

Full length article

Left ventricular diastolic function in the fifth decade of life in women with a history of spontaneous preterm birth

Laura E. Janssen^{a,*}, Marjon A. de Boer^{a,b}, Eline C.E. von Königslöw^a, Elisa Dal Canto^c, Martijn A. Oudijk^{a,b}, Daniëlle Robbers-Visser^d, Christianne J.M. de Groot^{a,b}

^a Amsterdam UMC, Location Vrije Universiteit Amsterdam, Department of Obstetrics and Gynaecology, De Boelelaan 1117, Amsterdam, The Netherlands

^b Amsterdam Reproduction and Development Research Institute, Amsterdam, The Netherlands

^c Department of Experimental Cardiology, Division Heart and Lungs, University Medical Center Utrecht, The Netherlands

^d Department of Cardiology, VU University Medical Center, Amsterdam, The Netherlands



ARTICLE INFO

Keywords:

Left ventricular diastolic function
Diastolic dysfunction
Heart failure
Cardiovascular disease
Cardiovascular risk
Hypertension
Spontaneous preterm birth
Preterm delivery

ABSTRACT

Objective: Cardiovascular disease (CVD) is the number one cause of death in women and defining its risk factors is necessary to reduce its prevalence. A history of preeclampsia is shown to be associated with hypertension and alterations in left ventricular (LV) diastolic function parameters. Because of overlapping mechanisms between preeclampsia and spontaneous preterm birth (SPTB), our most recent study investigated the association between SPTB and hypertension, and found an almost 2 times higher prevalence of hypertension after SPTB. No previous studies have focused on the association between SPTB and LV diastolic function. The aim of this study is to investigate LV diastolic function as potential early parameter of CVD in women with a history of SPTB.

Study design: We included cases with a history of SPTB between 22 and 37 weeks and controls who had a term birth. Women with hypertensive disorders or gestational diabetes in any of their pregnancies, were excluded. Both groups underwent cardiovascular risk assessment and transthoracic echocardiography 9 to 16 years after pregnancy. Echocardiographic measures were adjusted using a linear regression analysis accounting for hypertension and other risk factors known to be associated with CVD. A subgroup analysis was performed based on hypertension at follow-up.

Results: A total of 94 cases and 94 controls were included, on average 13 years after pregnancy. There were no significant differences in LV diastolic function parameters. Women with a history of SPTB and diagnosed hypertension at follow-up, showed significant higher late diastolic mitral flow velocity, lower e' septal velocity and higher E/e' ratio, compared to women with a history of SPTB without hypertension, although within normal ranges.

Conclusions: When a history of SPTB is accompanied by hypertension at follow-up, significant changes in LV diastolic function were seen. Therefore, hypertension is the central factor in preventive screening methods, and transthoracic echocardiography has no additional value at this follow-up duration.

Introduction

Despite abundant research and attempts to enhance prevention and treatment, cardiovascular disease (CVD) remains the number one cause of death among women in Europe. About 55% of female deaths are caused by CVD [1]. Sex-related differences in the clinical presentation and in the response to therapy may impede decreasing cardiovascular

burden in women [2–3].

An important example of CVD in which sex-specific manifestation occurs, is heart failure with preserved ejection fraction (HFpEF), which is defined by abnormal relaxation of the left ventricle, which may result in impaired filling and elevated LV filling pressure, and by a preserved systolic function (defined by left ventricle ejection fraction (LVEF) $\geq 50\%$) [4]. HFpEF is especially prevalent in women and is preceded in

Abbreviations: BMI, Body Mass Index; CVD, Cardiovascular disease; CVR, Cardiovascular risk; GDM, Gestational diabetes mellitus; HDP, Hypertensive disorders of pregnancy; HFpEF, Heart failure with preserved ejection fraction; LV, Left ventricular; LVDD, Left ventricular diastolic dysfunction; LVEF, Left ventricle ejection fraction.

* Corresponding author at: Gynaecology Department, Boelelaan 1117, Amsterdam 1081 HV, The Netherlands.

E-mail address: l.janssen2@amsterdamumc.nl (L.E. Janssen).

<https://doi.org/10.1016/j.ejogrb.2023.05.009>

Received 16 March 2023; Received in revised form 9 May 2023; Accepted 11 May 2023

Available online 15 May 2023

0301-2115/© 2023 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

middle age by preclinical left ventricular diastolic dysfunction (LVDD) [5–6]. Until recently, treatment was aimed at reducing symptoms of congestion and disease-modifying therapy was not available. Therefore, prevention and investigation of risk factors is important.

In recent years, pregnancy is recognized as a natural stress test to identify women at cardiovascular risk (CVR) [7–8]. Melchiorre et al. found that the risk of developing CVD is higher among women with hypertensive disorders of pregnancy (HDP) [9]. In addition, Benschop et al. suggested that women with a history of preeclampsia (PE) develop coronary artery calcifications, which is a risk factor for CVD, years earlier compared to women with a history of a normotensive pregnancy [10]. The study of Bokslag et al. was the first study investigating the association between PE and LV diastolic function assessed with transthoracic echocardiography as an early parameter for CVD [11]. They found a higher LV septal wall thickness, LV posterior wall thickness and LV indexed mass in women with a history of early onset PE.

Because of the possible shared pathophysiological mechanism between PE and SPTB in placental pathology, it is hypothesized that SPTB also predisposes to increased CVR [12]. Maternal vascular malperfusion (MVM), characterized by abnormal development of maternal blood vessels supplying the placenta, is thought to play an important role in the pathophysiology of both PE and PTB [13]. MVM can result in insufficient blood flow and oxygen delivery to the placenta, causing placental ischemia, fetal growth restriction, and the release of inflammatory factors into the maternal circulation [14]. These factors contribute to the pathogenesis of both PE and PTB. Additionally, PTB and PE have been associated with alterations in the maternal immune system, oxidative stress, and genetic factors [15]. These shared mechanisms suggest that PE and PTB may represent different manifestations of a common underlying pathophysiology. Our recent published study was the first investigating the direct association between SPTB and CVR by excluding all women with complications known to be associated with CVD. We found an almost 2 times higher prevalence of hypertension among women with a history of SPTB compared to women with an uncomplicated term pregnancy 13 years after pregnancy [16].

No previous studies have focused on investigating LVDD among women with a history of SPTB. Due to high burden of HFpEF among women, it is of great interest to investigate possible risk factors to lower its incidence by screening programs.

Material and methods

Study population

In this retrospective case-control study, we compared echocardiographic parameters of women with a history of SPTB with women who had a term birth. This study is a secondary analysis of the PreCaris study where CVR was compared between women with a history of SPTB and women with an uncomplicated term birth. SPTB was defined as preterm birth between 22+0 and 36+6 weeks after spontaneous contractions or spontaneous rupture of membranes. A history of a term birth was defined as giving birth at or after 37+0 weeks of gestation. In both groups exclusion criteria were a history of HDP, gestational diabetes mellitus (GDM) or major congenital anomalies in any of the pregnancies. Moreover, women with conditions that are already known to be related to an elevated risk of CVD from their general medical history were excluded. Medical records were screened for in- and exclusion criteria and eligible women were invited. All participants gave written informed consent and received cardiovascular risk assessment 9 to 16 years after pregnancy, at the Amsterdam UMC, location VU Medical Center. For a complete description of the methods we refer to the original PreCaris-study paper [16].

Measurements

Cardiac function was assessed as described by Bokslag et al. by

transthoracic echocardiography using a Philips X5-1 transducer on a Philips IE-33 cardiac ultrasound system [11]. Both sonographer and attending cardiologist were blinded for pregnancy history at the time of the echocardiographic examination. LV Septal wall thickness, posterior wall thickness and LV internal dimensions at end-diastole were measured with M-mode on parasternal long axis. LV mass was calculated according to recommended formula, and indexed by body surface area (LV mass index) [17]. LV volumes and ejection fraction were measured by 3D echocardiography or biplane method of disks summation. Peak early (E) and late (A) diastolic mitral flow velocity, and deceleration time of the mitral valve (MV dec time) were measured, and E/A ratio was calculated. The incidence of reverse E/A ratio (<0.8) and high E/A ratio (>2) were calculated, as indicators for LV diastolic dysfunction [18]. Maximal velocity of tricuspid regurgitation (TR max velocity) was measured in systole and left atrial maximal volume was measured at end-systole by disks summation algorithm and indexed by body surface area (LA volume index). Mitral annular lengthening velocities (e') were measured by tissue Doppler imaging on the lateral and septal part of the mitral valve annulus and the average e'mean was calculated. The E/e' ratio was calculated by dividing E by e'mean.

Birth weight percentiles were calculated based on The World Health Organization Fetal Growth Charts [19]. Hypertension was diagnosed according to the ACC Guideline for Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults, defined as a systolic blood pressure ≥ 130 and/or a diastolic blood pressure ≥ 80 , or the use of antihypertensive medication [20]. To account for potential confounding factors, a linear regression analysis was performed. We performed a subgroup analysis based upon the severity of SPTB; extreme preterm (GA 22+0 – 27+6 weeks), very preterm (GA 28+0 – 31+6 weeks) and moderate preterm birth (GA 32+0 – 36+6 weeks). Additionally, we compared echocardiographic results between women with a history of SPTB and hypertension at test day to women with a history of SPTB without hypertension. This comparison was prompted by our recent study, which revealed a significantly higher prevalence of hypertension among women with SPTB [16]. This analysis allowed us to assess any potential differences in echocardiographic parameters and further explore the relationship between SPTB and the development of hypertension-related cardiovascular complications.

Sample size calculation

The sample size calculation needed to detect a decrease in e'mean from 12.06 to 11.21 (SD of 2.02), based upon the previous study of Bokslag et al. [11]. With a power of 80% and a two-sided α of 0.05, we needed 94 women in both groups for analysis.

Statistical analysis

Normally distributed data were shown as means with standard deviations. Not normally distributed data as medians with interquartile ranges. Categorical data were shown as percentages. Differences were analyzed by unpaired *t*-test, Mann-Whitney *U* test and Fisher's exact test when appropriate. In all analyses, a *p*-value < 0.05 was considered statistically significant. Linear regression analysis was used to examine continuous variables and normality tests for residuals were performed. Data were analyzed using SPSS 22 software (Chicago, IL).

Results

A total of 350 women with a history of SPTB and 166 women with a history of an uncomplicated term birth underwent risk assessment in the PreCaris study, of which 94 women in both groups underwent echocardiographic measurements. For a complete description of the inclusion process we refer to the original PreCaris-study paper [16]. The flowchart is shown in Fig. 1.

Baseline characteristics at index pregnancy of both groups are shown

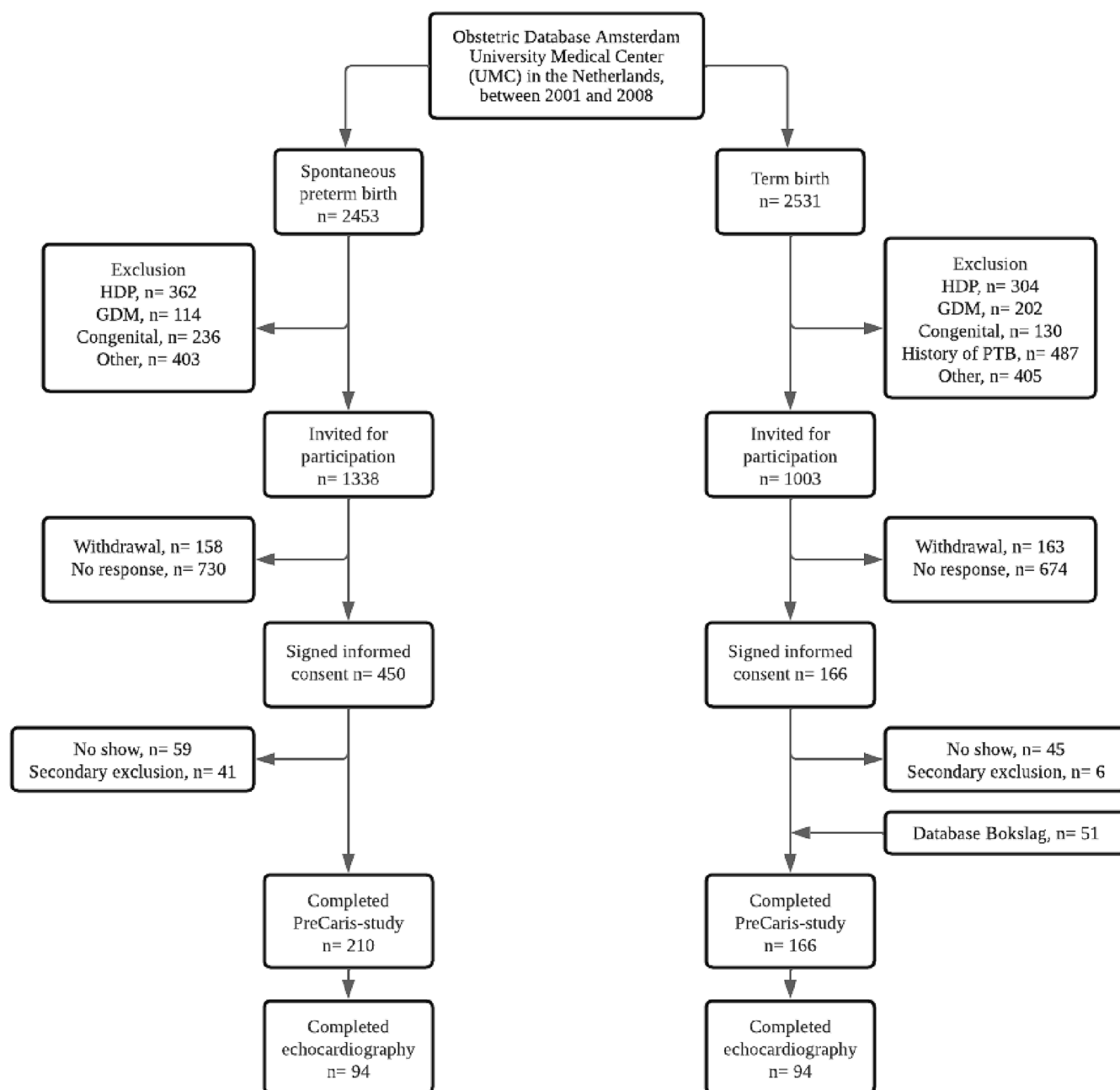


Fig. 1. Flowchart of the study population. Flowchart of the recruitment of the study population. HDP, hypertensive disorder pregnancy.

in Table 1. Among women with a SPTB, most delivered between 32+0 and 36+6 weeks of gestation. As expected, more perinatal deaths occurred among women with a SPTB. Characteristics of both groups at risk assessment 9 to 16 years after pregnancy are shown in Table 2. The mean age and time between pregnancy and the test day was comparable between the groups and all investigated women were in the fifth decade of their lives. There were no significant differences in country of birth, level of education, obstetric history, and first-degree family history of CVD. DBP at test day was significant higher among women with a history of SPTB ($p = .036$).

The results of echocardiographic measures at the test day are shown in Table 3. No significant differences in LV diastolic function parameters between the groups were found. An E/A ratio of <0.8 was seen in two controls and zero cases, $p = .497$. A total of 9 cases and 11 controls had an E/A ratio of >2.0 , $p = .407$. Only one woman showed a combination of E/A ratio >2 and reduced deceleration time (<150 ms). In the linear

regression analysis accounting for confounders including age, BMI, level of education, being white, smoking status, and hypertension, no significant differences between the groups were found. Subgroup analysis based upon the severity of preterm birth showed no significant differences in LV diastolic function parameters between the groups, results not shown. When comparing women with a history of SPTB diagnosed with hypertension at follow-up to women with a history of SPTB without hypertension, we found significant differences in echocardiographic measures. Late diastolic mitral flow velocity (A), and E/e' ratio were significantly higher, and E' septal velocity was significantly lower among women with a history of SPTB and hypertension at follow-up, results are shown in Table 4. An E/A ratio of >2 was seen in one woman with a history of SPTB with hypertension at follow-up, compared to eight women with a history of SPTB without hypertension, $p = .271$.

Table 1
Baseline characteristics at index pregnancy.

Characteristics	Preterm birth pregnancy n = 94	Uncomplicated term pregnancy n = 94	P value
Age, y	32.1±4.7	31.7±4.3	0.512
Primiparous	63 (67.0)	59 (62.8)	0.647
Blood pressure			
SBP at booking*, mmHg	110 [100–115]	110 [100–111]	0.305
DBP at booking*, mmHg	65 [60–70]	60 [60–70]	0.282
SBP highest, mmHg	120 [120–130]	120 [115–130]	0.397
DBP highest, mmHg	75 [70–80]	75 [70–80]	0.271
Severity†			
Extreme preterm	16 (17.0)	–	–
Very preterm	38 (40.4)	–	–
Moderate preterm	40 (42.6)	–	–
Mode of delivery			
Vaginal	80 (85.1)	76 (80.9)	0.561
Caesarean	14 (14.9)	18 (19.1)	0.561
Birth weight, percentile	44.5±27.2	49.1±25.9	0.241
Fetal sex, boy	56 (59.6)	46 (48.9)	0.188
Perinatal death	9 (9.6)	0	0.002

Values are mean ± SD or n (%) or median [IQR].

DBP, diastolic blood pressure; SBP, systolic blood pressure.

* First blood pressure measured in pregnancy, all in the first trimester.

† Extreme preterm: gestational age 22+0 – 27+6 weeks, very preterm: gestational age 28+0 – 31+6 weeks, moderate preterm: gestational age 32+0 – 36+6 weeks.

Discussion

In this study, LV diastolic function parameters were comparable between women with a history of SPTB and a history of term birth 9 to 16 years after pregnancy after adjustments for confounders. All LV diastolic function parameters were within the normal range for both groups [21]. We found significant differences in echocardiographic measures between women with a history of SPTB diagnosed with hypertension at follow-up and women with a history of SPTB without hypertension.

Strengths and limitations

To our knowledge, our study is the first that investigated LV diastolic function in women with a history of SPTB and compared them with healthy term controls. The major strength of our study is its design, a case-control study, excluding all women with a history of possible confounders such as HDP, DMG or iatrogenic preterm birth. In addition, we performed extensive transthoracic echocardiography by a blinded sonographer and attending cardiologist, in a large cohort of women, meeting our sample size. We were able to adjust echocardiographic results for possible confounders known to be associated with CVD. Women included in the study were in the fifth decade of life which gave us the opportunity to screen them within this window of opportunity.

Some limitations need to be addressed. Firstly, it is plausible that our follow-up period of 9 to 16 years was not long enough for women to develop changes in LV diastolic function. The mean age of the women at time of risk assessment was 45 years, so it is possible that a longer follow-up period could have shown significant differences between the groups. Secondly, even though no significant differences in first relative family history were found, women with a positive family history for CVD could have been potentially more interested in participating in this

Table 2
Characteristics at testing day.

Characteristics	Preterm birth pregnancy n = 94	Uncomplicated term pregnancy n = 94	P value
Age, y	45.0±5.2	45.1±5.0	0.931
Time post index pregnancy, y	12.9±2.5	13.1±2.4	0.503
White*	74 (78.7)	77 (81.9)	0.714
Current smoking	10 (10.6)	12 (12.8)	0.821
Education level‡			0.365
Low	13 (13.8)	7 (7.4)	
Intermediate	29 (30.9)	31 (33.0)	
High	52 (55.3)	56 (59.6)	
Obstetric history			
Miscarriage	28 (29.8)	31 (33.0)	0.753
Stillbirth	3 (3.2)	1 (1.1)	0.621
First degree family history			
Preterm birth	10 (10.6)	8 (8.5)	0.257
Myocardial infarction	17 (18.1)	26 (27.7)	0.306
Stroke	11 (11.7)	9 (9.6)	0.275
Cardiovascular risk			
SBP, mmHg	112.1±13.7	112.3±14.2	0.909
DBP, mmHg	73.8±8.6	71.1±9.3	0.036
Hypertension‡	27 (28.7)	19 (20.2)	0.235

Values are mean ± SD or n (%).

DBP = diastolic blood pressure; SBP = systolic blood pressure.

† Low: primary education, lower general secondary education; intermediate: high school, intermediate vocational education; high: pre university education, higher vocational education, and university.

‡ Defined as systolic blood pressure ≥130 and/or diastolic blood pressure ≥80, and/or the use of antihypertensive medication at testing day.

* Country of birth of participant and the minimum of one parent in Europe, or both parents in Europe despite de country of birth of the participant.

study. We included women from two tertiary hospitals, which could have led to the selection of women already at higher risk of CVD compared to the general Dutch population. Lastly, there was a risk of statistical errors due to multiple statistical testing. In our study, we chose not to correct for multiple testing because we had a primary hypothesis that was established a priori, and our other research questions were exploratory in nature. Additionally, we had a relatively small sample size, and we believed that correcting for multiple comparisons would have resulted in a high risk of type II errors and reduced statistical power. However, we recognize that this decision could potentially lead to false positive results, and we encourage future research to replicate and validate our findings.

Interpretation

In a healthy heart, the E velocity is greater than the A velocity which leads to a normal E/A ratio of >1. In Grade 1 of LVDD, the ventricular wall becomes stiff, leading to impaired ventricular relaxation, which results in reduced passive filling of the ventricle, and the early (E) filling flow velocity decreases. A larger blood volume needs to be ejected by the atrium during contraction, and late (A) filling flow velocity increases, leading to a reversed E/A ratio of <0.8. Worsening of LV diastolic function leads to an increase in left atrial pressure, resulting in a return of E to the normal range. This pseudonormal mitral inflow pattern is seen in Grade 2 LVDD. In severe LVDD, left atrial pressure increases and left ventricle relaxation decreases, leading to a further increase in E and an E/A ratio >2. Deceleration time becomes shorter, and e' mean is reduced, leading to a higher E/e' ratio. Grade 3 LVDD is characterized

Table 3
Echocardiographic parameters.

Characteristics	Spontaneous preterm birth n = 94	Uncomplicated term pregnancy n = 94	P value	B*	95% CI
IVSd, cm	0.72±0.12	0.74±0.13	0.422	−0.42	−0.89 −0.01
LA volume index, ml/m ²	24.4±5.9	24.0±5.6	0.905	0.60	−1.23 −2.42
LV ejection fraction, %	59.7±5.9	59.1±5.2	0.502	1.36	−1.31 −3.03
LV end diastolic volume index, ml/m ²	55.0±10.2	56.3±11.8	0.420	−0.57	−4.11 −2.98
E, cm/sec	78.7 [71.8–90.2]	80.5 [71.3–88.8]	0.740	1.13	−3.16 −5.42
A, cm/sec	59.4 [49.9–68.9]	58.3 [49.4–70.0]	0.864	1.62	−2.43 −5.66
E/A ratio	1.41±0.46	1.44±0.44	0.681	−0.01	−0.14 −0.12
MV dec time, ms	190 [180–215]	200 [180–210]	0.458	3.91	−5.88 −13.7
TR max velocity, m/sec	2.16±0.27	2.14±0.28	0.812	−0.01	−0.28 −0.26
E' lateral, cm/sec	13.4±2.5	13.9±3.1	0.174	−0.47	−1.30 −0.37
E' septal, cm/sec	10.5±1.8	11.0±2.2	0.370	−0.29	−0.82 −0.24
Ėmean, cm/sec	12.0±1.9	12.4±2.3	0.308	−0.06	−0.99 −0.88
E/e' ratio	6.5 [5.8–7.7]	6.5 [5.8–7.5]	0.630	0.15	−0.25 −0.54

Values are mean ± SD, or median [IQR].

A = late diastolic mitral flow velocity; E = early diastolic mitral flow velocity; Ė = mitral annular lengthening velocity; IVSd = interventricular septal thickness in diastole; LA = left atrial; LV = left ventricular; MV dec time = mitral valve deceleration time; TR = tricuspid regurgitation.

* Linear regression analysis adjusted for age, BMI, level of education, being white, smoking status, and hypertension.

Table 4
Sub analysis echocardiographic parameters based upon hypertension.

Characteristics	Spontaneous preterm birth with hypertension n = 27	Spontaneous preterm birth without hypertension n = 75	P value
IVSd, cm	0.75±0.13	0.71±0.11	0.429
LA volume index, ml/m ²	24.1±5.1	24.6±6.3	0.263
LV ejection fraction, %	59.0±6.5	60.0±5.6	0.619
LV end diastolic volume index, ml/m ²	57.9±9.3	54.0±10.3	0.241
E, cm/sec	82.5 [72.3–91.2]	77.1 [71.7–89.1]	0.259
A, cm/sec	64.9 [55.8–74.1]	56.9 [47.2–66.5]	0.019
E/A ratio	1.33±0.39	1.45±0.49	0.366
MV dec time, ms	190 [170–210]	190 [180–220]	0.660
TR max velocity, m/sec	2.28±0.20	2.11±0.28	0.352
E' lateral, cm/sec	13.3±2.8	13.5±2.8	0.370
E' septal, cm/sec	9.9±2.2	10.8±1.5	0.025
Ėmean, cm/sec	11.6±2.1	12.1±1.8	0.223
E/e' ratio	7.2 [6.4–8.1]	6.4 [5.7–7.3]	0.034

Values are mean ± SD or median [IQR].

A = late diastolic mitral flow velocity; E = early diastolic mitral flow velocity; Ė = mitral annular lengthening velocity; IVSd = interventricular septal thickness in diastole; LA = left atrial; LV = left ventricular; MV dec time = mitral valve deceleration time; TR = tricuspid regurgitation.

by restrictive cardiac filling, in which E/A ratio is >2, deceleration time is reduced (MV dec time <150 ms) and E/e' ratio exceeds normal ranges >15 [18]. In our study, LV diastolic parameters did not differ between the groups. Mean E/A ratio and incidence of reverse and high E/A ratio were comparable. An E/A ratio >2 was seen in a total of 20 women, of which 19 had normal deceleration time, which is characteristic in supranormal filling, seen in healthy young and physically active individuals [22].

The study of Bokslag et al. investigated LV diastolic function after PE and concluded that a history of PE predisposes in middle age to alterations in LV diastolic parameters, which could increase the likelihood of HFpEF later in life [11]. Even though these echocardiographic measures did not exceed normal ranges, women with a history of PE had worse LV diastolic function compared to women with a history of uncomplicated term birth. CVR will increase with age, making it plausible that a longer follow-up period might result in a progressive deterioration of LV diastolic function, ultimately leading to HFpEF. This study did not make corrections for presence of hypertension.

In our sub analysis, women with a history of SPTB diagnosed with hypertension at follow-up showed early yet significant signs of impaired LV diastolic function, evident from higher A wave, lower e' septal velocity and higher E/e' ratio, compared to women with SPTB without hypertension. This finding aligns with previous studies indicating that hypertension plays a key role in the development of LVDD [23–24]. Interestingly, in our most recent study, we found that women with SPTB were more frequently diagnosed with hypertension later in life [16]. While we did not find a direct significant association between a history of SPTB and alterations in diastolic function, our results indicate that women with a history of SPTB do not necessarily require specific screening for diastolic dysfunction. Instead, our findings suggest that screening programs should prioritize the early detection and management of hypertension in these women. Implementing early screening programs for hypertension among women with a history of SPTB might have clinical benefits by preventing the onset of hypertension and, subsequently, the potential development of LVDD. This preventive approach is crucial as LVDD has negative implications and can progress to HFpEF [25].

Mechanisms explaining the association between SPTB and CVD are not well understood. It is hypothesized that the inability to adapt to hemodynamic changes during pregnancy lead to both SPTB, and CVD later in life [7–8]. It is also thought that alterations in inflammatory mediators and immune function are important in the pathogenesis of both SPTB and CVD [26–27]. It is important to point out that SPTB is a heterogeneous condition, with multiple pathological processes leading to myometrial contractions, decidual activation and cervical ripening [28–29]. It is therefore hypothesized that only a subgroup of women with SPTB is at elevated CVR, based upon SPTB etiology. For example, it is thought that placental malperfusion marks women susceptible to a higher cardiometabolic burden [30]. If proven to be true, this could be of great significance as it might help to identify a specific subgroup of women that not yet developed CVD but at high risk of cardiovascular events and would thus benefit from clinical screening and monitoring. Future research is necessary to investigate whether SPTB etiology is associated with maternal CVR.

Conclusions

In conclusion, a history of SPTB alone, was not significantly associated with LVDD. When a history of SPTB is accompanied by hypertension at follow-up, significant changes in LV diastolic function were seen, making hypertension the central factor in preventive screening methods. In our most recent study, women with SPTB were more often diagnosed with hypertension later in life [16]. We therefore conclude that early screening programs would be clinically beneficial for women with a history of SPTB, preventing the onset of hypertension and consequently

LVDD potentially leading to HFpEF.

Declaration of Competing 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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejogrb.2023.05.009>.

References

- [1] McAloon CJ, Boylan LM, Hamborg T, Stallard N, Osman F, Lim PB, et al. The changing face of cardiovascular disease 2000–2012: An analysis of the world health organisation global health estimates data. *Int J Cardiol* 2016;224:256–64.
- [2] Stramba-Badiale M, Fox KM, Priori SG, Collins P, Daly C, Graham I, et al. Cardiovascular diseases in women: a statement from the policy conference of the European Society of Cardiology. *Eur Heart J* 2006;27(8):994–1005.
- [3] van Ommen AMLN, Dal Canto E, Cramer MJ, Rutten FH, Onland-Moret NC, den Ruijter HM. Diastolic dysfunction and sex-specific progression to HFpEF: current gaps in knowledge and future directions. *BMC Med* 2022;20:496.
- [4] Oren O, Goldberg S. Heart Failure with Preserved Ejection Fraction: Diagnosis and Management. *Am J Med* 2017;130(5):510–6.
- [5] Wan S-H, Vogel MW, Chen HH. Pre-clinical diastolic dysfunction. *J Am Coll Cardiol* 2014;63(5):407–16.
- [6] Redfield MM. Heart Failure with Preserved Ejection Fraction. *N Engl J Med* 2017;376(9):897.
- [7] Irgens HU, Reisaeter L, Irgens LM, Lie RT. Long term mortality of mothers and fathers after pre-eclampsia: Population based cohort study. *BMJ* 2001;323(7323):1213–7.
- [8] Rich-Edwards JW, McElrath TF, Karumanchi SA, Seely EW. Breathing life into the lifecourse approach: Pregnancy history and cardiovascular disease in women. *Hypertension* 2010;56(3):331–4.
- [9] Melchiorre K, Thilaganathan B, Giorgione V, Ridder A, Memmo A, Khalil A. Hypertensive Disorders of Pregnancy and Future Cardiovascular Health. *Front Cardiovasc Med* 2020;15(7):59.
- [10] Benschop L, Brouwers L, Zoet GA, Meun C, Boersma E, Budde RPJ, et al. Early Onset of Coronary Artery Calcification in Women With Previous Preeclampsia. *Circ Cardiovasc Imaging* 2020;13(11):e010340.
- [11] Bokslag A, Franssen C, Alma LJ, Kovacevic I, Kesteren FV, Teunissen PW, et al. Early-onset preeclampsia predisposes to preclinical diastolic left ventricular dysfunction in the fifth decade of life: An observational study. *PLoS One* 2018;13(6):e0198908.
- [12] Heida KY, Velthuis BK, Oudijk MA, Reitsma JB, Bots ML, Franx A, et al. Cardiovascular disease risk in women with a history of spontaneous preterm delivery: A systematic review and meta-analysis. *Eur J Prev Cardiol* 2016;23(3):253–63.
- [13] Kim YM, Bujold E, Chaiworapongsa T, Gomez R, Yoon BH, Thaler HT, et al. Failure of physiologic transformation of the spiral arteries in patients with preterm labor and intact membranes. *Am J Obstet Gynecol* 2003;189(4):1063–9.
- [14] Redline RW. Placental Pathology: A Systematic Approach with Clinical Correlations. *Placenta* 2008;29:86–91.
- [15] Parks WT, Catov JM. The Placenta as a Window to Maternal Vascular Health. *Obstet Gynecol Clin North Am* 2020;47(1):17–28.
- [16] Janssen LE, de Boer MA, von Königslöw ECE, Oudijk MA, de Groot CJM. The association between spontaneous preterm birth and maternal hypertension in the fifth decade of life: a retrospective case-control study. *BJOG* 2023;130(5):507–13.
- [17] Lang RM, Badano LP, Mor-Avi V, Afzalilo J, Armstrong A, Ernande L, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr* 2015;28(1):1–39.e14.
- [18] Little WC, Oh JK. Echocardiographic Evaluation of Diastolic Function Can Be Used to Guide Clinical Care. *Circulation* 2009;120(9):802–9.
- [19] Kiserud T, Piaggio G, Carroli G, Widmer M, Carvalho J, Neerup Jensen L, et al. The World Health Organization Fetal Growth Charts: A Multinational Longitudinal Study of Ultrasound Biometric Measurements and Estimated Fetal Weight. *PLoS Med* 2017;14(1):e1002220.
- [20] Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/.
- [21] PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension* 2018;71(6):e13–115.
- [22] Caballero L, Kou S, Delgheru R, et al. Echocardiographic reference ranges for normal cardiac Doppler data: results from the NORRE Study. *Eur Heart J Cardiovasc Imaging*. 2015. 16 (9). 1031–41.
- [23] Claessens PJ, Claessens CW, Claessens MM, Claessens MC, Claessens JE. Supernormal left ventricular diastolic function in triathletes. *Tex Heart Inst J* 2001;28(2):102–10.
- [24] Redfield MM, Jacobsen SJ, Burnett Jr JC, Mahoney DW, Bailey KR, Rodeheffer RJ. Burden of systolic and diastolic ventricular dysfunction in the community: appreciating the scope of the heart failure epidemic. *JAMA* 2003;289(2):194–202.
- [25] Kosmala W, Marwick TH. Asymptomatic Left Ventricular Diastolic Dysfunction: Predicting Progression to Symptomatic Heart Failure. *JACC Cardiovasc Imaging* 2020;13:215–27.
- [26] Sattar N. Do pregnancy complications and CVD share common antecedents? *Atheroscler Suppl* 2004;5(2):3–7.
- [27] Libby P. Inflammation and cardiovascular disease. *Am J Clin Nutr* 2006;83(2):456S–460S.
- [28] Romero R, Dey SK, Fisher SJ. Preterm Labor: One Syndrome, Many Causes. *Science* 2014;345(6198):760–5.
- [29] Romero R, Espinoza J, Kusanovic JP, Gotsch F, Hassan S, Erez O, et al. The preterm parturition syndrome. *BJOG* 2006;113:17–42.
- [30] Catov JM, Muldoon MF, Reis SE, Ness RB, Nguyen LN, Yamal J-M, et al. Preterm birth with placental evidence of malperfusion is associated with cardiovascular risk factors after pregnancy: a prospective cohort study. *BJOG* 2018;125(8):1009–17.



Laura E. Janssen Studies Medicine at the VU in Amsterdam, The Netherlands. Working as a PhD-student, primary focus on maternal cardiovascular health after spontaneous preterm birth and the identification of risk factors of spontaneous preterm birth. Worked as an obstetrical and surgical resident. Current work: medical content creator and operational manager at Incision.



Marjon A. de Boer Studied Medicine at the University in Leiden, The Netherlands. Finished her PhD in 2007: Molecular aspects of human papillomavirus in cervical cancer. Current work: gynecologist in Amsterdam UMC, location AMC, Amsterdam, The Netherlands. Specialized in perinatology, maternal health and preterm birth.



Eline C.E. von Königslöw Studied Medicine at the University in Leiden, The Netherlands. Worked as an obstetrical resident at the VU Medical Center in Amsterdam. Current work: Tropical Doctor in training.



Elisa Dal Canto Studies Medicine in Pisa, Italy. Worked as a medical doctor at the Department of Clinical and Experimental Medicine in the Amsterdam UMC, Location VUmc. Finished her PhD in 2021: Cardiovascular Disease in People with and without Diabetes: Current Trends and Emerging Risk Factors. Current work: Professor (assistant) on the early detection of HFpEF and diastolic dysfunction in people with type 2 diabetes through novel echocardiographic parameters in the UMCG, Utrecht, The Netherlands.



Daniëlle Robbers-Visser Studied Medicine at the University in Rotterdam, The Netherlands. Finished her PhD in 2012: Outcome, Hemodynamic and Genetic Assessment in Patients with Functionally Univentricular Hearts after the Fontan Operation at Young Age. Current work: cardiologist in Amsterdam UMC, location AMC, Amsterdam, The Netherlands. Specialized in preterm birth and cardiac diseases in pregnancy.



Martijn A. Oudijk Studied Medicine at the University in Utrecht, The Netherlands. Finished his PhD in 2003: Fetal tachycardia, diagnosis and treatment. Current work: professor in gynecology in Amsterdam UMC, location AMC, Amsterdam, The Netherlands. Specialized in preterm birth and cardiac diseases in pregnancy.



Christianne J.M. de Groot Studied Medicine at the University in Leiden, The Netherlands. Finished her PhD in 1995 about Preeclampsia. Current work: professor in gynecology in Amsterdam UMC, location AMC, Amsterdam, The Netherlands. Specialized in obstetric high care, pregnancy complications and hypertensive disorders in pregnancy.