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Original Article

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Arterial Stiffness in Children and Adolescents with Type 1 Diabetes Mellitus or Excess Weight

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BACKGROUND: The relationship between pediatric obesity or Type 1 Diabetes Mellitus (T1DM) and cardiovascular disease in adulthood is well established, with the pathophysiological mechanisms being already present in childhood. Arterial stiffness is a strong, independent predictor of cardiovascular disease in adulthood. In this study we evaluated arterial stiffness indices such as pulse wave velocity (PWV) and central blood pressure (cBP) in children and adolescents with T1DM or excess weight, in order to detect subclinical vascular alterations at a very early stage.

METHODS: A total of 199 children and adolescents aged 2-18 years participated in the study, including 96 with T1DM, 49 with overweight or obesity, and 54 healthy controls. PWV and cBP was measured using the automated oscillometric device Mobil-O-Graph.

RESULTS: Systolic BP (SBP) and central SBP (cSBP) were overall and especially in those > 10 years of age, significantly higher in both patients with overweight/obesity and those with T1DM compared to controls. Furthermore, overweight/obesity patients had higher SBP, cSBP and cDBP compared to T1DM patients, whereas DBP was significantly higher only in overweight/obesity patients compared to controls. Pulse wave velocity values were also significantly higher in both overweight/obesity patients and those with T1DM compared to controls, while overweight/obesity patients had higher PWV when compared to patients with T1DM.

CONCLUSIONS: Impaired arterial elasticity was found in children and adolescents older than 10 years, with T1DM and overweight/obesity, particularly in the latter. PWV could potentially serve as diagnostic tool for impaired vascular health in children and adolescents with T1DM or overweight/obesity.

Keywords: arterial stiffness; central blood pressure; hypertension; pulse wave velocity; type 1 diabetes; obesity.

Introduction

Pediatric obesity and type 1 diabetes mellitus (T1DM) represent two significant global health threats due to their rising prevalence and multilevel complications. Both diseases have a well-recognized relationship with cardiovascular diseases, which are a major health burden and the main cause of death, particularly in industrialized countries.[1,2] Although cardiovascular events occur mostly in adulthood, the underlying process of atherosclerosis is already detected in childhood, with the initial vascular alterations, such as fatty streaks and pro-atherosclerotic lesions, appearing in the first decade of life.[3]

Due to the high morbidity and mortality rates involved, cardiovascular risk estimation is considered crucial for patients with obesity and T1DM. There is a rising demand for non-invasive tools to forecast subclinical vascular disease that may lead to manifest cardiovascular disease in future life. Among the parameters used for the estimation of the cardiovascular risk, the arterial stiffness is highly indicative. Arterial stiffness is a dynamic property determined by the blood pressure and the structure and function of the arterial wall,[4] and is a strong, independent predictor of cardiovascular morbidity, and all-cause mortality in adults.[5] In children and adolescents, the metabolic syndrome, high blood pressure and impaired glucose metabolism have been associated with arterial stiffness.[6]

The most widely accepted method for the evaluation of the arterial stiffness is pulse wave velocity (PWV), which refers to the speed at which the pressure wave generated by the pulsatile ejection of the left ventricle is transmitted through the arterial system.[7,8] It is involved in the pathogenesis of atherosclerosis and also reflects compromised cardiac function, as reduced arterial distensibility leads to elevated brachial pulse pressure, elevated pulse wave velocity and higher left ventricular afterload, higher systolic blood pressure and reduced coronary perfusion.[9,10] In 2009 the American Heart Association emphasized the importance of standardizing noninvasive methods for quantifying the cardiovascular risk in the pediatric population also, mentioning the usefulness of PWV as a marker of end organ damage.[11] Although obesity has been linked to increased PWV in adults, data

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regarding the relationship between pediatric obesity and PWV are conflicting.[12–17] In populations with T1DM however, literature reports demonstrate consistency showing increased carotid-femoral PWV in both the adult and the pediatric populations.[18–20]

The aim of the present study was to evaluate the arterial stiffness in children and adolescents with T1DM or excess weight, considering the well-established relationship between these two conditions and cardiovascular risk, in order to detect subclinical vascular alterations at a very early stage.

Methods

Study population

One hundred ninety-nine children and adolescents aged 2-18 years were recruited from the Outpatient Clinic of the Division of Pediatric Endocrinology and Diabetes of the University Hospital of Patras (96 with T1DM, 49 with overweight/obesity, and 54 healthy controls). Children and adolescents who were referred to the Outpatient Clinics and were subsequently proved to have no substantial medical issue were enrolled as controls.

Exclusion criteria were acute febrile illness at the time or within the previous 3 days of the visit, diabetes duration less than 3 months, or any chronic diseases (cancer, asthma and malabsorption) that could affect cardiovascular risk.

The study was approved by the Research Ethics Committee of the University General Hospital of Patras (IRB Number:132/10-3/2022) and was conducted in accordance with the Declaration of Helsinki as revised in 2013. Written informed consent was obtained by the parents and/or guardians of the participating children and adolescents, and assent from the participants.

Anthropometric and laboratory measurements

Body weight and height were measured using portable scales and stadiometer (Seca, Hamburg, Germany) to the nearest of 0.1 kg and 0.1 cm, respectively, with the children in light clothes and without shoes. Pubertal status was clinically assessed according to Tanner stages. The Body Mass Index, calculated as a ratio of body weight (kg) per square height (m^2), was expressed as z-score, adjusted for age and sex, and was used for the classification of different degrees of weight status. A BMI z-score between -2 and + 1 was defined as normal, whereas a BMI z-score of > 1 and > 2 was used to define overweight and obesity, respectively.[21]

For participants with T1DM, data including age, duration of diabetes, glycemic control expressed as HbA1c, and mode of treatment (multiple dose injection treatment versus insulin pump use), were collected. The average HbA1c over the past 1 year was calculated. Good glycemic control was defined as a HbA1c of < 7%, whereas poor glycemic control as a value of ≥7%. HbA1c levels as well as parameters that may affect cardiovascular health, such as renal function (serum creatinine, eGFR), liver function (AST, ALT, γGT), thyroid function (FT4, TSH), lipid profile (Chol, LDL, HDL, triglycerides) and homocysteine, were also measured using an automated analyzer (ADVIA® 2400 Chemistry System, Siemens).

Blood pressure and arterial stiffness measurement

Peripheral systolic (pSBP) and diastolic (pDBP) blood pressure, central systolic (cSBP) and diastolic (cDBP) blood pressure, and PWV were measured using the Mobil-O-Graph NG monitor (IEM GmbH, Stolberg, Germany), an automated oscillometric device, which derives brachial artery pressure curves from arterial pressure signals obtained from a standard cuff sphygmomanometer. Among other indices, aortic SBP, DBP and PWV are calculated by the device's software.[22] The Mobil-O-Graph has shown comparable results for central blood pressure with tonometric-derived and invasively measured cSBP both in adults, children and adolescents, which is of clinical relevance since cSBP is considered to reflect better vascular changes and cardiovascular risk.[22–25]

Measurements were performed in a quiet room after a resting time of at least 5 minutes in the sitting position. Different cuff sizes were used according to the left upper arm circumference. Measurements were done in triplicates for each participant and the resulting value of each indice consisted of the mean of the three measurements.

Elevated blood pressure was defined as ≥90th percentile to < 95th percentile for children aged <13 years, and as 120-129/<80 mmHg for children aged ≥13 years. Stage-I hypertension was defined as blood pressure ≥95th percentile to < (95th percentile + 12 mmHg) or 130/80 to 139/89 mmHg (whichever is lower), for children aged <13 years, and as 130/80 to 139/89 mmHg for children aged >13 years. Stage-II hypertension was defined as blood pressure ≥95th percentile + 12 mmHg, or ≥140/90 mmHg (whichever is lower), for children aged < 13 years, and as ≥140/90 mmHg for children aged > 13 years.[26]

Statistical analysis

Continuous variables are presented as means with standard deviations (SD) while qualitative variables with frequencies and percentages. For normality analysis of the continuous variables, we used the Kolmogorov-Smirnov test. Data of BP, PWV and other indices were analyzed by ANOVA with Tukey post-hoc tests for normally distributed data, or Kruskal-Wallis with Dunn's post-hoc tests for skewed data. Data obtained by the Mobil-O-graph NG monitor from T1DM patients with different disease characteristics (T1DM duration, mode of treatment etc.) were compared by t-test or Mann-Whitney test for normally distributed and skewed data respectively. Correlation analyses between systolic and diastolic BP as well as arterial stiffness indices (cSBP, DBP and PWV) were performed using Spearman's rank correlation coefficient.

All statistical analyses were carried out with either SPSS for Windows (version 16.0 SPSS Inc. Chicago II, USA) or GraphPad Prism (version 8.0.2 for Windows, GraphPad Software, San Diego California, USA). Statistical significance was set at *P*-value level < 0.05.

Results

Overall, 199 children and adolescents were included in the study and their anthropometric data are presented in Table 1. The 3 groups had similar age. All controls had normal BMI z-score (–0.067 ± 0.8) while among T1DM patients, 23 had overweight and 3 obesity (mean BMI z-score: 0.52 ± 0.9), and in the overweight/obesity group, 19 had overweight and 30 obesity (mean BMI z-score: 2.18 ± 0.4). All patients showed normal kidney function (eGFR), whereas two of the patients with T1DM had persistent microalbuminuria. None of the patients had retinopathy.

The mean duration of T1DM was 3.79 ± 3.3 years. Forty-three children (44.8%) had a disease duration of more than 3 years and 26 children (27.0%) of more than 5 years. Well controlled T1DM, defined as HbA1c < 7%, was observed in 43 children (44.8%). Mean HbA1c levels were 7.31 ± 1.33%. 15.6% of the patients were treated via an insulin pump, whereas the remaining 84.4% were on multiple dose injection (MDI) therapy.

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Blood pressure and arterial stiffness indices

The majority of the controls (94.4%) had normal pBP, whereas one participant had elevated BP, one had stage-I and one had stage-II hypertension. In overweight/obesity patients, pBP was normal in 40.4%, and elevated in 29.8%, while 17% had stage-I hypertension and 12.8% stage-II hypertension. 80.2% of patients with T1DM had normal pBP, 15.6% had elevated BP, 2.1% had stage-I hypertension, and 2.1% had stage-II hypertension.

Peripheral SBP was significantly higher in both patients with overweight/obesity and those with T1DM compared to controls ($P < 0.0001$, $P = 0.004$, respectively). In addition, overweight/obesity patients had higher pSBP compared to T1DM patients ($P < 0.0001$), whereas pDBP was significantly higher only in overweight/obesity patients compared to controls ($P = 0.001$) (Table 2, Figure 1A and B).

Central SBP was significantly higher in both overweight/obesity and T1DM patients compared to controls ($P < 0.0001$, $P = 0.018$, respectively), but more pronounced in overweight/obesity patients. Patients with excess weight also had higher cSBP compared to T1DM patients ($P < 0.0001$) and cDBP compared to controls ($P = 0.0002$) (Table 2, Figure 1.C & D). PWV values were significantly higher in overweight/obesity patients compared to T1DM patients and to controls ($P < 0.0001$, $P < 0.0001$, respectively), and in T1DM patients compared to controls ($P = 0.01$) (Table 2, Figure 1.E).

In the overweight/obesity group, those with obesity showed significantly higher pSBP and pDBP, as well as cSBP, cDBP and PWV compared to those with overweight (Supplementary Table S1). In T1DM patients, no significant differences were found in all BP measured parameters between those who were overweight and those with normal BMI z-score (data not shown). Moreover, in T1DM patients with normal BMI z-score all measured BP parameters were significantly higher compared to controls, with the exception of pDBP (data not shown).

Blood pressure and arterial stiffness indices according to age groups

The study participants were divided into two major age groups, < 10 or ≥10 years of age, based on the data produced by Elmenhorst et al, who showed that central BP and PWV values were very similar in children younger than 10 years, but increased in older children.[27] In children < 10 years old, pSBP was similar among the three groups. Likewise, no significant differences were found in pDBP, cSBP, cDBP and PWV among groups (Table 3, Figure 2A–E, respectively).

On the other hand, among participants > 10 years of age, pSBP was significantly higher in overweight/obesity compared to T1DM patients ($P < 0.001$) and controls ($P < 0.001$), as well as in T1DM patients compared to controls ($P = 0.002$). Similarly, pDBP was significantly higher in overweight/obesity compared to T1DM patients ($P = 0.009$), and controls ($P < 0.001$), whereas no statistical significance was found between T1DM patients and controls ($P = 0.09$) (Table 3, Figure 2F and G**).** Furthermore, cSBP was significantly higher in overweight/obesity compared to T1DM patients and controls ($P < 0.001$ and $P < 0.001$ respectively), as well as in T1DM patients compared to controls ($P = 0.015$). cDBP was significantly higher in overweight/obesity compared to T1DM patients ($P = 0.01$), and controls ($P < 0.001$), whereas no statistical significance was found between T1DM patients and controls ($P = 0.18$) (Table 3, Figure 2H and I**).** PWV was significantly higher in both patients with overweight/obesity ($P < 0.001$) and those with T1DM ($P = 0.005$) compared to controls, as well as in overweight/obesity compared to T1DM patients ($P < 0.001$) (Table 3, Figure 2J**).**

Table 1. Basic demographic and biochemical characteristics of controls and patients with T1DM or obesity.

	Controls ($n = 54$)	Obesity group ($n = 49$)	T1DM group ($n = 96$)	P value
Age (years)	13.16 ± 20.99	11.04 ± 2.83	11.9 ± 3.88	0.14
Sex (males/females)	25/29	25/24	50/46	0.79
BMI	17.75 ± 2.27	29.03 ± 6.14	20.2 ± 3.74	<0.001
BMI z-score	-0.07 ± 0.84	2.18 ± 0.41	0.52 ± 0.9	<0.001
Serum creatinine (mg/dl)	0.58 ± 0.11	0.63 ± 0.11	0.64 ± 0.15	0.045
eGFR (ml/min/1.73m²)	102,7 ± 19.5	99,91 ± 13.9	99,75 ± 16.8	0.013
AST (U/L)	31.6 ± 27.7	25.4 ± 10.9	21 ± 6.7	0.001
ALT (U/L)	22.8 ± 19.3	28.9 ± 18.4	17.2 ± 6.7	<0.001
γGT (U/L)	17.1 ± 26.9	16.8 ± 4.2	12.9 ± 6.4	0.18
HbA1c (%)	-	-	7.31 ± 1.33	
TSH (μIU/ml)	2.31 ± 0.87	3.48 ± 5.88	2.12 ± 1.29	0.048
FT4 (ng/dl)	1.28 ± 0.18	1.31 ± 0.2	1.43 ± 1.32	0.66
CHOL (mg/dl)	167.5 ± 37.8	161.8 ± 30.4	163.9 ± 32.1	0.76
LDL (mg/dl)	100.5 ± 40.3	97.2 ± 25.6	93.1 ± 25.9	0.45
HDL (mg/dl)	51.7 ± 12.3	46.5 ± 13.2	57.7 ± 12	<0.001
Triglycerides (mg/dl)	78.8 ± 51.6	98.5 ± 62.8	69.7 ± 37.9	0.01
Homocysteine (μmol/L)	5.69 ± 1.35	7.4 ± 1.8	5.67 ± 2.04	0.003

Table 2. Peripheral and central BP (mmHg) and PWV (m/sec) among groups.

	Controls	Obesity group	T1DM group	P value
SBP	98.78 ± 11.58	117.5 ± 16.33	106.0 ± 12.40	<0.001
DBP	58.72 ± 9.562	66.59 ± 9.434	62.64 ± 9.305	0.0014
cSBP	87.86 ± 11.00	102.2 ± 13.71	93.12 ± 10.14	<0.001
cDBP	60.47 ± 9.709	69.53 ± 10.37	64.64 ± 9.187	0.0004
PWV	4.130 ± 0.4	4.685 ± 0.55	4.346 ± 0.39	<0.001

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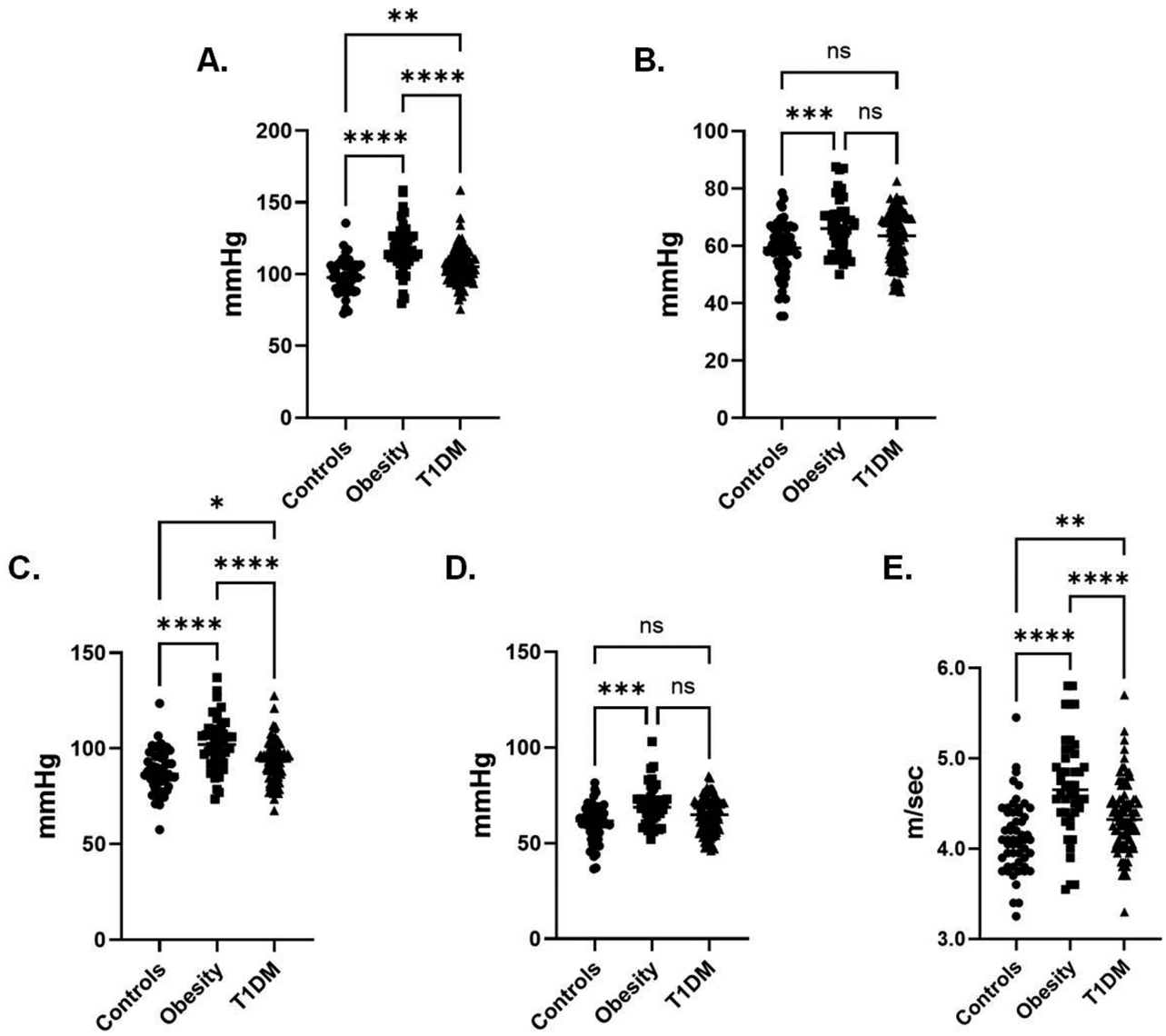

Figure 1. pSBP (A), pDBP (B), cSBP (C), cDBP (D) and PWV (E) in the total population. (*P < 0.05, **P < 0.01, ***P < 0.001, ****P < 0.0001; Dots, squares and triangles represent individual subject data points and horizontal lines represent group means).

Table 3. Peripheral and central BP (mmHg) and PWV (m/sec) according to age.

	Controls	Obesity group	T1DM group	P value
< 10 years of age				
SBP	100.4 ± 11.03	108.9 ± 14.42	103.3 ± 11.29	0.1
DBP	61.61 ± 7.644	64.45 ± 8.376	65.19 ± 9.106	0.2
cSBP	90.44 ± 10.37	95.68 ± 12.14	93.31 ± 10.12	0.34
cDBP	63.69 ± 7.748	66.63 ± 8.613	67.28 ± 9.346	0.38
PWV	4.161 ± 0.4107	4.400 ± 0.4813	4.253 ± 0.3701	0.22
≥ 10 years of age				
SBP	97.97 ± 11.91	123.9 ± 14.85	107.2 ± 12.75	<0.001
DBP	57.27 ± 10.18	68.17 ± 10.00	61.53 ± 9.238	<0.001
cSBP	86.57 ± 11.22	107.1 ± 12.95	93.04 ± 10.22	<0.001
cDBP	58.86 ± 10.27	71.74 ± 11.20	63.50 ± 8.947	<0.001
PWV	4.114 ± 0.4	4.902 ± 0.5	4.387 ± 0.39	<0.001

Blood pressure and arterial stiffness indices in patients with T1DM

No differences were found between pSBP, pDBP, cSBP, cDBP, or PWV according to the mode of insulin treatment (MDI versus insulin pump). Also, no differences were found in the measured parameters between patients with T1DM who had HbA1c of < 7% and those with HbA1c ≥7%, or patients with diabetes duration < 3 years vs > 3 years (Table 4).

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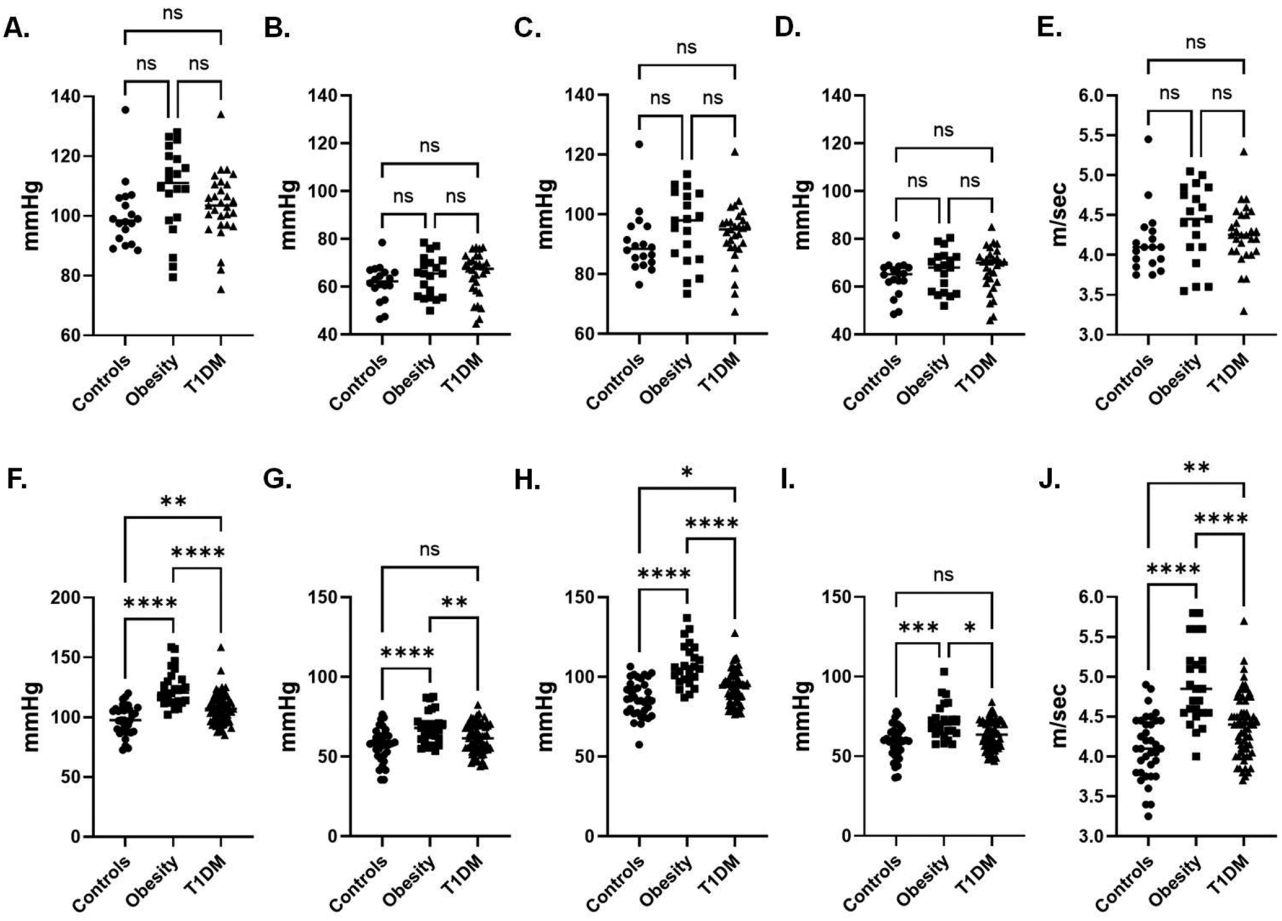

Figure 2. SBP, DBP, cSBP, cDBP and PWV in children < 10 years of age (A, B, C, D, and E, respectively) and in children > 10 years of age (F, G, H, I and J, respectively). (*P < 0.05, **P < 0.01, ***P < 0.001, ****P < 0.0001; Dots, squares and triangles represent individual subject data points and horizontal lines represent group means).

Table 4. Peripheral and central BP (mmHg) and PWV (m/sec) in subgroups of patients with T1DM.

	HbA1c < 7% (*N* = 43)	HbA1c > 7% (*N* = 52)	P-value	T1DM > 3 years (*N* = 43)	T1DM < 3 years (*N* = 52)	*P* value	MDI (*N* = 81)	Pump (*N* = 15)	*P* value
SBP	104.5 ± 12.4	107.0 ± 12.4	0.33	106.4 ± 10.6	105.4 ± 13.8	0.69	106.1 ± 12.8	105.6 ± 10.1	0.89
DBP	62.59 ± 8.9	63.03 ± 9.4	0.69	62.94 ± 8.7	62.74 ± 9.6	0.84	62.41 ± 9.4	63.83 ± 9	0.65
cSBP	92.51 ± 11.2	93.70 ± 9.3	0.57	93.03 ± 8.8	93.27 ± 11.3	0.91	92.88 ± 10.3	94.43 ± 9.3	0.59
cDBP	64.51 ± 9.2	64.82 ± 9.3	0.69	64.71 ± 8.5	64.65 ± 9.9	0.83	64.46 ± 9.3	65.60 ± 9	0.69
PWV	4.295 ± 0.4	4.386 ± 0.4	0.26	4.379 ± 0.3	4.316 ± 0.4	0.44	4.347 ± 0.4	4.343 ± 0.3	0.97

Correlations of clinical and biochemical characteristics with BP measured indices

Overall, weight, BMI and BMI z-score showed a significant positive correlation with all BP measured indices. Age showed a weak positive correlation with peripheral SBP and PWV.

When patients with overweight/obesity were examined separately, weight, BMI and BMI z-score showed a significant positive correlation with almost all BP measured indices. Age showed a positive correlation with peripheral and central SBP and with PWV.

In patients with T1DM, weight and BMI showed a positive correlation with peripheral SBP and PWV, while BMI z-score did not correlate with any measured parameter. Age showed a positive correlation only with peripheral SBP and PWV (Supplementary Table S2).

Differences of BP and arterial stiffness indices according to pubertal status

Among all participants, those who had entered puberty ($n = 123$) did not show significantly higher values of SBP, cSBP and PWV (data not shown). Likewise, in controls, peripheral BP, cBP and PWV values did not show significant differences between those who had entered puberty and those who had not. In patients with overweight/obesity, only peripheral SBP and in patients with T1DM only cDBP values were higher in patients who had entered puberty (data not shown).

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Discussion

The present study presents data comparing pBP, cBP, and PWV in children and adolescents with T1DM, obesity/overweight and healthy controls. Our first major observation is the increased cSBP and PWV, which indicates increased arterial stiffness, in children and adolescents with excess weight and T1DM compared to the controls. It has been suggested that cSBP is a better indicator of cardiovascular risk compared to brachial pressure as it reflects the left ventricular load more accurately.[28]

It is well known that increased systolic blood pressure elevates PWV.[29] As excess weight is strongly associated with increased blood pressure, PWV is expected to be affected in subjects with overweight and obesity. Indeed, it has been established that obesity accelerates arterial stiffness in adults,[12] however research data are contradictory for the pediatric population. Several studies have demonstrated increased PWV in children with obesity,[13–16] whereas others have reported either decreased PWV or no difference compared to healthy controls.[17,30] More detailed assessment of the aforementioned studies indicates that the ones that showed no correlation between PWV and BMI either included children or adolescents with BMI values within the normal range or consisted of a small sample of children with obesity. Recently, a meta-analysis by Cote et al showed a strong association between obesity and arterial stiffness in children.[31] Of interest, a study by Stabouli et al has demonstrated that children with overweight and obesity had increased 24-hour PWV measurements, as well as increased 24-hour peripheral and central SBP.[32] Similarly, our results showed that peripheral BP, cBP, and PWV were increased in children and adolescents with overweight or obesity, and a positive correlation was found between PWV and BMI in this group suggesting established vascular alterations.

In addition, one of the most important findings of this study is the increased PWV in children and adolescents with T1DM compared to controls. T1DM is associated with premature death caused predominantly by cardiovascular disease and end-stage kidney disease.[33,34] Furthermore, a positive association between carotid-femoral PWV and progression in albuminuria, a decline in eGFR, cardiovascular events and all-cause mortality has been found in adults with T1DM.[19] In another study, carotid-femoral PWV was higher in adolescents and young adults with T1DM, independently of the presence of known cardiovascular risk factors.[20] In addition, Bradley et al have reported impaired endothelial function, arterial stiffness, myocardial velocities and strain in adolescents with T1DM using ultrasonographic measurements.[18] Moreover, according to a meta-analysis of 21 studies, arterial stiffness was increased in youths with T1DM compared to healthy controls.[35] Our results also showed that peripheral SBP and cSBP were increased in children and adolescents with T1DM compared to the controls, further suggesting impaired vascular health in this population.

Additionally, the present study showed increased pBP, cBP, and PWV in children with T1DM or excess weight compared to the controls only after the age of 10. A study by Thurn et al, as well as three more studies, have shown an increase in PWV with age from the age of 6.[12,36–38] In another study held in a healthy pediatric population of children between 3 and 18 years, PWV was found unchanged before puberty initiation and started to increase at 10.4 years in girls and at 12.1 years in boys, suggesting an effect of pubertal status rather than age on arterial stiffness.[39] However, although our study showed increased arterial stiffness parameters after the age of 10 in the populations of excess weight and T1DM, no difference was demonstrated in PWV between pubertal and non-pubertal children in the total population.

Interestingly, in children with T1DM no association was found between all measured indices and diabetes duration or glycemic control expressed as HbA1c. Of note, this result should be interpreted with caution due to the relatively short duration of T1DM in our diabetes population. Also, no differences were found in the studied parameters between participants treated with MDI or those treated via an insulin pump, although the insulin pump diminishes glucose variability, which may influence arterial stiffness.[40]

Of further importance is our finding of higher cBP and PWV in patients with excessive weight compared to those with T1DM. Although several studies have investigated the PWV in patients with T1DM or patients with obesity, to the best of our knowledge this study is the first among all age groups (adults or children) to compare arterial stiffness indices in patients with obesity and patients with T1DM at the same time. Knowing that PWV independently predicts mortality and cardiovascular risk in adults,[36] our finding of higher values of PWV in the population with obesity may be reflecting a higher impact of obesity, even in comparison to T1DM, on cardiovascular health during childhood and adolescence. Also, our finding of increased central systolic BP, in children with obesity compared to the controls or to children with T1DM, further supports the hypothesis that obesity may be a better indicator of vascular damage and impaired future cardiovascular health in the pediatric population.

The present study has certain limitations. Firstly, BP and PWV measurements were obtained as three consecutive readings at a specific time point and not as out-of-office 24-hour measurements, which might have yielded more accurate data and helped mitigate the white coat phenomenon or challenges with younger children's cooperation. In addition, the oscillometric method used is not the gold standard technique for the assessment of PWV. An additional limitation of this study is its cross-sectional design which does not allow for the determination of any causal relationships.

In conclusion, our findings of increased pBP, cBP, and PWV in children and adolescents with T1DM or excess weight suggest impaired arterial elasticity in these populations before manifest complications of T1DM or obesity are present. The finding that the above differences were observed only in children older than 10 years, may suggest that arterial properties change or that possible protective mechanisms against arterial stiffening are alleviated after the age of 10 years. Further investigation is required for safer conclusions to be drawn. More importantly, significantly increased arterial stiffness in patients with excess weight compared to those with T1DM emphasizes the ongoing cardiovascular modifications with significant probable future implications in this particular group.

Supplementary Data

Supplementary materials are available at *American Journal of Hypertension* (http://ajh.oxfordjournals.org).

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

The data underlying this article will be shared on reasonable request to the corresponding author.

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