RESEARCH ARTICLE

Maternal Cardiovascular and Birth Outcome Responses to At-Home vs. In-person Prenatal Exercise during COVID-19 Pandemic

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Abstract

Background. The COVID-19 pandemic led to decreased physical activity, as well as increased stress, especially for pregnant women. Exercise is effective for decreasing stress and improving overall maternal and infant health. To date, research has not determined whether an at-home exercise program during pregnancy elicits similar results to in-person exercise.
Objective. To examine the effect of in-person vs at-home moderate-intensity exercise training during pregnancy on maternal cardiovascular and birth outcomes during the COVID-19 pandemic.
Methods. Pregnant women were recruited between 13-16 weeks' gestation and randomized to either an exercise or control group. No control subjects were included in this analysis; exercisers were asked to complete at least 50-minutes of moderate-intensity activity 3 times each week either in-person (n=20) or at-home (n-17). Both groups were provided individualized exercise prescriptions including a 5-minute warm-up, 50-minutes of exercise related to group allocation, and a cool-down period. Maternal resting heart rate and blood pressure (BP) were recorded at 16- and 36-weeks' gestation. Gestational weight gain and birth outcomes were obtained via electronic health record at delivery.
Results. From enrollment to late pregnancy, at-home exercisers have significant increases in systolic and diastolic BP (SBP and DBP, p<0.001 and 0.0003, respectively) whereas the in-person group did not (p=0.30 and 0.78, respectively). In-person exercisers had lower SBP and DBP in late pregnancy (p=0.04 and 0.01, respectively) relative to at-home exercisers. At-home exercise was correlated with higher late pregnancy SBP (r=-0.34, p=0.04), DBP (r=-0.42,p=0.01), and SBP change (r=-0.496, p=0.002). Group allocation was a predictor for late pregnancy DBP (p=0.007) and SBP change (0.036). There were no differences in infant birth outcomes.
Conclusion. Supervised in-person exercise training with the proper precautions has similar birth outcomes and may be more beneficial for maternal cardiovascular health relative to at-home training.

Keywords: pregnancy, exercise, physical activity, blood pressure, cardiovascular, supervised training

1. Introduction

The COVID-19 pandemic resulted in less physical activity across the world and increased stress levels, specifically among pregnant women.[1–4] Exercise has shown to be an effective method for managing stress[5] and has shown to be beneficial for both maternal and infant health. [6–11] Due to the numerous benefits associated with exercise during pregnancy, the U.S. Department of Health and Human Services recommends 150-minutes of moderate physical activity each week during pregnancy and is supported by the American College of Obstetrics and Gynecology (ACOG).[12,13] Despite the benefits seen with regular exercise, recent literature reported decreased activity levels during the pandemic due to barriers such as lack of gym access and increased dependence on at home physical activity.[1,2] For these reasons, it is important to ensure pregnant women are receiving effective methods for improving and/or maintaining physical activity levels during gestation.

During the COVID-19 pandemic new methods for being active (e.g., at-home classes) arose to attempt to counteract these obstacles. However, little research has examined whether virtual-based exercise training is as effective as supervised, in-person training during pregnancy on maternal cardiovascular and birth outcomes. Therefore, this analysis was to examine whether there were physiological differences in maternal cardiovascular and birth outcomes born to women who participated in at-home vs in-person exercise sessions during the COVID-19 pandemic. We hypothesized that pregnant women participating in supervised training sessions during COVID would have similar maternal cardiovascular and birth outcomes relative to pregnant women participating in at-home exercise training sessions.

2. Methods

2.1 Study Design

This secondary analysis of a randomized control study was focused on determining the influence of different types of maternal exercise during pregnancy on maternal cardiovascular and birth outcomes. This data was part of a larger longitudinal study focused on the influence of maternal exercise on offspring health outcomes.[14] Participants were randomly assigned to aerobic, resistance, combination (aerobic and resistance) exercise or no exercise control group. The randomization sequence was generated from GraphPad (GraphPad, San Diego, CA) that was concealed prior to group assignment. The study intervention was ~24 weeks in duration, from 16-weeks' gestation until delivery. All protocols have been approved by East Carolina University Institutional Review Board University and registered in clinicaltrials.gov (NCT03517293). Written informed consent was obtained from all participants as well as a clearance letter from their obstetric provider confirming their pregnancy, and ability to exercise for the study.

2.2 Study Population

For the longitudinal study, we recruited low-risk, healthy women with a singleton pregnancy through flyer distribution at local obstetric clinics and email announcements. Women were eligible for participation if they met the following criteria: between the ages of 18 and 40, pre-pregnancy body mass index (BMI) of 18.5-34.9, gestational age $\leq$ 16 weeks, not currently using alcohol, tobacco, recreational drugs, or medications for chronic disorders. Women were excluded if they had any contraindications to exercise in pregnancy as outlined by the American College of Obstetricians and Gynecologists[13] or had pre-existing conditions such as diabetes, hypertension, or other cardiovascular diseases. During the COVID pandemic, pregnant participants chose to either continue exercise with an exercise trainer or continue with at-home sessions. Therefore, we had 52 participants identified as being recruited during the COVID-19 pandemic and were randomized to either exercise or control. Due to our secondary study aim, we excluded 14 women that were randomized to the control group leaving a potential sample of 38 participants for analysis. Since we have found differences in maternal cardiovascular response to type of exercise[15], at-home exercisers were matched based on exercise group allocation, as well as pre-pregnancy BMI, and age (mean ± standard deviation) to participants that participated in-person; some participants had more than one match.

2.3 Pre-Intervention Exercise Testing

Participants recruited prior to March 2020, the COVID-19 pandemic, completed a submaximal Modified Balke treadmill test as validated by Mottola et al.[16] to determine the target heart rate zone (THR). During the test, oxygen consumption and carbon dioxide production levels were assessed via indirect calorimetry (Parvo Medics, TrueOne 2400, Sandy, UT) to determine VO_{2peak} (ml O_2□kg^{-1}□min^{-1}) while maternal heart rate (HR) was continuously measured (Polar FS2C HR monitor). To minimize exposure and potential risk associated with gas exchange after the start of the pandemic, due to the aerosol transmission associated with COVID-19, women recruited following March 2020 did not complete the treadmill protocol. Therefore, THRs for these participants were determined using published guidelines based on their pre-pregnancy physical activity level and age.[16] THRs for this study corresponded to maternal HRs at 60 to 80% VO_{2peak}, reflecting moderate exercise intensity. [17]

2.4 In-Person Exercise Intervention

All participants were supervised by an ACSM certified study staff exercise instructors wearing full personal protective equipment (PPE) and followed a standard protocol as described previously.[14] Briefly, all exercisers performed a 5-minute warm-up, 50-minute exercise maintained in moderate intensity, followed by a cool-down period, 3 times per week for ~24 weeks (13-16-weeks' to 36-weeks' gestation or until delivery). Women were instructed to maintain their THR corresponding to a moderate intensity. To ensure adherence to this exercise intensity through the entirety of each session, maternal HR was monitored during each training session using a Polar FS2C HR monitor and the Borg scale of rating of perceived exertion with the goal of 12-14 was used to determine moderate intensity. The aerobic exercise was performed on a treadmill, elliptical, or cycle ergometer, at the discretion of the participant. The resistance exercise was performed utilizing machines, dumbbells, barbells, and resistance bands based on personal preference. The combination exercisers alternated between 4.5 minutes of aerobic activity and resistance exercises. Each session began with a 5-minute warm-up consisting of slow walking on a treadmill, elliptical, or cycle ergometer. Participants were then guided by a trained staff through several breathing and stretching exercises. HR monitors were worn to ensure that maternal HRs remained in a low intensity range (<50% VO_{2peak}). The of the in-person exercise sessions were conducted at one of two university-affiliated exercise facilities.

2.5 At-Home Exercise Intervention

Due to the COVID-19 pandemic, at-home exercise options were offered. Participants that opted in for this were provided at-home exercise prescriptions that consisted of a 5-minute warm-up, 50 minutes of exercise specific to their randomization group, and a 5-minute cool-down. Participants were informed on how to obtain a manual HR and instructed to maintain their HR within their specific THR. To verify the activity performed and intensity, forms were given to record resting, exercising, and post-exercise HRs, exercise duration, and any changes to prescribed exercises. Average exercising HR was calculated by averaging the HRs recorded throughout the exercise session.

2.6 Maternal Measures

All participants completed measures in person at our study facility. Height was measured in inches to the nearest 0.25 inch and converted to meters on a stadiometer. Weight was measured in light clothing to the nearest 0.1 kg. Body mass index (BMI) was calculated by dividing participant self-reported pre-pregnancy weight by the product of height squared (kg/m^2). Maternal physical measurements such as systolic (SBP) and diastolic blood pressure (DBP) and HR were measured at 16 and 36 weeks' gestation. Maternal resting SBP, DBP, and HR were assessed in a sitting position. Blood pressure was recorded using a manual sphygmomanometer at the brachial artery just proximal to the elbow (arm straight or in mild elbow flexion) with an appropriately sized cuff. All measures were performed by trained research staff at each time point. Maternal age, gravida and parity were collected via an eligibility questionnaire following the initial participant contact with study personnel, prior to enrollment.

2.7 Pregnancy Outcome Measures

Gestational age (weeks) and weight at delivery (kilograms) were acquired from the electronic health records. Gestational weight gain (GWG) was calculated by subtracting maternal self-reported pre-pregnancy weight from weight at delivery. Birth weight (grams), birth length (cm), Apgar scores at 1 and 5 minutes were also collected from electronic health records. Neonatal BMI and Ponderal Index were calculated using the following equations:

$$\text{Ponderal Index} = 100\,(\text{weight (g)}) \div (\text{length (cm)})^3$$

$$\text{Neonatal BMI} = (\text{weight (kg)}) \div (\text{height (m)})^2$$

2.8 Statistical Analysis

The primary outcomes of the present research analyses were SBP and DBP. To reach statistical significance for SBP, power analysis indicated a total of 66 participants, or 33 per group; for DBP, power analysis indicated 44 total participants, or 22 per group. Based on this sample size justification, we need a minimum of 22 per group for statistical significance at $p<0.05$ and a power of 80%. To test for between-group differences in maternal characteristics, t-tests and chi square tests were performed for continuous and categorical variables, respectively. Paired t-tests were done to determine within group differences for repeated measures of resting maternal HR (RHR), SBP, and DBP. The *a priori* alpha level for statistical significance was set at $p<0.05$ for all analyses. Pearson correlations were performed to evaluate relationships with the dependent variables and to inform regression analyses. Regression analyses were performed to determine significant predictors of primary outcome variables while controlling for early-pregnancy HR and blood pressure, pre-pregnancy BMI, GWG, and/or group allocation. All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, N.Y., USA).

3. Results

3.1 Study Population

From the sample of 38 potential participants, one participant was excluded due to missing data on the neonatal birth outcomes. Participants were matched for randomized group allocation, BMI, and maternal age the sample consisted of 37 pregnant women (at-home= 17 and in-person= 20); some participants had more than one appropriate match.

3.2 Maternal Descriptive Characteristics

There are no differences in maternal descriptive characteristics between groups (Table 1). The average participant is 30.6 years old, overweight (BMI=25.8), on their second pregnancy, and gained an average of 35 lbs. In-person exercisers tended to have lighter neonates, although not statistically significant (p=0.08) relative to at-home exercisers. Of the population, one at-home participant tested positive for COVID at delivery. No trainers or other participants tested positive throughout the duration of the study.

Table 1. Maternal descriptors by group

Variable	At-Home Exercisers (n=17)	In-Person Exercisers (n=20)	p-value
Maternal Age (years)	30.59 ± 4.29	30.85 ± 4.25	0.85
Pre-Pregnancy BMI (kg/m2)	25.06 ± 2.48	24.62 ± 2.59	0.61
Gravida [a]	1 (1,4)	1.5 (1,3)	0.78
Parity [a]	0 (0,2)	0 (0, 1)	0.60
Compliance (%)	82.1±23.2	76.3±22.4	0.44

Values displayed as mean ± SD; [a] Values reported as median (minimum, maximum) and used a Mann-Whitney U test due to non-normal unconditional distributions. Pre-pregnancy BMI: Pre-pregnancy body mass index.

3.3 Between Group Differences

We observed differences in some maternal measures and birth outcomes (Table 2). At baseline, in-person exercisers had significantly higher systolic blood pressure ($p<0.05$). By 36-weeks' gestation, in-person exercisers systolic and diastolic blood pressures were significantly lower (p=0.04 and 0.01, respectively). Similarly, the change in SBP across gestation was significantly higher in the at-home exercising group (p=0.002). Although there were no differences in GWG, gestational age, or infant birth outcomes, the trend of lower birth weight for the in-person group demonstrates neonates weighed about 330 grams lighter than babies from the at-home exercise group.

Table 2. Maternal and infant measures by group

Measure	At-Home Exercisers (n=17)	In-Person Exercisers (n=20)	p-value
Maternal Measures			
16-weeks' Gestation			
RHR (bpm)	82.41 ± 11.05	86.35 ± 13.85	0.35
SBP (mmHg)	93.41 ± 6.20	101.45 ± 11.99	**0.01***
DBP (mmHg)	56.53 ± 8.73	57.2 ± 10.02	0.83
36-weeks' Gestation			
RHR (bpm)	77.82 ± 12.12	85.95 ± 14.3	0.07
RHR Change (bpm)	-4.59 ± 10.09	-0.40 ± 11.08	0.24
SBP (mmHg)	106.35 ± 10.70	98.80 ± 10.69	**0.04***
SBP Change (mmHg)	12.94 ± 13.05	-2.65 ± 14.76	**0.002****
DBP (mmHg)	66.0 ± 7.39	59.6 ± 6.82	**0.01***
DBP Change (mmHg)	9.47 ± 12.22	2.4 ± 12.03	**0.09**
GWG (lbs.)	37.82 ± 9.20	34.93 ± 11.31	0.41
Infant Birth Outcomes			
Gestation Age (weeks)	39.66 ± 1.07	39.21 ± 2.22	0.45
Infant Body Length (m)	0.497 ± 0.02	0.486 ± 0.03	0.22
Infant Birth Weight (kg)	3.67 ± 0.50	3.34 ± 0.60	**0.08**
Infant BMI (kg/m2)	14.83 ± 1.62	13.98 ± 1.52	0.11
Ponderal Index	2.99 ± 0.36	2.88 ± 0.28	0.29
Apgar 1 min [a]	8 (6, 9)	8 (2, 9)	0.66
Apgar 5 min [a]	9 (7, 9)	9 (4, 9)	0.60

Values displayed as mean ± SD. Regression analysis controlled for exercise group (control vs exercise), maternal age, gravida, parity, and pre-pregnancy BMI. [a] Values reported as median (minimum, maximum) and used a Mann-Whitney U test due to non-normal unconditional distributions. RHR: resting heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; GWG: gestational weight gain, calculated subtracting pre-pregnancy weight from delivery weight. *p<0.05, ** p<0.01, *** p<0.001

3.4 Within Group Differences

There were no differences in RHR change from enrollment to late pregnancy for the in-person group or the at-home group. From enrollment to late pregnancy, women in the at-home group had a significant increase in SBP change (p<0.001); whereas the in-person exercisers had a slight decrease in SBP change, but this was not significant. Similarly, from enrollment to late pregnancy in women who exercised at-home had a significant increase in resting DBP change (p=0.003); while there was no significant difference in resting DBP change for in-person exercisers from 16 to 36 weeks gestation.

3.5 Correlations and Regressions

There was a significant negative correlation between at-home exercise group with late pregnancy SBP (r=-0.34, p=0.04) and DBP (r=-0.42,p=0.01). At home exercise group was also negatively correlated with the change in SBP from 16- to 36-weeks' gestation (r=-0.496, p=0.002). Regression analyses are displayed in Table 3. Overall, group allocation was a significant predictor for SBP change and late pregnancy DBP (Table 3, Model 1). Baseline SBP and DBP values were also significant predictors for SBP change and DBP change, respectively (Table 3). Interestingly, late pregnancy DBP significantly predicted birth weight when controlling for group allocation, GWG, and late pregnancy blood pressure (Table 3, Model 3).

Table 3. Regression analyses.

		p-values	95% CI Lower Bound	95% CI Upper Bound	Unstandardized Beta Value	STD Error
Model 1	**36-week RHR**	p-value= <0.001*** adjusted R^2= 0.46				
	Group	0.12	-1.42	12.36	5.47	3.39
	Pre-Pregnancy BMI	0.38	-0.79	2.05	0.63	0.7
	RHR 16-week	<0.001***	0.45	1.04	0.75	0.14
	RHR Change	p-value= 0.16 adjusted R^2=0.048				
	Group	0.45	-4.31	9.63	2.66	3.46
	Pre-Pregnancy BMI	0.81	-1.20	0.94	-0.13	0.53
	RHR 16-week	0.029*	-0.62	-0.04	-0.33	0.15
	36-week SBP	p-value= 0.19 adjusted R squared 0.05				
	Group	0.036*	-16.91	-0.63	-8.77	4.00
	Pre-Pregnancy BMI	0.48	-2.08	1	-0.54	0.76
	SBP 16-week	0.55	-0.29	0.53	0.12	0.20
	SBP Change	p-value= <0.001*** adjusted R^2= 0.529				
	Group	0.036*	-16.91	-0.63	-8.77	4.00
	Pre-Pregnancy BMI	0.48	-2.08	1	-0.54	0.76
	SBP 16-week	<0.001***	-1.29	-0.47	-0.88	0.20
	36-week DBP	p-value=0.03* adjusted R^2= 0.165				
	Group	0.007**	-11.5	-1.995	-6.75	2.34
	Pre-Pregnancy BMI	0.13	-1.73	0.23	-0.75	0.48
	16-week DBP	0.85	-0.25	0.30	0.025	0.13
	DBP Change	p-value=<0.001*** adjusted R^2= 0.418				
	Group	0.14	-9.11	1.35	-3.88	2.60
	Pre-Pregnancy BMI	0.61	-0.58	0.99	0.20	0.39

	16-week DBP	<0.001***	-1.15	-0.52	-0.84	0.16
Model 2	Gestational Age	p-value=0.08 adjusted R^2= 0.109				
	Group	0.66	-1.51	0.99	-0.26	0.61
	36-week SBP	0.033*	-0.14	-0.006	-0.071	0.032
	36-week DBP	0.024*	0.016	0.21	0.12	0.049
	Birth Length	p-value=0.08 adjusted R^2= 0.109				
	Group	0.66	-1.51	0.99	-0.26	-0.074
	36-week SBP	0.033*	-0.14	-0.006	-0.071	-0.45
	36-week DBP	0.024*	0.016	0.21	0.12	0.50
Model 3	**Birth Weight**	p-value= 0.020* adjusted R^2= 0.211				
	Group	0.3	-0.59	0.19	-0.20	0.19
	GWG	0.066	-0.001	0.033	0.016	0.008
	36-week SBP	0.081	-0.038	0.002	-0.018	0.01
	36-week DBP	0.025*	0.005	0.065	0.035	0.015

Model 1 controls for group, pre-pregnancy BMI, and baseline values
Model 2 controls for group and late pregnancy blood pressure
Model 3 controls for group, GWG, and late pregnancy blood pressure
Group: RHR= resting heart rate; group: group allocation, at-home, or in-person; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; GWG: gestational weight gain
Bolded headers indicate significant models. *p<0.05, **p<0.01, ***p<0.001

4. Discussion

The present study aimed to examine differences in maternal cardiovascular and birth outcomes of pregnant women who participated in at-home or supervised, in-person exercise sessions during the COVID-19 pandemic. We hypothesized that pregnant women in the in-person training group would have similar maternal cardiovascular and birth outcomes relative to pregnant women in the at-home training group. Our main findings were 1) late pregnancy SBP and DBP as well as SBP change was negatively correlated with in-person training, 2) at-home exercisers experienced an increase in SBP and DBP across pregnancy with higher blood pressure in late-pregnancy compared to in-person exercisers, 3) although not statistically different, women in the in-person group tended to have lighter neonates than at-home exercisers, and 4) either form of exercise was safe for maternal health and birth outcomes.

4.1 Maternal Outcomes

Similar to previous findings, we observed no differences in GWG between groups. A recent meta-analysis that compared the effect of supervised or unsupervised exercise interventions on GWG also reports no differences between intervention types.[18] Supervised, in-person exercise training predicted lower late pregnancy diastolic blood pressure and SBP change. Previous research suggests that exercise during pregnancy has no effect on maternal blood pressure[19–21] while more recent studies reported lower BP.[15,22–24] Research that reports no change in maternal blood pressure did not meet the recommended level of exericse or had low adherence rates. Whereas supervised interventions with high adherence and met, or were close to meeting, recommended guidelines find that exercise during gestation results in lower maternal blood pressure in late pregnancy compared to non-exercisers.

[23,24] Since our findings showed the change in SBP was predicted by group allocation and previous literature notes exercise level and adherance are important for outcomes, it is possible that the at-home group exercised at less than moderate intensity or for a shorter duration. Thus, for those women exercising at home they would not have a trainer to remind them to work harder if they were below their target heart rate zone or RPE for moderate intensity. Furthermore, there may have been inaccuracies in the self-report of exercise duration from participants in the at-home group. At-home exercisers experienced an *increase* in SBP and DBP by approximately 13 and 9 mmHg, respectively, from early to late pregnancy compared to in-person exercisers whom experienced a *decrease* of 3 and 2 mmHg for SBP and DBP, respectively. While all participants in both groups began and remained within a normal blood pressure range, previous literature has found that reductions in SBP and DBP of greater than 2 mmHg have significantly reduced risk for cardiovascular disease, and are reported to be minimally clinically significant. [25,26] Although exercise is typically associated with lowering blood pressure, the reason for the at-home group increase may be due to increased stress. Inherently, there may have been differences between groups related to their physiological response to stress, as seen by their choice to stay quarantined during their pregnancy. The influence of perceived stress on pregnancy and the influence of exercise needs further study. Overall, our results suggest that participating in a supervised, in-person exercise program during gestation may result in more beneficial cardiovascular responses relative to at-home exercising.

Similar to the present study, a recent article examined the effect of a supervised, virtual-based training intervention on blood pressure in pregnant women.[27] They reported no differences in first, second, or third-trimester blood pressure between virtual exercisers and non-exercising controls but did see a reduced SBP at delivery in the exercising group.[27] Similarly, our exercise groups have lower BP relative to controls[15], however, we additionally demonstrated supervised, in-person exercise intervention may be more effective than virtual, at-home exercise intervention. A possible reason for the discrepancy between this research and the present study could potentially be due to the type of exercise prescribed. Silva-Jose et al. utilized a combination style intervention combining aerobic and strength training for each exercise session[27]; whereas, due to sample size limitations, we pooled all of our exercising groups (aerobic, resistance, and combination) together for analysis. Future research is needed to examine whether there is an effect between in-person or at-home exercise during pregnancy on blood pressure between different exercise modalities.

4.2 Birth Outcomes

We found that women who participated in at-home exercise training during pregnancy had similar birth outcomes relative to women who participated in the in-person sessions.

Although this did not reach significance, neonates born to women of the in-person group tended to be 330 grams lighter compared to infants of at-home exercisers. Newborns of women that exercised during gestation have previously exhibited lower percent birth weight, which is typically associated with less infant body fat.[10,11,28,29] Some research from counseling only exercise interventions appeared to be less effective at normalizing, into the normal weight range, infant birth weight. The lack of differences in counseling or at-home exercise interventions could be explained by having less frequent contact and feedback with researchers or lack of real-time feedback.[30,31] Thus, further research should be done on real-time, synchronous, virtual training relative to supervised, in-person training.

An important point of this study is that, regardless of whether women chose to exercise at a gym or at home, exercise was safe and resulted in healthy pregnancy outcomes. In addition, despite one participant in the at-home exercising group testing positive for COVID at delivery, there were no positive cases among in-person exercisers during the study period nor was there transmission. This supports that pregnant women can safely be trained during the pandemic in-person without transmission. Thus, PPE protocols for in-person exercising is safe and enables pregnant women to continue to be benefit from exercise throughout the course of their gestation.

4.3 Strengths and Limitations

The present study has several strengths. First, to our knowledge, this is the first study to compare the effectiveness of an in-person vs at-home exercise intervention on maternal cardiovascular and birth outcomes in pregnant women. Our findings add to the scientific literature for exercise in pregnancy, thus supporting that participating in-person may be more beneficial for modulating maternal cardiovascular measures across pregnancy compared to exercising at-home. Importantly, although one participant tested COVID positive at delivery, there was no transmission between participants or study staff. This suggests the present study implemented effective precautions to prevent the spread of COVID-19 and created a safe environment for pregnant women to participate in supervised physical activity.

Despite our strengths, we recognize our study has limitations. Despite the small sample size and being slightly underpowered for this secondary analysis, we did observe significant differences between groups. Second, we did not control for the perceived stress level experienced by participants during their study involvement, which may have influenced their choice of at-home or in-person group allocation as well as our outcome measures; although their choice of exercise location presents a bias in the data, we also understand that this would help attenuate their stress levels by allowing them control over their environment during the uncertainty of COVID changes. Due to the increased risk of exposure with aerosol, the treadmill test could not be completed for every participant within the study and thus, baseline cardiorespiratory fitness levels were not obtained; though, we do not know if there are baseline differences between groups, the resting heart rate between groups was not different suggesting they may have had similar fitness levels prior to staring the intervention. We acknowledge the intervention may have differed between at-home and in-person exercisers due to equipment availability, however, we attempted to counteract this effect by providing similar exercise routines for at-home and in-person exercisers; we also provided resistance bands and similar ideas for both groups to achieve moderate intensity (i.e., body weight, additional circuits, slower repetitions). The at-home group self-reported their exercise session duration, average exercise heart rate and thus may be subject to error. Despite some at-home participants initiating in-person exercise at the of their pregnancy, our data still demonstrated some differences for supervised, in-person; though, this switch may have diluted some of our differences between groups. Though the sample was small, we found differences between groups suggesting the treatment effects is strong, thus providing support for the interpretation of the finding. Lastly, we were not able to report on delivery mode between groups, thus, further research should be done to determine if there are differences in labor and delivery associated with at-home versus in-person exercise training at recommended levels.

4.4 Conclusion

In conclusion, this research confirms the beneficial effect of exercise during pregnancy on maternal and birth outcomes and suggests that supervised exercise may be more advantageous than an at-home program. Additionally, despite one participant testing positive for COVID-19 during the study period, there was no transmission between participants or study staff. Our findings indicate that with proper precautions in place, exercise at-home or in-person is safe for mother and child. Furthermore, supervised exercise may be more beneficial for pregnant women relative to at-home training. Future research should examine how exercise-dose or type could further influence maternal cardiovascular and birth outcomes in women who participate in supervised vs at-home exercise during pregnancy.

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References:

1. Caputo EL, Reichert FF. Studies of physical activity and COVID-19 during the pandemic: A scoping review. *J Phys Act Health*. 2020;17(12):1275-1284. doi:10.1123/jpah.2020-0406
2. Folk AL, Wagner BE, Hahn SL, Larson N, Barr-Anderson DJ, Neumark-Sztainer D. Changes to physical activity during a global pandemic: A mixed methods analysis among a diverse population-based sample of emerging adults in the U.S. *Int J Environ Res Public Health.* 2021;18(7):3674. doi:10.3390/ijerph18073674
3. Stress in AmericaTM 2020: A national mental health crisis. https://www.apa.org. Accessed January 11, 2021. https://www.apa.org/news/press/releases/stress/2020/report-october
4. Preis H, Mahaffey B, Heiselman C, Lobel M. Pandemic-related pregnancy stress and anxiety among women pregnant during the coronavirus disease 2019 pandemic. *Am J Obstet Gynecol Mfm.* 2020;2(3):100155. doi:10.1016/j.ajogmf.2020.100155
5. Parker KM, Smith SA. Aquatic-aerobic exercise as a means of stress reduction during pregnancy. *J Perinat Educ*. 2003;12(1):6-17. doi:10.1891/1058-1243.12.1.6
6. Kołomańska D, Zarawski M, Mazur-Bialy A. Physical activity and depressive disorders in pregnant women—A systematic review. *Medicina (Mex).* 2019;55(5):212. doi:10.3390/medicina55050212
7. Barakat R, Pelaez M, Lopez C, Montejo R, Coteron J. Exercise during pregnancy reduces the rate of cesarean and instrumental deliveries: results of a randomized controlled trial. *J Matern Fetal Neonatal Med.* 2012;25(11):2372-2376. doi:10.3109/14767058.2012.696165
8. May LE, Scholtz SA, Suminski R, Gustafson KM. Aerobic exercise during pregnancy influences infant heart rate variability at one month of age. *Early Hum Dev*. 2014;90(1):33-38. doi:10.1016/j.earlhumdev.2013.11.001
9. Barakat R, Pelaez M, Cordero Y, et al. Exercise during pregnancy protects against hypertension and macrosomia: randomized clinical trial. *Am J Obstet Gynecol*. 2016;214(5):649.e1-649.e8. doi:10.1016/j.ajog.2015.11.039
10. Vargas-Terrones M, Nagpal TS, Barakat R. Impact of exercise during pregnancy on gestational weight gain and birth weight: an overview. *Braz J Phys Ther*. 2019;23(2):164-169. doi:10.1016/j.bjpt.2018.11.012
11. McDonald SM, Isler C, Haven K, et al. Moderate intensity aerobic exercise during pregnancy and 1-month infant morphometry. *Birth Defects Res*. 2021;113(3):238-247. doi:10.1002/bdr2.1671
12. Department of Health and Human Services. Physical activity guidelines for Americans, 2nd edition. Published online 2018:118.
13. American College of Obstetricians and Gynecologists Committee on Obstetric Practice. ACOG Committee Opinion: Physical activity and exercise during pregnancy and the postpartum period. 2020;130(4):11.
14. Moyer C, Livingston J, Fang X, May LE. Influence of exercise mode on pregnancy outcomes: ENHANCED by Mom project. *BMC Pregnancy Childbirth*. 2015;15(1):133. doi:10.1186/s12884-015-0556-6
15. Murphy S, Johnston C, Isler C, Newton E, McDonald S, Strom C, May L.

Influence of Exercise Type on Maternal Blood Pressure Adaptation Throughout Pregnancy. *AJOG Glob Rep*. In print: 2021.

16. Mottola MF, Davenport MH, Brun CR, Inglis SD, Charlesworth S, Sopper MM. VO2peak prediction and exercise prescription for pregnant women. *Med Sci Sports Exerc*. 2006;38(8):1389-1395. doi:10.1249/01.mss.0000228940.09411.9c

17. Swain DP, American College of Sports Medicine. *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription*. 7th ed. Wolters Kluwer Health/Lippincott Williams & Wilkins; 2014.
18. Craemer K, Sampene E, Safdar N, Antony K, Wautlet C. Nutrition and exercise strategies to prevent excessive pregnancy weight gain: A Meta-analysis. *Am J Perinatol Rep*. 2019;09(01):e92-e120. doi:10.1055/s-0039-1683377
19. Petrov Fieril K, Glantz A, Fagevik Olsen M. The efficacy of moderate-to-vigorous resistance exercise during pregnancy: a randomized controlled trial. *Acta Obstet Gynecol Scand*. 2015;94(1):35-42. doi:10.1111/aogs.12525
20. Nascimento S, Surita F, Parpinelli M, Siani S, Pinto e Silva J. The effect of an antenatal physical exercise programme on maternal/perinatal outcomes and quality of life in overweight and obese pregnant women: a randomised clinical trial: Physical exercise in overweight and obese pregnant women. *BJOG Int J Obstet Gynaecol*. 2011;118(12):1455-1463. doi:10.1111/j.1471-0528.2011.03084.x
21. O'Connor PJ, Poudevigne MS, Cress ME, Motl RW, Clapp JF. Safety and efficacy of supervised strength training adopted in pregnancy. *J Phys Act Health*. 2011;8(3):309-320. doi:10.1123/jpah.8.3.309
22. Bisson M, Tremblay F, St-Onge O, et al. Influence of maternal physical activity on infant's body composition. *Pediatr Obes*. 2017;12(S1):38-46. doi:https://doi.org/10.1111/ijpo.12174
23. Haakstad LAH, Edvardsen E, Bø K. Effect of regular exercise on blood pressure in normotensive pregnant women. A randomized controlled trial. *Hypertens Pregnancy*. 2016;35(2):170-180. doi:10.3109/10641955.2015.1122036
24. Garnæs KK, Mørkved S, Salvesen Ø, Moholdt T. Exercise training and weight gain in obese pregnant women: A randomized controlled trial (ETIP Trial). *PLOS Med*. 2016;13(7):e1002079. doi:10.1371/journal.pmed.1002079
25. Turnbull F, Blood Pressure Lowering Treatment Trialists' Collaboration. Effects of different blood-pressure-lowering regimens on major cardiovascular events: results of prospectively-designed overviews of randomised trials. *Lancet Lond Engl*. 2003;362(9395):1527-1535. doi:10.1016/s0140-6736(03)14739-3
26. Badrov M, Stiller-Moldovan C, Dibartolomeo M, Millar P, Mcnevin N, McGowan C. Effects of isometric handgrip training dose on resting blood pressure and resistance vessel endothelial function normotensive women. *Eur J Appl Physiol*. 2013;113. doi:10.1007/s00421-013-2644-5
27. Silva-Jose C, Sánchez-Polán M, Diaz-Blanco Á, Coterón J, Barakat R, Refoyo I. Effectiveness of a virtual exercise program during COVID-19 confinement on blood pressure control in healthy pregnant women. *Front*

Physiol. 2021;12:645136. doi:10.3389/fphys.2021.645136
28. Hui A, Back L, Ludwig S, et al. Lifestyle intervention on diet and exercise reduced excessive gestational weight gain in pregnant women under a randomised controlled trial. *BJOG Int J Obstet Gynaecol*. 2012;119(1):70-77. doi:https://doi.org/10.1111/j.1471-0528.2011.03184.x
29. Berghella V, Saccone G. Exercise in pregnancy! *Am J Obstet Gynecol*. 2017;216(4):335-337. doi:10.1016/j.ajog.2017.01.023
30. Simmons D, Devlieger R, van Assche A, et al. Effect of physical activity and/or healthy eating on GDM risk: The DALI Lifestyle Study. *J Clin Endocrinol Metab*. Published online December 9, 2016:jc.2016-3455. doi:10.1210/jc.2016-3455
31. Dodd JM, Deussen AR, Louise J. A randomised trial to optimise gestational weight gain and improve maternal and infant health outcomes through antenatal dietary, lifestyle and exercise advice: The OPTIMISE Randomised Trial. *Nutrients*. 2019;11(12):2911. doi:10.3390/nu11122911

