haemodynamic cardiovascular risk factor. Nat Rev Nephrol 2013; 9:726-38.
32. Hanson P, Slane PR, Rueckert PA, Clark SV. Squatting revisited: comparison of haemodynamic responses in normal individuals and heart transplantation recipients. Br Heart J 1995;74(2):154-8.