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Hemodynamic Fetal Response to Maternal Isometric Exercise in Pregnant Patients with Hypertension

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Abstract

Objective: to evaluate the maternal-fetal hemodynamic response with Doppler in pregnant women with chronic arterial hypertension and preeclampsia submitted to controlled isometric activity. **Methods:** experimental study comparing 50 healthy and 26 hypertensive and 24 preeclamptic pregnant women, from 26 to 36 weeks of gestational age, submitted to isometric contraction with handgrip dynamometer. Maternal hemodynamic parameters (systolic and diastolic blood pressure; heart rate; uterine arteries Doppler) and fetal (heart rate; umbilical artery, middle cerebral and venous duct Doppler) were evaluated before, during and post-isometry. **Results:** in preeclampsia were observed higher values of blood pressure and uterine artery indexes in all times; middle cerebral artery indexes in the pre and post-isometry; and of maternal heart rate post-isometry. In hypertensive women, systolic blood pressure is increased all the times, with indexes of the right uterine and middle cerebral arteries higher in pre-isometry; middle cerebral and umbilical arteries greater during isometry; and maternal heart rate and umbilical artery indexes bigger after isometry. **Conclusion:** blood pressure is higher in preeclamptic and hypertension women. The right uterine artery has more resistance in preeclampsia, with a significant decrease in pre to isometry in hypertensive and preeclamptic women; and increased in contraction to post-isometry in healthy and hypertensive women. The left uterine artery increases resistance post-isometry in all groups. The fetal hemodynamic parameters did not show significant differences when comparing the before, during and post-isometry.

Keywords

Exercise, Isometric, Pregnancy, High-Risk, Hemodynamics, Ultrasonography,

Doppler, Fetal-Placental Circulation

1. Introduction

Regular physical activity has been associated with physical, psychological, and social benefits in the general population. Thus, interest has grown in the beneficial and risk effects of physical activity during pregnancy and the perinatal period [1].

Systematic reviews, meta-analyses, and guidelines support that a prenatal exercise program, in addition to benefiting newborns, can control maternal weight gain, accelerate postpartum recovery, improve cardiovascular performance, physical fitness and mental well-being, preventing constipation, back pain, sleep disturbances, and leg cramps, reducing cesarean and operative vaginal delivery rates, and reducing the risk of pregnancy comorbidities such as chronic hypertension (HBP) and preeclampsia (PE) [2] [3] [4].

Despite these benefits, it is noted that only 15% of pregnant women follow the recommendations of moderate intensity exercise for 150 minutes a week, as suggested by the American College of Obstetricians and Gynecologists (ACOG) [1] [5].

Still, guidelines around the world have encouraged women to be physically active during pregnancy based on evidence about uncomplicated pregnancies and aerobic exercise [6], there are few recommendations and studies on the practice of resistance activities or isometrics during pregnancy and its repercussion on maternal and fetal health [4]. As is known several daily activities require isometric exercise not limited to the context of seeking health benefits such as carrying groceries, house work and others, once. Taking that in account, there are even fewer recommendations for isometric exercise in pregnant women who have complications such as SAH and PE, mainly due to the scarcity of studies that address organic responses, risks, and benefits in performing activities in these special populations, which contributes to uncertainties and inconsistent guidelines in this regard [1] [6].

Thus, the objective of this study was to evaluate the maternal-fetal hemodynamic response by Dopplerfluxometric study in pregnant women with secondary chronic SAH and PE submitted to isometric activity and compare it with the response obtained in pregnant women without identifies pathology. The main hypothesis was that there would be changes in maternal-fetal hemodynamic parameters due to isometric physical activity in pregnant women with the comorbidities evaluated.

2. Methods

An experimental case-control study was conducted, with three distinct groups: two study groups (one of pregnant women with secondary chronic SAH and another of pregnant women with isolated PE) and a control group with pregnant women without identified pathology (considered as healthy), all from the city of Santa Maria, Rio Grande do Sul, Brazil, in the period from September 2017 to October 2019.

The sample size calculation was performed for significance of 5% and test power of 80%, based on a meta-analysis already published [4], and indicated a sample of 50 pregnant women in the control group, 25 pregnant women with chronic SAH, and 25 pregnant women with PE. All participants were informed about the study and signed the Informed Consent Form provided by the researchers.

The samples were composed of pregnant women from the high-risk prenatal care of the Santa Maria University Hospital (HUSM) and of pregnant women from the Basic Health Care network of the city of Santa Maria, RS, who were invited to participate by means of an invitation letter prepared by the researchers.

The samples were both acquired by convenience. The recruitment was performed depending on study group. The control group was identified by basic health care physicians and in a second moment received an invitation to participate in the study. The study group similar to the control group was identified by the high-risk prenatal care physician and received an invitation to participate in the study.

Inclusion criteria were for the control group pregnant women without identified pathology, with a single fetus, from low-risk prenatal care in the city of Santa Maria, with GA between 26 and 36 weeks, who agreed to participate in the study. The first study group included single fetus pregnant women with secondary chronic SAH from the high-risk prenatal care at HUSM, with GA between 26 and 36 weeks, who wished to participate in the study and the second study group included single fetus pregnant women with isolated PE from the high-risk prenatal care at HUSM, with GA between 26 and 36 weeks, who agreed to participate voluntarily in the study.

Exclusion criteria were for the control group: with a history of chronic pathologies (such as secondary SAH, type I and II diabetes mellitus, and thyroid disorders); with smoking, alcoholism, or illicit drug users; with gestational complications diagnosed before collection (such as preterm delivery, premature rupture of membranes, placenta previa, multiple gestation, GDM, and PE); as well as the presence of any of the contraindications for physical activity, listed according to the Canadian guidelines for physical activity during pregnancy [7] [8] (**Table 1**). For the first study group, the same exclusion criteria were used as for the control group, except for patients with a history of secondary chronic SAH. For the second study group, the same exclusion criteria were used as for the control group, except pregnant women with an isolated diagnosis of PE. Patients with chronic secondary NASH who were diagnosed with overlapping PE were also excluded from the study.

Table 1. Absolute and related contraindications to physical activity in pregnant women.

Absolute	Related
• Membrane disruption. • Premature labor. • Unexplained persistent vaginal bleeding. • Placenta predicted after 28 weeks of GA. • Preeclampsia. • Incompetent cervix. • Intrauterine growth restriction. • Multiple pregnancy of high order (for example, triplets). • Uncontrolled type I diabetes. • Uncontrolled hypertension. • Uncontrolled thyroid disease. • Other serious cardiovascular, respiratory or systemic diseases.	• Recurrent pregnancy loss. • Gestational hypertension. • A history of spontaneous premature birth. • Mild/moderate cardiovascular or respiratory disease. • Symptomatic anemia. • Malnutrition. • Eating disorder. • Twin pregnancy after the 28th week. • Other significant medical conditions.

Source: adapted from Mottola *et al.*, 2019 [8].

Data were collected in the Fetal Medicine sector of HUSM, from September to December 2017 for control group and from April 2018 to October 2019 for study groups, after project approval by the Research Ethics Committee (CEP) of the Federal University of Santa Maria (UFSM). This project was submitted for evaluation to the Scientific Committee of Management in Teaching and Research of HUSM and to the CEP of the Universidade Federal de Santa Maria, recognized by the National Committee for Ethics in Research (CONEP-MS), under number CAAE 71095317.0.0000.5346 and given as approved in the CEP opinion number 2.546.010. Data collection only began after the approval of the CEP and the project was developed according to law 466/2012, which regulates research with human beings in Brazil.

Pregnant women who agreed to participate in the research were contacted by phone or during prenatal appointments. Arriving at the sector, they were accompanied by one of the researchers responsible to a room where the TCLE was read and signed and initial information was recorded: date, maternal age, dominant hand, GI at collection, sedentarism before pregnancy and sedentarism during pregnancy. Then they were instructed on how to use the handgrip dynamometer (Crown 100 kgf hand dynamometer) and performed three consecutive attempts of maximum voluntary contraction (MVC), being used in data collection the isometric activity at 50% of the average MVC of these measurements, during 1 minute for each vessel studied. Then, they remained at rest for at least 15 minutes in semifowler position.

Maternal blood pressure (BP) was checked with a Welch AllynTM manual sphygmomanometer, maternal heart rate (HRM) with a Contec Montserrat Cms50d digital oximeter, and maternal and fetal ultrasound data with a GE Voluson I ultrasound device with a 3.5 to 5.0 MHz convex transducer. For Doppler, data were performed following the "ISUOG practice guidelines for performing Doppler ultrasound of the feto-placental circulation" 11, with the capture of four to seven waves for each blood vessel studied. Only for the verification of the ductus venosus it was necessary to perform manual reading of the spectral pattern, due to the better adjustment of the sensitivity of the wave captured in the device used.

Thus, maternal pre-isometry data were collected: systolic (SBP) and diastolic blood pressure (DBP), maternal heart rate (MHR) and Doppler of the right and left uterine arteries (VAS); and fetal pre-isometry data: fetal heart rate (FHR), Doppler of the umbilical artery (UmA), middle cerebral artery (MCA) and venous duct (VD). The Doppler study variables used were pulsatility index (PI), resistance index (RI), and systole/diastole (S/D) ratio.

After collecting the resting data, the pregnant women started the isometric test on the hand dynamometer, with isometry maintained for at least one minute to start capturing the Doppler flow parameters, being maintained until the end of the collection of each wave considered adequate by the examiner. This isometric effort was repeated for the collection of each of the maternal and fetal variables of the Doppler study (right and left AU, MCA, UmA, RV), with an interval of one minute between contractions. There was no order for data collection, as it depended on fetal static, the fetus being at rest, and the absence of fetal respiratory movements. If fetal movements prevented the collection of some fetal variable, the pregnant women were instructed to repeat the isometry after the usual one-minute interval, which was counted as extra isometry.

During the isometric test, the participants were qualitatively evaluated for pain or discomfort in the hand or forearm, muscle tremor, and increased respiratory rate.

At the end of the isometric test, the participants rested again for five minutes. At this time, fetal biometry, amniotic fluid quantification, and placental evaluation were performed. Then, all post-isometric maternal and fetal Doppler flow variables were collected.

Dopplerfluxometric parameter collections were always performed by the most experienced researcher of the Fetal Medicine service of HUSM and, at the end of each collection, data were tabulated in Microsoft Office Excel® 2010 program. For statistical evaluation, these spreadsheets were imported into the statistical package SPSS version 13.0 (Statistical Package for the Social Science), belonging to the Teaching and Research Management of HUSM.

To compare the values found for maternal and fetal variables before, during and after the isometric test in each group, the Friedman double analysis of variance test of related samples was used, considering significance for $p < 0.05$, and for comparative statistical analysis between the groups, the Mann-Whitney U test of independent samples was used, considering significance for $p < 0.05$, to compare the values found for maternal and fetal variables of each of the two study groups (chronic SAH and PE) with the control group. Subsequently, the

Bonferroni post-hoc test was also used to compare the collection periods, pre-, during and post-isometry.

3. Results

Pregnant women without identifies pathology (control group) from the low-risk prenatal care of eight basic health units and from the high-risk prenatal care of the HUSM in Santa Maria, RS, were invited and voluntarily participated in this study, obtaining data collected from 50 pregnant women in the control group, 26 from the group with chronic SAH, and 24 from the group with isolated PE, as shown in Figure 1.

The descriptive aspects of the sample initially considered the basic characteristics of the pregnant women included in the study (Table 2).

The overall mean CVM was 22.56 kgf (±3.61), with minimum of 13 kgf and maximum of 31.4 kgf.

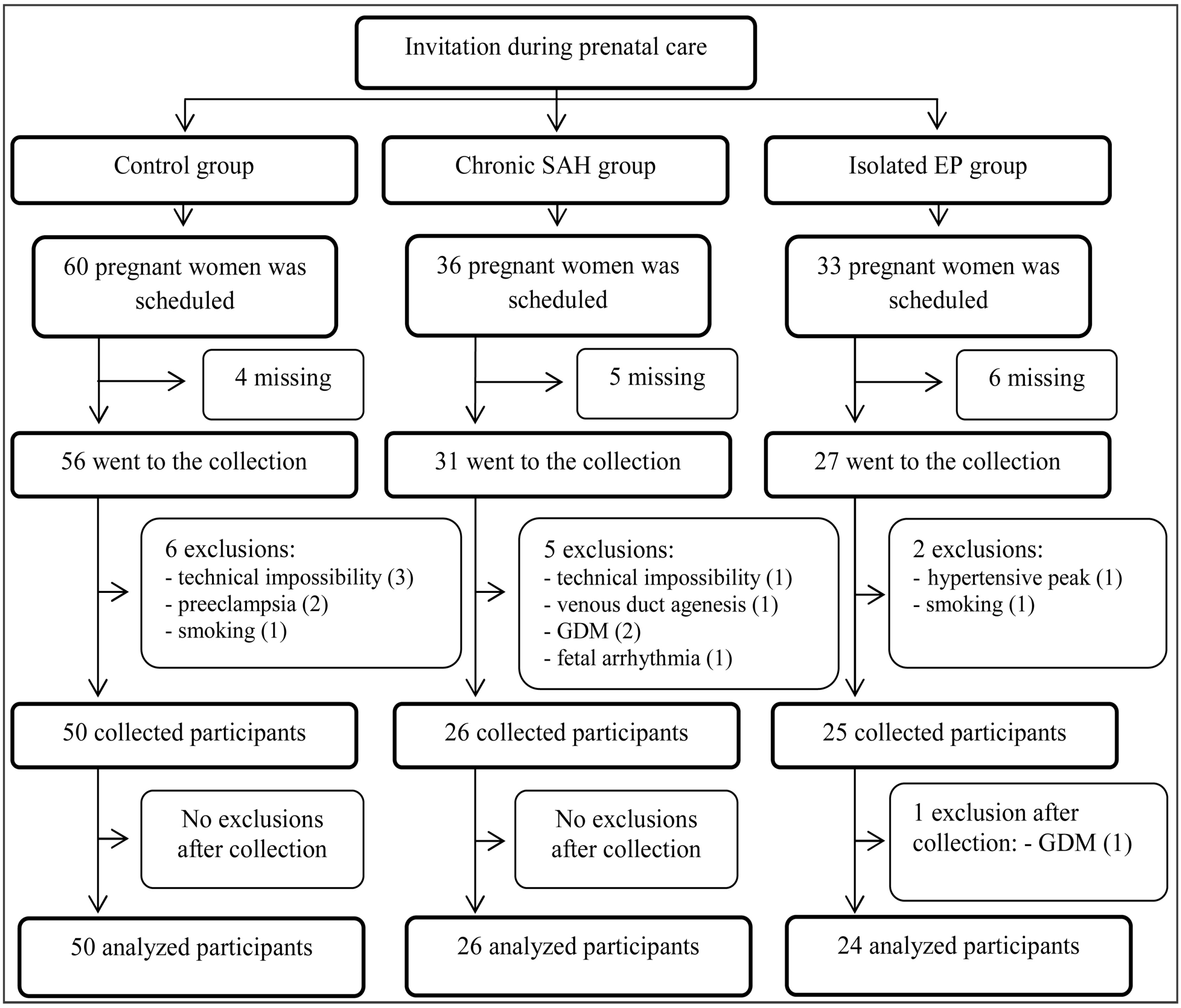

Figure 1. Flowchart of the method. Source: author.

Table 2. Description of the averages and standard deviation of maternal age, parity, gestational age, physical inactivity and dominant hand of the control, in healty, isolated PE and with chronic SAH groups.

	Control	Chronic SAH	Isolated PE
Maternal age	25.69 (±6.90)	32.92 (±6.92)	28.20 (±7.69)
Parity			
Nulliparous	26 (52.17%)	4 (15.40%)	8 (33.33%)
Multiparous	24 (47.83%)	22 (84.60%)	16 (66.67%)
Mean gestational age (weeks)	33.22 (±2.05)	31.49 (±2.37)	33.91 (±1.94)
Sedentary lifestyle before pregnancy			
Yes	37 (76.08%)	23 (88.46%)	21 (87.50%)
No	13 (23.91%)	3 (11.54%)	3 (12.50%)
Sedentary lifestyle during pregnancy			
Yes	44 (91.30%)	25 (96.15%)	22 (91.67%)
No	6 (8.70%)	1 (3.85%)	2 (8.33%)
Dominant hand			
Right	42 (86.96%)	25 (96.15%)	23 (95.83%)
Left	8 (13.04%)	1 (3.85%)	1 (4.17%)

The data represent the means ± standard deviation or the number of cases with their percentages. Source: author.

The comparison of maternal and fetal hemodynamic parameters between the control group and patients with PE (**Table 2**) and between the control group and patients with chronic SAH (**Table 3**) showed differences in the behavior of variables in each group according to the analysis performed by the hypothesis test.

In the evaluation of fetal biometry, using biparietal diameter, head circumference, abdominal circumference, femur, humerus and estimated fetal weight measurements, it was noted that the values obtained were lower in the fetuses of pregnant women with chronic hypertension than in those of the control group. However, when comparing the control group with the pregnant women with PE alone, there was no significant difference in these parameters. It is noteworthy that the mean gestational age of the chronically hypertensive women was slightly lower (31.49 ± 2.37) than the other groups (control 33.22 ± 2.05 and PE alone 33.91 ± 1.94).

Maternal hemodynamic parameters also resulted in data with statistical significance when comparing the differences found in the three groups evaluated in each period of isometric activity (pre-, trans- and post-isometry) by the Bonferroni test (**Table 4** and **Table 5**).

In the control group, maternal hemodynamic parameters showed significant increase ($p = 0.001$) in SBP from rest to isometry and significant decrease ($p = 0.002$) from trans to post-isometry (mean values pre-isometry 113.68 ± 9.69, trans 117.84 ± 10.30 and post-isometry 113.20 ± 10.00). We observed a significant increase in HRM (mean values pre 86.82 ± 13.90, trans 96.22 ± 15.67 and post 84.20 ± 13.20) from rest to exercise ($p = 0.000$) and its significant decrease

Table 3. Comparison of the mean and standard deviation of the maternal-fetal hemodynamic parameters pre-isometry, trans-isometry and post-isometry, of the control and with isolated PE groups.

	Control group	Isolated PE	*Mann-Whitney U test of independent samples* ($p < 0.05$)
Pre-isometry			
SBP	113.68 (±9.69)	127.92 (±11.03)	**0.000**
DBP	73.00 (±7.69)	84.58 (±10.21)	**0.000**
MHR	86.82 (±13.90)	91.95 (±12.89)	0.132
UA D PI	0.66 (±0.21)	0.91 (±0.48)	**0.017**
UA D RI	0.45 (±0.09)	0.52 (±0.13)	**0.025**
UA D S/D	1.87 (±0.36)	2.38 (±1.30)	**0.027**
UA E PI	0.68 (±0.27)	1.03 (±0.55)	**0.001**
UA E RI	0.45 (±0.10)	0.56 (±0.13)	**0.001**
UA E S/D	1.92 (±0.56)	2.58 (±1.24)	**0.001**
FHR	140.45 (±11.19)	133.89 (±29.89)	0.630
MCA PI	1.79 (±0.37)	2.02 (±0.33)	**0.012**
MCA RI	0.81 (±0.07)	0.85 (±0.06)	**0.027**
MCA S/D	6.09 (±2.25)	7.19 (±2.70)	0.070
UmA PI	0.92 (±0.16)	0.90 (±0.25)	0.954
UmA RI	0.61 (±0.07)	0.64 (±0.12)	0.595
UmA S/D	2.65 (±0.52)	2.53 (±0.68)	0.913
VD	0.60 (±0.23)	0.62 (±0.14)	0.355
Transisometry			
SBP	117.84 (±10.30)	134.25 (±12.87)	**0.000**
DBP	74.20 (±9.29)	90.00 (±10.63)	**0.000**
MHR	96.22 (±15.67)	94.12 (13.95)	0.540
UA D PI	0.63 (±0.21)	0.83 (±0.32)	**0.005**
UA D RI	0.44 (±0.09)	0.51 (±0.11)	**0.009**
UA D S/D	1.83 (±0.39)	2.14 (±0.55)	**0.006**
UA E PI	0.60 (±0.24)	0.91 (±0.53)	**0.000**
UA E RI	0.41 (±0.10)	0.52 (±0.14)	**0.000**
UA E S/D	1.76 (±0.44)	2.38 (±1.19)	**0.000**
FHR	140.95 (±11.00)	139.87 (±7.40)	0.787
MCA PI	1.85 (±0.36)	2.02 (±0.33)	0.073
MCA RI	0.82 (±0.06)	0.85 (±0.05)	0.143
MCA S/D	6.48 (±2.34)	7.17 (±2.44)	0.232
UmA PI	0.93 (±0.17)	0.93 (±0.19)	0.619
UmA RI	0.61 (±0.07)	0.60 (±0.10)	0.652

Continued

UmA S/D	2.64 (±0.55)	2.63 (±0.52)	0.661
VD	0.57 (±0.17)	0.65 (±0.18)	0.102
Post-isometry			
SBP	113.2 (±10.00)	128.8 (±10.90)	**0.000**
DBP	74.4 (±7.40)	87.1 (±9.10)	**0.000**
MHR	84.2 (±13.20)	89.7 (±11.00)	**0.047**
UA D PI	0.68 (±0.22)	0.95 (±0.41)	**0.005**
UA D RI	0.46 (±0.09)	0.54 (±0.12)	**0.005**
UA D S/D	1.90 (±0.38)	2.37 (±0.74)	**0.005**
UA E PI	0.72 (±0.36)	1.05 (±0.73)	**0.003**
UA E RI	0.47 (±0.11)	0.55 (±0.14)	**0.004**
UA E S/D	2.01 (±0.84)	4.92 (±11.99)	**0.004**
FHR	139.68 (±9.35)	141.54 (11.30)	0.619
MCA PI	1.81 (±0.35)	2.05 (±0.40)	**0.008**
MCA RI	0.82 (±0.06)	0.86 (±0.07)	**0.005**
MCA S/D	6.25 (±1.98)	8.04 (±2.74)	**0.005**
UmA PI	0.93 (±0.19)	0.91 (±0.21)	0.632
UmA RI	0.61 (±0.08)	0.61 (±0.15)	0.858
UmA S/D	2.69 (±0.63)	2.63 (±0.71)	0.738
VD	0.60 (±0.17)	0.61 (±0.14)	0.917

Values represent mean ± standard deviation. PE: pre-eclampsia; SBP: systolic blood pressure; DBP: diastolic blood pressure; MHR: maternal heart rate; PI: pulsatility index; RI: resistance index; S/D: systole/diastole ratio; UA D: right uterine artery; UA E: left uterine artery; FHR: fetal heart rate; MCA: middle cerebral artery; UmA: umbilical artery; VD: venous duct. Source: author.

when comparing the HRF of the period of isometric activity with the post-effort period (p = 0.000).

It was also found, in control group patients, statistical significance in PI (mean values pre 0.68 ± 0.27, trans 0.60 ± 0.24 and post 0.72 ± 0.36); IR (mean values pre 0.45 ± 0.10, trans 0.41 ± 0.10 and post 0.47 ± 0.11) and S/D (mean values pre 1.92 ± 0.56, trans 1.76 ± 0.44 and post 2.01 ± 0.84) of the left AU, with decreased values from pre to trans and increased from trans to post-isometry. There was a significant increase in PI (mean values pre 0.66 ± 0.21, trans 0.63 ± 0.21 and post 0.68 ± 0.22, with p = 0.037) of the right UA only from trans to post-isometry.

In pregnant women with chronic SAH, there was an increase in SBP from rest to the moment of isometrics, with a reduction from trans to post-stress, but there was no statistical significance of this finding. There was a statistically significant increase in DBP (mean values pre 76.15 ± 8.31, trans 83.08 ± 11.23 and post-isometry 80.5 ± 12.90) only from pre to trans-isometry (p = 0.025). Unlike the control group, HR did not show statistically significant variation in the collection phases in this group.

Table 4. Comparison of the mean and standard deviation of the maternal-fetal hemodynamic parameters pre-isometry, trans-isometry and post-isometry, of the control and with chronic SAH groups.

	Control group	Chronic SAH	*Mann-Whitney U test of independent samples* ($p < 0.05$)
Pre-isometry			
SBP	113.68 (±9.69)	124.08 (±13.27)	**0.000**
DBP	73.00 (±7.69)	76.15 (±8.31)	0.116
MHR	86.8 (±13.90)	88.65 (±11.46)	0.273
UA D PI	0.66 (±0.21)	0.85 (±0.35)	**0.010**
UA D RI	0.45 (±0.09)	0.53 (±0.10)	**0.006**
UA D S/D	1.87 (±0.36)	2.26 (±0.78)	**0.009**
UA E PI	0.68 (±0.27)	0.75 (±0.27)	0.187
UA E RI	0.45 (±0.10)	0.49 (±0.10)	0.137
UA E S/D	1.92 (±0.56)	2.06 (±0.53)	0.166
FHR	140.45 (±11.19)	142.96 (±12.02)	0.511
MCA PI	1.79 (±0.37)	2.06 (±0.42)	**0.004**
MCA RI	0.81 (±0.07)	0.85 (±0.07)	**0.024**
MCA S/D	6.09 (±2.25)	7.78 (±3.09)	**0.013**
UmA PI	0.92 (±0.16)	0.99 (±0.17)	0.135
UmA RI	0.61 (±0.07)	0.63 (±0.07)	0.211
UmA S/D	2.64 (±0.52)	2.83 (±0.56)	0.187
VD	0.60 (±0.23)	0.64 (±0.16)	0.204
Transisometry			
SBP	117.84 (±10.30)	129.23 (±13.24)	**0.000**
DBP	74.20 (±9.29)	83.08 (±11.23)	**0.001**
MHR	96.22 (±15.67)	90.27 (±17.34)	**0.141**
UA D PI	0.63 (±0.21)	0.69 (±0.18)	0.166
UA D RI	0.43 (±0.09)	0.49 (±0.16)	0.075
UA D S/D	1.83 (±0.39)	1.97 (±0.38)	0.092
UA E PI	0.60 (±0.24)	0.65 (±0.21)	0.087
UA E RI	0.41 (±0.10)	0.45 (±0.09)	0.055
UA E S/D	1.76 (±0.44)	1.88 (±0.45)	0.065
FHR	140.96 (±11.01)	142.19 (±10.63)	0.574
MCA PI	1.86 (±0.36)	2.09 (±0.39)	**0.014**
MCA RI	0.82 (±0.06)	0.85 (±0.06)	0.080
MCA S/D	6.48 (±2.34)	7.71 (±2.78)	0.084
UmA PI	0.93 (±0.16)	1.03 (±0.19)	**0.027**
UmA RI	0.61 (±0.07)	0.65 (±0.08)	**0.020**

Continued

UmA S/D	2.65 (±0.52)	2.95 (±0.62)	**0.020**
VD	0.57 (±0.17)	0.66 (±0.21)	0.072
Post-isometry			
SBP	113.2 (±10.00)	125.4 (±16.10)	**0.001**
DBP	74.4 (±7.37)	80.5 (±12.88)	**0.034**
MHR	84.2 (±13.20)	84.9 (±12.50)	0.405
UA D PI	0.68 (±0.22)	0.80 (±0.27)	0.084
UA D RI	0.46 (±0.89)	0.51 (±0.10)	0.080
UA D S/D	1.90 (±0.38)	2.14 (±0.61)	0.105
UA E PI	0.72 (±0.36)	0.77 (±0.25)	0.084
UA E RI	0.47 (±0.10)	0.49 (±0.08)	0.083
UA E S/D	2.00 (±0.84)	2.05 (±0.43)	0.079
FHR	139.68 (±9.35)	139.19 (±9.87)	0.742
MCA PI	1.81 (±0.35)	1.98 (±0.40)	0.052
MCA RI	0.82 (±0.06)	0.84 (±0.07)	0.150
MCA S/D	6.25 (±1.98)	7.21 (±2.79)	0.124
UmA PI	0.94 (±0.19)	1.01 (±0.21)	**0.041**
UmA RI	0.61 (±0.08)	0.63 (±0.09)	0.050
UmA S/D	2.69 (±0.63)	2.87 (±0.55)	**0.048**
VD	0.60 (±0.17)	0.69 (±0.24)	0.136

Values represent mean ± standard deviation. PE: pre-eclampsia; SBP: systolic blood pressure; DBP: diastolic blood pressure; MHR: maternal heart rate; PI: pulsatility index; RI: resistance index; S/D: systole/diastole ratio; UA D: right uterine artery; UA E: left uterine artery; FHR: fetal heart rate; MCA: middle cerebral artery; UmA: umbilical artery; VD: venous duct. Source: author.

It was also found in this group a significant decrease in PI (mean values pre-isometry 0.85 ± 0.35, trans-isometry 0.69 ± 0.18 and post-isometry 0.80 ± 0.27) and RI (mean values pre-isometry 0.53 ± 0.10, trans-isometry 0.50 ± 0.16 and post-isometry 0.51 ± 0.10) of the right UA from pre- to trans-isometry, with a subsequent significant increase from trans to post-isometry. For the left AU we demonstrated an increase in PI (mean values pre-isometry 0.76 ± 0.27, trans-isometry 0.65 ± 0.21 and post-isometry 0.77 ± 0.25), IR (mean values pre-isometry 0.49 ± 0.10, trans-isometry 0.45 ± 0.09 and post-isometry 0.50 ± 0.08) and the S/D ratio (mean values pre-isometry 2.06 ± 0.53, trans-isometry 1.88 ± 0.45 and post-isometry 2.05 ± 0.43) only from trans to post-isometry.

In pregnant women with isolated PE, SBP showed a significant increase from pre- to trans-isometry ($p = 0.009$). DBP behaved with general statistical significance ($p = 0.013$), with an increase when under exertion and a reduction when returning from rest. Similarly, to the group with chronic SAH and unlike the control group, HR did not show statistically significant variation between the phases of physical activity in PE.

Table 5. Comparison of maternal hemodynamic parameters pre, trans and post-isometry, with Bonferroni post-test, for the control, isolated PE and chronic SAH groups.

						post-hoc Bonferroni		
	Group	**Pre**	**Trans**	**Post**	**P**	P1 Pre-trans	P2 Trans-post	P3 Pre-post
SBP	Control	113.68 (±9.69)	117.84 (±10.30)	113.2 (±10.00)	**0.000**	**0.001**	**0.002**	1.000
	PE	127.92 (±11.03)	134.25 (±12.87)	128.8 (±10.90)	**0.001**	**0.009**	0.130	1.000
	SAH	124.08 (±13.27)	129.23 (±13.24)	125.4 (±16.10)	0.056	-	-	-
DBP	Control	73.00 (±7.69)	74.20 (±9.29)	74.4 (±7.40)	0.459	-	-	-
	PE	84.58 (±10.21)	90.00 (±10.63)	87.1 (±9.10)	**0.013**	0.109	1.000	0.745
	SAH	76.15 (±8.31)	83.08 (±11.23)	80.5 (±12.90)	**0.009**	**0.025**	0.802	0.381
MHR	Control	86.82 (±13.90)	96.22 (±15.67)	84.2 (±13.20)	**0.000**	**0.000**	**0.000**	0.267
	PE	91.96 (±12.89)	94.13 (±13.95)	89.7 (±11.00)	0.160	-	-	-
	SAH	88.65 (±11.46)	90.27 (±17.34)	84.9 (±12.50)	0.051	-	-	-
PI UA D	Control	0.66 (±0.21)	0.63 (±0.21)	0.68 (±0.22)	**0.043**	0.634	**0.037**	0.634
	PE	0.91 (±0.48)	0.83 (±0.32)	0.95 (±0.41)	0.099	-	-	-
	SAH	0.85 (±0.35)	0.69 (±0.18)	0.80 (±0.27)	**0.001**	**0.001**	**0.021**	1.000
RI UA D	Control	0.45 (±0.09)	0.44 (±0.09)	0.46 (±0.09)	0.060	-	-	-
	PE	0.52 (±0.13)	0.51 (±0.11)	0.54 (±0.12)	0.067	-	-	-
	SAH	0.53 (±0.10)	0.50 (±0.16)	0.51 (±0.10)	**0.008**	**0.009**	**0.080**	1.000
S/D UA D	Control	1.87 (±0.36)	1.83 (±0.39)	1.90 (±0.38)	0.058	-	-	-
	PE	2.38 (±1.30)	2.14 (±0.55)	2.37 (±0.74)	**0.003**	**0.003**	0.066	0.895
	SAH	2.26 (±0.78)	1.97 (±0.39)	2.14 (±0.61)	0.087	-	-	-
PI UA E	Control	0.68 (±0.27)	0.60 (±0.24)	0.72 (±0.36)	**0.014**	**0.003**	**0.000**	1.000
	PE	1.03 (±0.55)	0.91 (±0.53)	1.05 (±0.73)	**0.027**	0.130	**0.035**	1.000
	SAH	0.76 (±0.27)	0.65 (±0.21)	0.77 (±0.25)	**0.014**	0.157	**0.013**	1.000
RI UA E	Control	0.45 (±0.10)	0.41 (±0.10)	0.47 (±0.11)	**0.000**	**0.002**	**0.000**	1.000
	PE	0.56 (±0.13)	0.52 (±0.14)	0.55 (±0.14)	**0.036**	0.154	**0.050**	1.000
	SAH	0.49 (±0.10)	0.45 (±0.09)	0.50 (±0.08)	**0.023**	0.381	**0.025**	0.802
S/D UA E	Control	1.92 (±0.56)	1.76 (±0.44)	2.01 (±0.84)	**0.000**	**0.001**	**0.000**	1.000
	PE	2.58 (±1.24)	2.38 (±1.19)	4.92 (±11.99)	**0.035**	0.182	**0.042**	1.000
	SAH	2.06 (±0.53)	1.88 (±0.45)	2.05 (±0.43)	**0.018**	0.214	**0.017**	0.995

Values represent mean ± standard deviation. P: double Friedman analysis of variance of related samples by stations. P1: post-test comparing pre and trans; P2: post-test comparing trans and post; P3: post-test comparing pre and post. SBP: systolic blood pressure; DBP: diastolic blood pressure; MHR: maternal heart rate; PI: pulsatility index; RI: resistance index; S/D: systole/diastole ratio; UA D: right uterine artery; UA E: left uterine artery. Source: author.

In the evaluation of the right UA of patients with isolated PE, the only parameter that showed statistical significance was the S/D ratio, which decreased from the pre to the trans-isometric period. On the other hand, there was statistical relevance in the three parameters evaluated in the left UA (PI, RI, and S/D), with an increase in these indices from the trans- to the post-isometry period.

It is worth noting that although differences were found in the maternal variables, there was no statistically significant difference for all fetal parameters when comparing the before, during, and after isometric physical activity, both for the control and study groups.

4. Discussion

The study of maternal-fetal hemodynamics has been expanded in order to understand how the activities performed during pregnancy can cause changes in the mother-fetus binomial, as well as to facilitate the approach and recommendations for exercise and physical activity for all patient groups in order to prevent pregnancy complications and decrease sedentary rates during pregnancy. [9] [10] However, there are still few studies on physical activity, both isometric and aerobic, in high-risk pregnant women, such as women diagnosed with chronic SAH and PE.

The large number of sedentary women of reproductive age is evident today, and it is known that these sedentary rates tend to increase greatly during pregnancy, especially in women who have pregnancies complicated by hypertensive pathologies, and in the third trimester this estimate may even reach 100% [11]. Thus, it was found that pregnant women in the study groups of this research, when compared to the control group, had higher rates of physical inactivity, making up 96.15% in patients with chronic SAH and 91.67% in those with PE, which is quite significant, although the percentage of pregnant women without identified pathology who practiced some regular physical activity was also lower than expected (8.7%).

Spracklen *et al.* (2016) when examining associations between composite measures of sedentary and non-sedentary activity with pre-eclampsia obtained results that women who spend most of their time active have a 42% reduced risk of pre-eclampsia compared to less active women and suggested that physical activities, whether aerobic or isometric, are beneficial for placental growth and development because they divert blood flow to the skin and muscles, creating a short-term hypoxic environment that promotes angiogenesis, stimulate antioxidant defenses, and increase the number of mitochondria in the body, allowing it to become more resistant to oxidation [12]. However, the performance of isometric exercises and the fetal hemodynamic response and consequently its perinatal results are still poorly studied [13].

Our analysis was performed based on a protocol published in 2018 [2] in which healthy patients were subjected to isometric contractions by using a dynamometer, for a period of one minute, performing 50% of the CVM. This study was based on a 2013 review article [14] who cited isometric training protocols using 30% to 50% of the MCV, for at least two minutes, with an interval of one to four minutes between each contraction.

In our findings on the isometric activity with the use of 50% of the MCV load for one minute, it was noticed that higher SBP and DBP values occur in pregnant women with PE and chronic SAH, both at rest and during isometrics, and also at rest after the completion of the contraction, but it is noted that the most significant variation of this increase is during isometrics in patients without identified pathology and patients with PE. Moreover, at the end of the isometric effort, with new rest of the muscle grouping required, there is a significant decrease in SBP in healthy pregnant women, but this response was not evidenced significantly in patients with SAH or PE.

Studies performed for functional hemodynamic assessment with manual grip pressure today advocate the use of 20% to 40% of FVC, for a period of two to three minutes, in order to assess the increase in DBP and HRM, because exaggerated BP responses during this effort could identify pregnant women at greater risk of developing hypertensive disorders of pregnancy, since research has indicated that women who develop hypertensive disorders of pregnancy have an increased sensitivity to vasoconstrictor stimuli (by increasing cardiac afterload, HR, and sympathetic nervous system activity), as in handgrip isometrics [13].

Our results in patients with isolated PE corroborate such studies, since increases in SBP and DBP were identified in these patients at the three collection moments (pre-, trans- and post-handgrip measurement) when compared to healthy patients. On the other hand, in patients with chronic SAH, it was evidenced statistically significant elevation only in SBP at the same three collection moments in relation to healthy patients.

The HRM presented the physiologically expected elevation during isometry in the three groups, with a reduction after the end of physical activity. We observed that patients with PE alone and chronic SAH maintained higher values than healthy pregnant women post-isometry, but during isometric activity the increase in HRM was higher and significant only in healthy patients. This finding demonstrates that the physiological adaptation mechanism of HR variation under isometric stress may present a more significant response in healthy pregnant women than in those with hypertensive alterations, contradicting some literature findings [15] [16] [17] [18].

There was a relevant reduction in the PI and RI values in the right UA from pre to trans-isometry and from during to post-isometry in patients with chronic SAH, and also in the S/D ratio from pre to trans-isometry of the right UA in patients with PE; this finding demonstrates the compensatory vasodilation of this artery. This compensatory mechanism attempts to maintain placental flow in order to keep fetal parameters stable during periods of physical activity [19] [20].

The right UA showed higher resistance values in patients with PE. There was a significant decrease in the Doppler flowmetry indexes related to the resistance of this artery when isometric contraction was performed, both in pregnant women with PE and in those with chronic arterial hypertension, as well as an increase in resistance when resting after the end of the sustained contraction effort in healthy pregnant women and those with chronic arterial hypertension.

Also, the left UA showed Doppler flow resistance indexes decreased when comparing the resting period before physical activity with the isometric contraction in healthy patients, but this decrease was not relevant in patients with PE and chronic SAH, which may be associated with changes in the adaptation mechanism of the uterine arteries facing situations of isometric effort as it occurs in healthy pregnant women. Also, the left UA resistance increased significantly in all patients in this study from the contraction period to the post-isometric rest period, referring to the physiological goal of returning to the hemodynamic patterns prior to the effort.

Despite all resistance variations in the studied arteries, there was no picture of severe flow decrease evident in the execution of the proposed isometric activity and there was no significant difference for all maternal comparisons between pre- and post-isometry.

Regarding fetal parameters, the resistance in MCA showed higher values in pregnant women with chronic SAH before and during isometrics and in PE before and after the effort when compared to healthy women; and MU had higher resistance only in patients with chronic SAH during and after isometric effort. However, there was no statistically significant difference in all comparisons of fetal hemodynamic parameters when comparing the pre-, trans-, and post-isometric periods of all groups, showing that compensatory mechanisms in maternal hemodynamics favor the maintenance of fetal hemodynamic values during isometric physical activity.

Many patients complained of discomfort in the hand when performing the grip with the dynamometer, and some of them stopped the isometry before the end of the desired time or the Doppler study because they could not sustain the contraction for 1 minute, making it necessary to perform extra isometries with these patients. As suggested by Weiner *et al.* (2012), performing isometric activity for more than one minute may favor stopping the exercise before the desired end due to muscle fatigue or pain. In this study it was evident that a shorter isometric time was more feasible for the experiment.

As positive points of the present study we highlight: 1) The practicality of performing isometric exercise, which can be encouraged at home with simple and low-cost devices; 2) Collection of all data from the Doppler study and fetal biometry were performed by the most experienced researcher, who was always the same in all collections and with the same ultrasound device; 3) The research protocol was carried out by three interviewers; 4) The low percentage of sample losses.

Regarding the limitations of the study, we must point out: 1) Difficulty in obtaining patients with the desired profiles in the study groups, since most patients with chronic SAH and PE present other associated pathologies which may or may not influence in Doppler finding; 2) Partial collection of data from the births to obtain the gestational and fetal outcomes due to the loss of bond of the patients with the reference institution of the study; 3) The isometry was performed for only one minute, isometric exercise performed for longer periods might have hemodynamic repercussions on fetal-maternal circulation; 4) The collection was carried out in only one moment, not being possible to evaluate the systemic adaptive responses in the long term; 5) Convenience sampling limits the capability of the study to be fully representative of the population, undermining the ability to make generalizations and to replicate the results. Nonrespondents may affect the accuracy of data, important cases may not be detected. And finally high risk of observer bias.

The importance of prenatal monitoring and the recommendation of physical activity in a targeted manner is increasingly important in order to encourage good health practices and healthy lifestyles and may help prevent complications during pregnancy and in the future of newborns. Thus, knowing the physiological and pathological responses of isometric aerobic activity meets the need for well-founded exercise guidelines and physical activities during pregnancy.

5. Conclusions

Isometric physical activity has been the object of research for diagnostic purposes and to improve recommendations on activities of daily living and exercises performed during pregnancy.

The evaluation of maternal parameters showed that SBP and DBP are higher, especially when comparing the preoperative period with the period during the execution of isometrics in patients with isolated PE and with chronic SAH compared to healthy pregnant women. The HRM in pregnant women with isolated PE is higher than in healthy women in the post-isometry, but without statistical relevance in the other periods and in the variation between pre-, trans- and post-isometry. In the case of pregnant women with chronic SAH, a lower mean value of HRM was confirmed compared to healthy women only in the trans-isometry period, with evidence of increase pre to trans and decrease trans to post-isometry confirmed only for patients without comorbidities.

In the control group, there was a significant decrease in the PI, RI and S/D from pre to transisometry in the left AU and a relevant increase in the PI of the right AU and in the PI, RI and S/D of the left AU from trans to post-isometry. In pregnant women with isolated PE, a decrease in the S/D ratio of the right UA from pre to transisometry and a significant increase in the PI, RI and S/D of the left UA from trans to post-isometry were confirmed. In the chronic SAH group there was a significant decrease in the PI and IR of the right UA, with a significant increase in the PI and IR of the right UA and PI, IR and S/D of the left UA from trans to post-isometry. Despite all the variations in resistance indices in the studied maternal arteries, there was no significant difference for all maternal comparisons between pre- and post-isometry in all groups.

In fetal hemodynamic parameters, higher values were observed in the PI and RI of the MCA before isometric activity and in the PI, RI and S/D after the activity in patients with isolated PE compared to healthy ones. Also, higher values in pregnant women with chronic SAH compared to healthy women in PI, IR and S/D in pre-isometric MCA, PI in MCA and PI, IR and S/D in trans-isometric AI, as well as in PI and S/D in post-isometric AUm, but there was no statistical significance in the variations of all fetal parameters in the comparison of pre, trans and post isometric activity in all groups studied.

Thus, this research contributed to demonstrate that there are compensatory maternal hemodynamic changes caused by isometric activity in pregnant women with SAH and chronic PE compared to healthy patients, but without evidence of variation in fetal hemodynamic parameters to isometry in the three groups.

Contributors

The authors contributed to the design, data collection and interpretation, writing of the article, critical review of the intellectual content, and final approval of the version to be published.

Conflicts of Interest

The authors have no conflict of interests to declare.

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