Exercise during pregnancy (frequency, intensity, type, time, volume): birth outcomes in women at risk of hypertensive disorders of pregnancy

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BACKGROUND: Hypertensive disorders of pregnancy (HDP) hold negative health implications for mothers and offspring. While the beneficial influence of prenatal exercise on reducing HDP risk has been previously shown, there is a lack of specific information on the effect on birth outcomes in at-risk women, and in-depth analysis of appropriate exercise dose is lacking.
OBJECTIVE: We aimed to elucidate the effects of exercise training FITT-V (frequency, intensity, type, time, volume) on hypertension and birth outcomes in pregnant women.
STUDY DESIGN: This study is a retrospective, secondary analysis of pooled data from three blinded, prospective, randomized controlled trials. Women at risk of HDP (11 control, 27 exercise) were identified from the population and monitored in supervised exercise sessions throughout pregnancy. Upon delivery, birth measures were obtained. Pearson correlations and stepwise regressions determined associations. Tests for outcomes between exercise types were completed using one-way ANOVA.
RESULTS: Women at risk of HDP with higher total exercise volume trended lower systolic blood pressure during pregnancy (P=.07). In at-risk women, total and weekly exercise volume were then associated with gestational age at birth (R=0.42, P=.03; R=0.46, P=.02) and increased birthweight (R=0.43, P=.03). Weekly exercise duration predicted birthweight (P=.02) independent of gestational age at birth.
CONCLUSION: The current findings add to a body of literature showing the beneficial influence of exercise during pregnancy on HDP risk, and importantly the effect on exposed offspring. Prenatal exercise improved birth outcomes in women with higher HDP risk in a dose-dependent manner, whereby higher exercise volume and duration are associated with improvements in birth outcomes.

Key words: birth measures, dose-response, exercise, FITT-V, hypertensive disorders of pregnancy, pregnancy

Introduction

Hypertensive disorders of pregnancy (HDP), a group of conditions including chronic and gestational hypertension which may or may not preclude pre-eclampsia, present serious maternal and fetal health risks for women during pregnancy.[1] This condition can cause failure of maternal organs including the

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Ethics Approval: This study used data from participants enrolled in a randomized control trial (ClinicalTrials.gov Identifier: NCT03517293). Approval for this study was obtained from the East Carolina University Institutional Review Board. All experimental procedures were conducted at East Carolina University.

Data Transparency: Data will be made available upon request.

Condensation: In women at risk of developing hypertension during pregnancy, higher exercise volume led to lower blood pressure during pregnancy, while also increasing gestational age at birth and increasing birthweight in their offspring.

Conflicts of Interest: The authors report no conflict of interest.

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Why was this study conducted?
While the beneficial influence of prenatal exercise on reducing HDP risk has been previously shown, information is lacking for proper dosing of exercise training regimens in at-risk women.

What are the key findings?
Higher exercise volume led to lower systolic blood pressure during pregnancy and thereby normalized gestational length and increased offspring birthweight. Further, weekly exercise duration predicted birthweight independent of gestational length.

What does this study add to what is already known?
Evidence has shown a beneficial influence of exercise in at-risk pregnancies. The current findings further show a volume-dependent effect of prenatal exercise on improving birth outcomes in at-risk pregnancies. These findings highlight the importance of meeting recommended levels of exercise in women at risk of HDP.

placenta, therefore necessitating preterm birth (before 37 completed weeks of gestation) and leading to poor health consequences in offspring.[2,3] Beyond gestation, HDP can have lasting consequences through predisposition for metabolic disease in both the mother and offspring.[2] Specifically, mortality from cardiovascular causes is increased in mothers with HDP,[4] while offspring are at increased risk of developing cardiovascular disease later in life.[5]

Finding an alternative, low-cost treatment to attenuate the incidence and delay the onset of HDP is important, as low-dose aspirin is the only known preventive measure available, but the treatment lacks specificity and efficacy.[6] Exercise has a well-documented protective effect on hypertension in nongravid adults[2,7] and recent evidence suggests that exercise performed during pregnancy reduces the odds of developing HDP.[8−13] Relevant studies have primarily focused on exercise performed early in pregnancy; however, reports show contrasting evidence for either an inverse relationship or no relationship, between prenatal physical activity and risk of HDP.[14−17] Insight specifying the most efficacious dose and type of exercise for at-risk women is limited.[8] Furthermore, the effect of supervised exercise throughout gestation on birth outcomes in at-risk women is unclear.

The current study assessed women at risk of HDP as having prior pregnancy with hypertension or > 1 moderate-risk factor such as age ≥35, BMI > 30, family history of hypertension. Though we hypothesize that exercise dose will have an inverse relationship to the occurrence of HDP, the independent effects of exercise type have not been tested. Further investigation is therefore needed to elucidate the influence of prenatal exercise metrics, “FITT-V”: Frequency (number of sessions), intensity (metabolic equivalents “METs”), time (duration of sessions), type (exercise mode), volume (exercise MET*minutes) on birth outcomes for pregnancies at risk. The current study aims to determine the effect of prenatal exercise FITT-V on birth outcomes in women at risk for developing HDP. We hypothesize that higher exercise dose will be associated with reduced blood pressure in these women and be positively associated with gestational age at birth and birthweight, regardless of exercise type (T).

Materials and methods

Study participants

The current report is a secondary analysis of maternal blood pressure and birth outcomes from three prospective, randomized control trials (RCTs) investigating the influence of prenatal exercise types on fetal and infant outcomes. This analysis focuses on outcomes in pregnancies at risk for HDP. The primary focus was to examine whether prenatal exercise dose metrics (frequency, intensity, time, type, and volume) impact maternal blood pressure throughout at-risk pregnancies, and influence birth outcomes in offspring. All protocols were approved by the East Carolina University (ECU) Institutional Review Board. Women enrolled in these studies met the following criteria: clearance from a health care provider to participate in physical activity; between 18 and 40 years of age; prepregnancy body mass index (BMI; kg·m^{-2}) >18.5 kg·m^{-2}; singleton pregnancy; ≤16 weeks gestation; no current alcohol or tobacco use. Inclusion for this analysis was also limited to participants with any high-risk factor for HDP (ie, prior preeclampsia) and those with more than one moderate-risk factor (first pregnancy, maternal age ≥35, BMI>30, family history of hypertension, and/or applicable sociodemographic or personal history factors) based on ACOG guidelines. Criteria for exclusion included smoking, known pre-existing conditions (ie, diabetes mellitus, chronic hypertension, cardiovascular disease, comorbidities, systemic lupus erythematosus), and/or medications known to affect fetal growth and well-being. This being a secondary analysis of existing data from three randomized controlled trials, these individuals were also excluded from the analysis of HDP risk. The diagnosis of HDP was the development of hypertension (>140/90 mmHg) on two occasions at least 4 hours apart after 20 weeks gestation with previously normal BP.[18]

Ethics statement

The three included studies used data from birth records collected from participants enrolled in an initial pilot RCT study,[19] a second RCT (ClinicalTrials.gov Identifier: NCT03517293),[20] and a third RCT (ClinicalTrials.gov Identifier: NCT03838146).[21] All trials included a similar, supervised exercise intervention during pregnancy, though the first study involved an aerobic exercise (AE) group only, with the latter two including also resistance and combination exercise group. Approval for these studies was obtained from the ECU Institutional Review Board. Written informed consent was obtained from each participant upon enrollment. All experimental procedures were conducted at ECU.

Preintervention exercise testing and randomization

After study enrollment, participants completed a submaximal treadmill test to determine aerobic capacity and calculate the target heart rate (THR) range for moderate-intensity training. Peak oxygen consumption (VO_2peak) was estimated via the modified Balke protocol previously validated for pregnant women.[22] To minimize exposure risk after the start of the COVID-19 pandemic, women recruited between March 2020 and October 2021 had THR zones for AE determined based on their prepregnancy physical activity level and age.[22] THR zones for exercise components corresponded to maternal HR at 60% to 80% of maximal oxygen consumption, ie, moderate intensity. Next, participants were randomized via computerized sequencing (GraphPad, Boston, USA) to aerobic, resistance, combination (aerobic and resistance), or a stretching/breathing control group.

Exercise intervention

All participants were supervised by trained exercise instructors in ECU University facilities following a standard protocol. All sessions started at 16 weeks gestation and women were scheduled three times weekly until delivery.[23] All participants' sessions included a 5-minute warm-up, 50 minutes of their randomized group activity, and a 5-minute cool-down.

The AE group completed moderate-intensity training on treadmills, ellipticals, recumbent bicycles, rowing, and/or stair-stepping equipment. To maintain the appropriate HR zone, speed and grade were adjusted on the treadmill, and resistance and speed levels were adjusted on the elliptical and bicycle. The resistance exercise (RE) group completed sessions of two to three sets aiming for 12 repetitions of each exercise at ~60% of 1 repetition maximum.[24] Exercises for RE were performed in a circuit with minimal rest (5–10 seconds) using seated machines (Cybex) (ie, leg extension, leg curl, shoulder press, chest press, triceps extension, latissimus dorsi pull-down), dumbbells (ie, biceps curls, lateral shoulder raises, front shoulder raises), resistance bands, dumbbells, exercise balls, benches, and/or mats. The combination exercise (AE+RE) group performed half of the aerobic protocol and half of the resistance protocol exercises in five circuits, lasting 4.5 to 5 minutes each. REs were performed aiming for 12 repetitions (same exercises and equipment as the RE group), while AEs were performed on the same equipment as the AE group.

To ensure proper intensity was achieved during exercise sessions, the Borg scale rating of perceived exertion (RPE 6–20), and "talk test" were used.[25] HR monitoring (Polar FS2C, Kempele, Finland) ensured appropriate target HR ranges were maintained; target HR zones validated for pregnant women were utilized.[22]

Prenatal exercise dose

Exercising women aimed to complete aerobic, resistance, or combination exercise 3 times per week, for 50 minutes per session, at moderate intensity (3–6 METs). To control for differences in the duration of pregnancy and the start of intervention, exercise dose was analyzed from 16 weeks until delivery for all participants.

Frequency was calculated as the number of times the participant attended supervised exercise each week and is expressed as sessions per week. Intensity was calculated using the published compendium of physical activity[26,27] for each specific exercise performed. The average METs were calculated via an average of these METs through all of the exercise sessions. Time was determined by exercise duration in minutes within each week, with average duration reported as minutes/wk. Lastly, prenatal exercise volume was calculated by 1) multiplying average intensity (METs) by the average weekly duration for volume in MET*minute/wk (weekly exercise volume), and 2) multiplying weekly MET*minute by the total number of weeks prenatal exercise was performed through pregnancy for total MET*minute (total pregnancy volume). Further stratified analysis was made on women who did (high-volume) or did not (low-volume) surpass 10,000 MET*minutes of exercise through pregnancy, as this number signifies completing the ACOG-prescribed dose of 500 MET*minutes per week for at least 20 weeks during gestation.

Birth outcomes

At birth, delivery mode (spontaneous vaginal delivery, C-section), neonate sex, gestational age, and neonatal measures (heart rate, chest, head, and abdominal circumferences, birthweight, length) were measured by labor and delivery nurses, using standard protocols, and entered into the electronic health record. Head circumference-abdominal circumference (HC:AC) and weight-length ratios were calculated. Apgar scores were measured at 1 and 5 minutes after birth by the labor and delivery nurse per standard hospital protocol.

Statistical analysis

Outcomes were analyzed continuously against exercise frequency, intensity, time, and volume. One-way ANOVAs were performed for outcomes based on exercise type, as well as exercise volume. Pearson product-moment correlations were performed between each exercise dose metric and each birth outcome. Significance for all tests was accepted at the α=0.05 level. Stepwise regressions were conducted to determine significant associated variables with birth outcomes from pregnancies at risk of HDP, controlling for covariates. Correlations and ANOVAs were performed using SPSS software (version 28.0.1.1, SPSS Inc. IBM Corp., Chicago, IL, USA) software, and stepwise regressions were executed using JMP Pro 17 (SAS, Cary, NC, USA).

TABLE 1
Maternal characteristics across exercise type

Maternal characteristic	Control *n*=9	Aerobic *n*=12	Resistance *n*=6	Combination *n*=10	*P*
Age, *y*	29.6 ± 4.4	28.4 ± 4.7	30.7 ± 2.8	29.7 ± 4.9	*.79*
Prepregnancy BMI, $kg \cdot m^{-2}$	26.7 ± 3.4	28.3 ± 7.1	27.3 ± 3.0	28.5 ± 5.3	*.91*
Prepregnancy VO_2peak, $mL \cdot kg^{-1} \cdot min^{-1}$	21.3 ± 1.9	22.6 ± 5.8	26.4 ± 7.5	24.6 ± 5.3	*.12*
1st-trimester SBP/DBP, *mmHg*	106/60	103/59	100/56	104/60	*.27*
% BIPOC	37	40	40	30	*.97*
Gestational age at birth, *wk*	38.0 ± 1.2	39.0 ± 1.3	39.2 ± 1.1	38.5 ± 1.3	*.35*
Gravida	2 (1.4)	1 (1.2)	1 (1.2)	2 (1.4)	*.21*
Parity	1 (0.2)	0 (0.2)	0 (0.1)	0 (0.2)	*.22*

Maternal characteristics measured before commencement of exercise (12−16 weeks of gestation). Data are mean ± SD.

BIPOC, Black or Indigenous People of Color; *BMI*, body mass index; *DBP*, diastolic blood pressure; *SBP*, systolic blood pressure; *VO_2peak*, maximum volume of oxygen consumption.

Claiborne. Exercise during pregnancy frequency, intensity, type, time, volume. AJOG Glob Rep 2025.

Results

Of 366 women who enrolled in the studies, only 39 (11%) women were considered at risk for HDP, delivering 15 female and 24 male neonates. Three (8%) of these deliveries were preterm, ie, before 37 completed weeks of gestation. Women at risk for HDP were on average 29 years of age, BMI of 27.9 kg·m^{-2}, on their 2nd pregnancy, and delivered in the 38th gestational week (Table 1). Of at-risk participants, 37% identified as Black or Indigenous People of Color (BIPOC). There were no significant differences between groups for prepregnancy fitness expressed as VO_2peak (P=.13) or first-trimester resting blood pressure (P=.27). Prepregnancy VO_2peak was not significantly correlated with first trimester systolic (P=.65) or diastolic (P=.13) blood pressure.

Women exercised for an average of 20.2 weeks during pregnancy (range=16−25 weeks). Among at-risk pregnancies, women with higher total prenatal exercise volume had trends of lower systolic blood pressure in the 1st, 2nd, and 3rd trimesters (Figure 1). Furthermore, total exercise volume had a significant positive association with gestational age at birth leading to a positive trend between exercise volume and infant birthweight (Figure 2). After controlling for the number of training weeks during pregnancy, weekly exercise volume also was positively associated with gestational age at birth as well as birthweight (Figure 3). Stepwise regressions revealed significant predictive effects of weekly exercise volume on gestational age at birth (P=.02) and weekly exercise duration with birthweight (P=.02), independent of gestational age at birth (Table 2).

Discussion

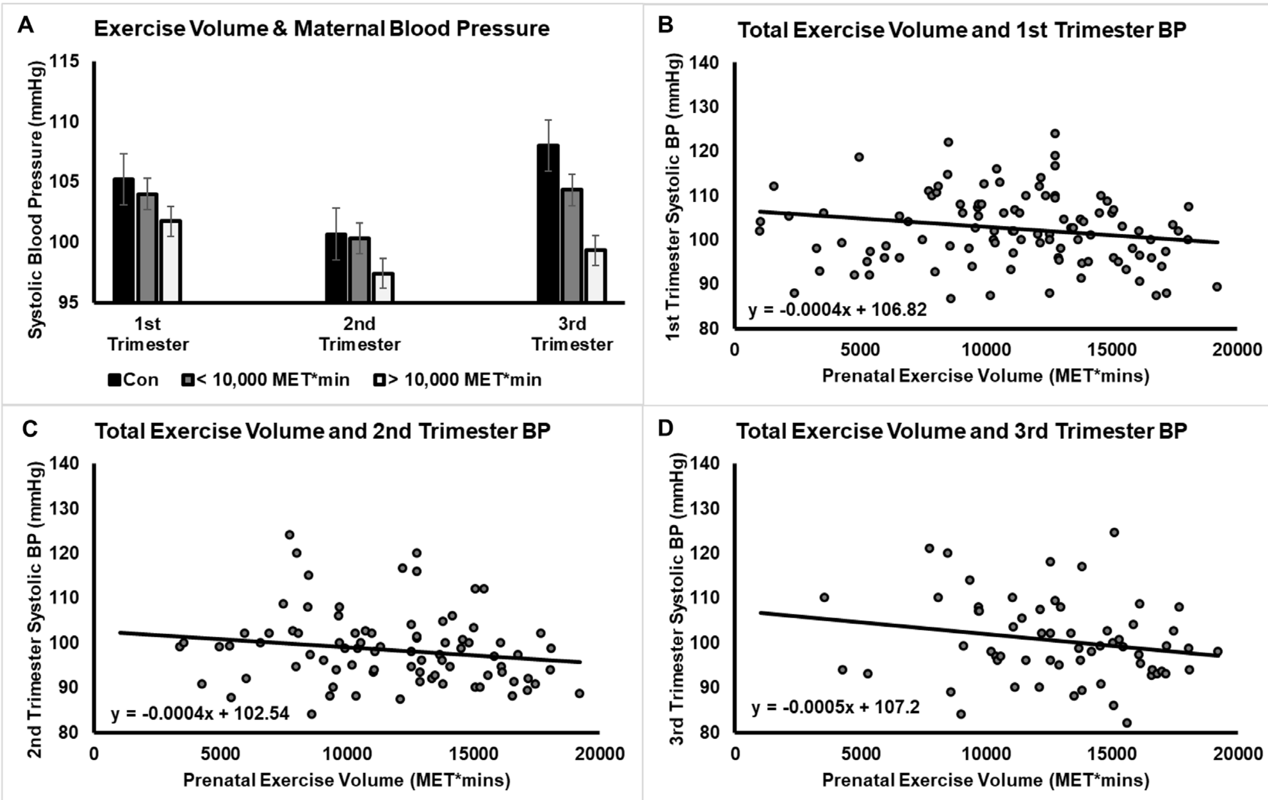
Principal findings

The current study aimed to determine the effect of prenatal exercise FITT-V on birth outcomes in women at risk for developing HDP. We hypothesized that women at risk would benefit directly from increased exercise frequency, intensity, time, and volume of exercise, in an exercise dose-dependent manner. Specifically, we expected reduced blood pressure in higher dose exercisers, and for exercise dose to therefore improve birth outcomes. We confirmed that women with higher exercise volume, total across pregnancy and weekly, have deliveries closer to the due date with increased birthweights, without the occurrence of macrosomia (>4500 grams)[28]; weekly exercise duration predicts this relationship. It is also interesting to note that exercise in the prescribed intensity range (3−6 METs) did not lead to decreased birthweight.

Results

Among this population of at-risk pregnancies, we found gestational age at birth to range from 25 to 41 weeks, with most deliveries evenly distributed across weeks 37 to 40. As has been shown in our previous work in healthy pregnancies, higher total and weekly exercise volume extends the gestational period ~1 week.[29] This finding is supported by past evidence from other groups,[30,31] however the specific effect on pregnancies at risk for HDP has not been previously reported. Previous literature supports our findings that participation in regular exercise during pregnancy reduces the risk for HDP.[2,8,32] A previous scoping review has found this evident, especially in women undergoing supervised exercise at a low-to-moderate intensity level, such as that prescribed in the current study.[10] While it appears that as little as 60 minutes of exercise per week could significantly reduce the risk of HDP,[11] further evidence has shown that risk mitigation can be more than doubled in those who engage in vigorous physical activity during pregnancy.[8] One other investigation has suggested women achieve at least 600 MET*minutes of exercise per week to achieve a 25% reduction in the odds of developing HDP.[12] As further evidence refuting hesitation to participate in vigorous physical activity during

FIGURE 1
Total exercise dose-response and 1st-trimester blood pressure



Total exercise volume based on MET*minutes from exercise during pregnancy. (A) Higher volume exercisers (>10,000 MET*minutes throughout pregnancy) show lower systolic blood pressure at each trimester during pregnancy 1st: P=.22, 2nd: P=.14, 3rd P=.07. (B) 1st-trimester BP trended for association with total exercise volume R=−0.18, P=.06; (C) 2nd trimester BP trended for association with total exercise volume R=−0.15, P=.15; (D) 3rd trimester BP trended for association with total exercise volume R=0.20, P=.12. A n=105, B n=84, C n=62. A: Data are mean ± SE.

Claiborne. Exercise during pregnancy frequency, intensity, type, time, volume. AJOG Glob Rep 2025.

pregnancy, exercise intensity did not negatively influence outcomes such as birthweight in the current study. Our findings generally support the idea that exercise regulates maternal blood pressure during pregnancy and offer a novel insight to improved birth outcomes in at-risk pregnancies which warrants further investigation. The findings of improved blood pressure and birth outcomes in women at risk of HDP add to our knowledge on the effects of prenatal exercise on women at risk of HDP.[33–35]

Clinical implications

Our finding of increased gestational age at birth partially explains the increased birthweight also seen in prenatal exercisers that perform a higher volume and/or higher duration of weekly exercise across pregnancy; importantly, regressions revealed that exercise duration is a significant independent contributor to increasing birthweight in this population. While our study involved no more than moderate-intensity exercise, our findings show that exercise duration also provides a similar benefit in reducing maternal blood pressure. In support, exercise during pregnancy has been shown to directly reduce maternal blood pressure when compared to no exercise.[34,35]

Research implications

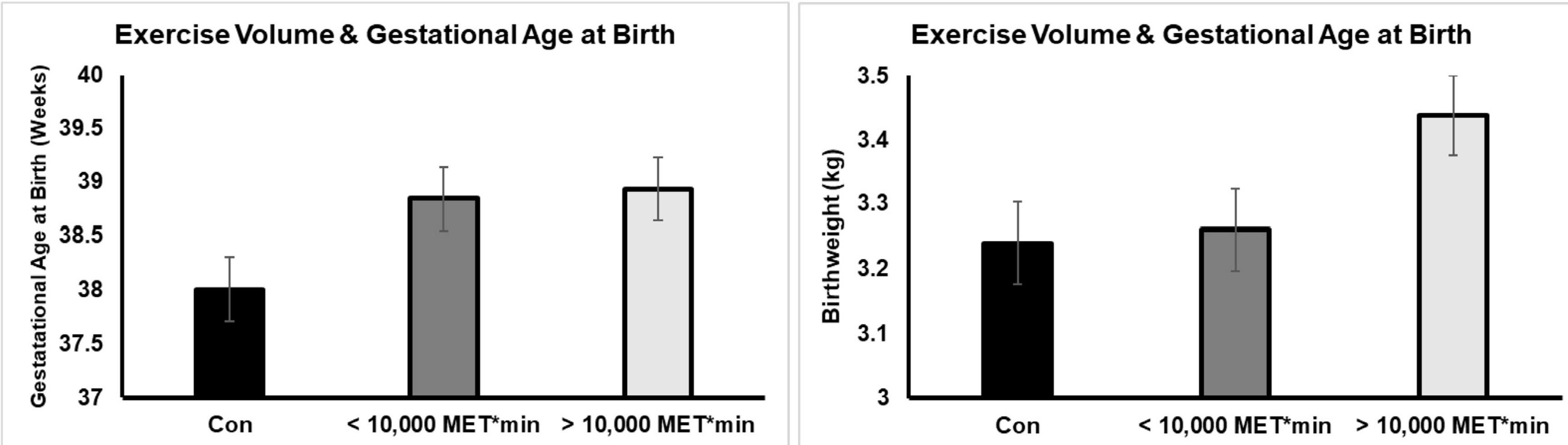
As it has been shown that as low as 27% of women engage in the minimum recommended dose of prenatal exercise,[36] the current findings highlight the need for proper adherence to the published guidelines for overall pregnancy health and risk mitigation.[23] As exercise volume and duration both have a beneficial effect on neonatal outcome in at-risk pregnancies, clinicians and exercise professionals should encourage pregnant women to achieve at least the minimum recommended dose.

Strengths and limitations

Our findings are strengthened by the design of this study, ie, a supervised exercise intervention with trained professionals. To the best of our knowledge, this is the first report of exercise volume and duration during pregnancy impacting gestational age at birth and birthweight in offspring from pregnancies at risk of HDP. Furthermore, consideration of these findings in the scope of a

FIGURE 2

Prenatal exercise and birth outcomes

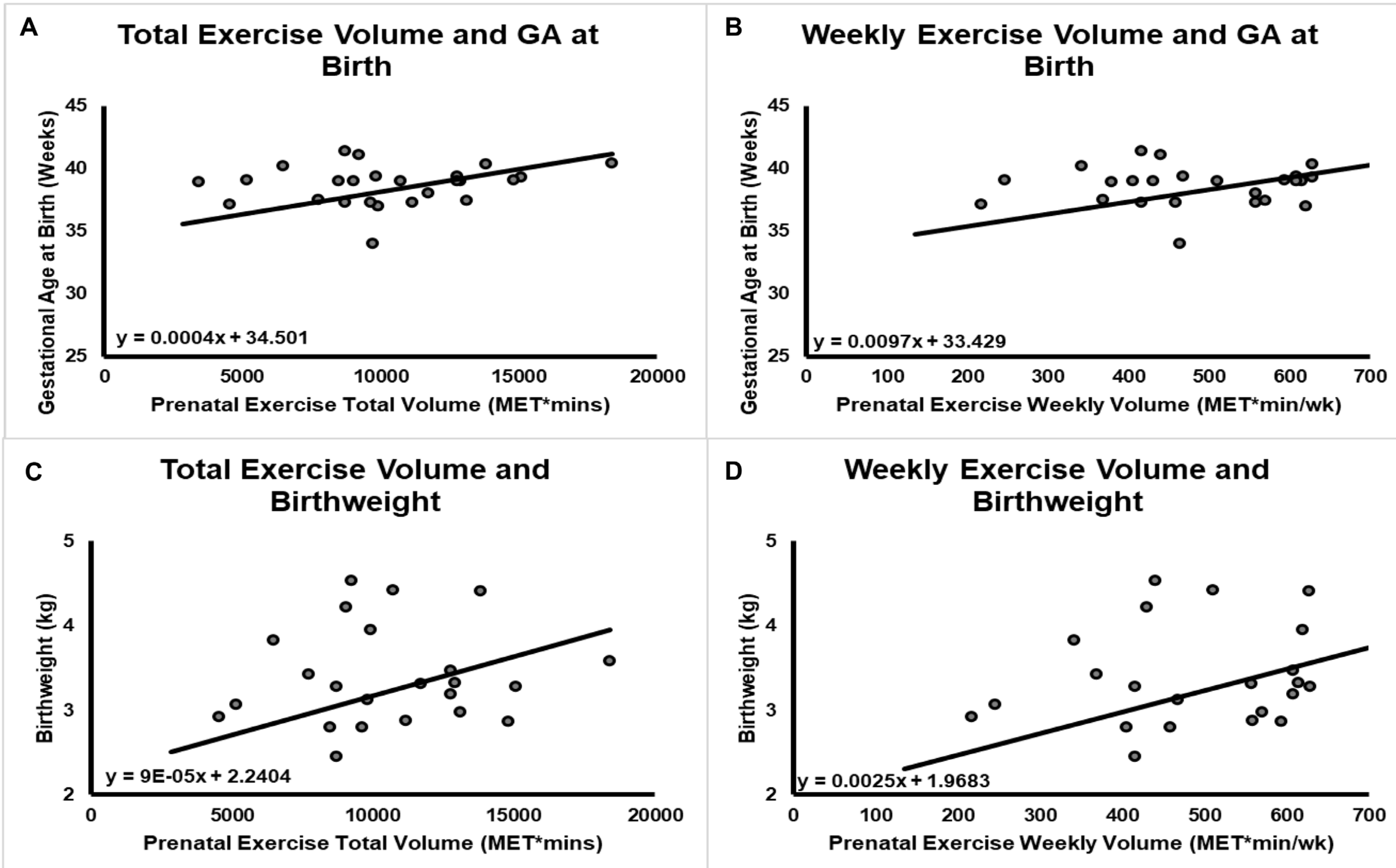


Total exercise volume based on MET*minutes from exercise during pregnancy. (A) GA (gestational age) at birth trended higher in women exercising >10,000 MET*minutes throughout pregnancy P=.31 vs CON. (B) Birthweight was nonsignificantly higher in women exercising >10,000 MET*minutes throughout pregnancy P=.81 vs CON. Data are mean ± SE.

Claiborne. Exercise during pregnancy frequency, intensity, type, time, volume. AJOG Glob Rep 2025.

FIGURE 3

Prenatal exercise dose-response and birth outcomes



Total exercise volume based on MET*minutes from exercise during pregnancy. Weekly exercise volume based on MET*minutes per week of exercise during pregnancy. (A) GA (gestational age) at birth positively associated with total exercise volume R=0.42, P=.03; (B) GA at birth positively associated with weekly exercise volume R=0.46, P=.01; (C) birthweight trended for positive association with total exercise volume R=0.36, P=.07; (D) birthweight positively associated with weekly exercise volume R=0.43, P=.03. n=25.

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TABLE 2
Prenatal exercise with at-risk birth outcomes: Regression

Birth outcomes	Estimate	Std. error	*t* ratio	*P* value
Gestational age at birth	**Adjusted R^2=0.46, F=6.46, P=.005**			
Gravida	−3.16	2.80	13.04	**.006**
Parity	2.37	1.32	−3.15	.09
Weekly exercise volume	0.01	0.004	2.62	**.02**
Apgar 1-min score	**Adjusted R^2=0.67, F=7.53, P=.001**			
Gestational age at birth	0.35	0.07	5.15	**.0002**
Weekly exercise duration	0.02	0.008	2.63	**.02**
Apgar 5-min score	**Adjusted R^2=0.08, F=2.51, P<.0001**			
Gestational age at birth	0.09	0.02	5.55	**<.0001**

All models also included: maternal age, race, gravida, parity, and intervention group.

All Bold values are significant

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diverse study sample (37% BIPOC), as families that identify as BIPOC are greatly impacted by birth complications.[37] In addition to strengths, there are several potential limitations. First, prenatal exercise FITT-V was controlled as part of a prescribed exercise dose, therefore limiting our ability to study high- and low-dose prenatal exercise effects. Second, our sample size was limited relative to some epidemiological studies and did not include the individuals at the highest risk of developing HDP. These individuals were excluded as part of the primary study design, due to the focus on the prenatal exercise intervention. Third, this was a secondary analysis of data rather than a focused study recruiting women at risk of HDP. Therefore, we recommend larger intervention studies are needed specifically recruiting women at risk of HDP to confirm our findings. Our results will better inform sample size calculations for larger intervention studies.

Conclusion

HDP poses metabolic health risks to the mother and can influence gestational age at birth and birth outcomes. Exercise during pregnancy is a strong mitigator of the risk of HDP. While there is ample evidence to suggest improved pregnancy outcomes in women who exercise during pregnancy, the specific effect of exercise dose remains unexplored, something that our group has, and will continue to, study. Though evidence of improved infant outcomes in exercise during pregnancy is growing, specific investigations, especially randomized controlled trials, in at-risk pregnancies are limited. The current findings contribute to this critical gap, as they show a volume-dependent effect of prenatal exercise on improving birth outcomes in at-risk pregnancies. Weekly duration and volume of prenatal exercise were associated with lengthened gestational period and increased birthweight. These findings highlight the importance of obstetricians encouraging women at risk of HDP to exercise during pregnancy at recommended levels. ■

CRediT authorship contribution statement

Alex Claiborne: Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Breanna Wisseman:** Writing – review & editing, Project administration, Data curation. **Kara Kern:** Writing – review & editing, Data curation. **Dylan Steen:** Writing – review & editing, Data curation. **Filip Jevtovic:** Writing – review & editing, Visualization, Validation, Data curation. **Samantha Mcdonald:** Writing – review & editing, Validation, Investigation, Data curation. **Cody Strom:** Writing – review & editing, Data curation. **Edward Newton:** Writing – review & editing, Validation, Supervision. **James Devente:** Writing – review & editing, Validation, Methodology, Investigation. **Steven Mouro:** Writing – review & editing, Visualization, Validation, Investigation. **James Whiteside:** Writing – review & editing, Validation, Investigation. **Jacqui Muhammad:** Writing – review & editing, Validation. **David Collier:** Writing – review & editing, Validation. **Devon Kuehn:** Writing – review & editing, Validation. **George A. Kelley:** Writing – review & editing, Validation. **Linda E. May:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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