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Impact of Early Exercise Interventions on Gestational Weight Gain and Fetal Outcomes: A Randomized Trial

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Abstract: Gestational weight gain (GWG) exceeding recommended guidelines poses significant risks to maternal and fetal health. While exercise interventions during pregnancy have been extensively studied, limited evidence exists regarding their comprehensive impact on both GWG and fetal outcomes. This randomized controlled trial aimed to evaluate the effect of an early, structured exercise program on GWG and fetal outcomes in a diverse cohort of pregnant women. Participants (n=200) were randomized into an intervention group receiving supervised aerobic and resistance training sessions three times weekly from gestational week 12 to 36 and a control group receiving standard antenatal care. Results demonstrated statistically significant reductions in GWG in the intervention group compared to controls (mean \pm SD: 10.4 \pm 2.5 kg vs. 13.1 \pm 3.2 kg; $p < 0.001$). Additionally, the incidence of macrosomia was significantly lower in the intervention group (6% vs. 14%; $p = 0.032$). Neonatal outcomes, including Apgar scores and birth weights, were within healthy ranges in both groups, emphasizing the safety of the intervention.

This study presents novel evidence supporting early exercise interventions in mitigating excessive GWG and improving fetal outcomes. These findings highlight the importance of incorporating structured exercise into routine prenatal care to enhance maternal and neonatal health outcomes.

Keywords: gestational weight gain, exercise intervention, fetal outcomes

Introduction: Gestational weight gain (GWG) is a critical determinant of maternal and neonatal health outcomes. The Institute of Medicine (IOM) provides guidelines for optimal GWG based on pre-pregnancy body mass index (BMI), emphasizing its importance for reducing the risk of adverse pregnancy outcomes such as gestational diabetes mellitus (GDM), preeclampsia, and fetal macrosomia (Rasmussen et al., 2009). However, a significant proportion of pregnant women globally exceed these recommendations, contributing to a rising prevalence of maternal obesity and its associated complications (Lowe et al., 2021). This underscores the need for targeted interventions to optimize GWG and enhance perinatal outcomes.

Recent evidence highlights the potential of exercise interventions during pregnancy to mitigate excessive GWG and improve maternal metabolic health. Structured aerobic and resistance training programs have been shown to reduce the risk of GDM, preterm birth, and postpartum weight retention while promoting favorable fetal growth patterns (Davenport et al., 2022). Despite these benefits, adherence to exercise guidelines during pregnancy remains suboptimal, with many pregnant individuals facing barriers such as misconceptions about exercise safety, lack of access to resources, and time constraints (Mottola et al., 2021).

Emerging data also suggest that the timing of exercise initiation may play a pivotal role in optimizing its benefits. Early pregnancy interventions, particularly those initiated in the first trimester or early second trimester, may have a more pronounced impact on GWG and metabolic adaptations (Goh et al., 2022). Yet, few randomized controlled trials (RCTs) have systematically evaluated the impact of early, structured exercise interventions on GWG and fetal outcomes, leaving a critical gap in the literature. Furthermore, existing studies often lack robust methodological designs, such as adequately powered sample sizes and long-term follow-up, limiting the generalizability of their findings (Ruchat et al., 2022).

The physiological mechanisms underlying the effects of exercise on maternal and fetal health warrant further exploration. Regular physical activity during pregnancy has been associated with improved insulin sensitivity, reduced systemic inflammation, and enhanced placental function, all of which contribute to healthier pregnancy trajectories (Hopkins et al., 2021). Additionally, exercise has been shown to modulate fetal growth by improving uteroplacental blood flow and oxygen delivery, thereby reducing the risk of macrosomia and related complications (Clapp et al.,

2021). These findings underscore the potential for exercise interventions to address multiple dimensions of maternal-fetal health.

Given the rising global burden of maternal obesity and its intergenerational effects, there is an urgent need for innovative strategies to promote healthy GWG. The integration of exercise into routine antenatal care represents a promising approach, yet its implementation remains limited by logistical and cultural barriers. Addressing these challenges requires a nuanced understanding of the factors influencing exercise adherence during pregnancy and the development of tailored interventions that are culturally sensitive and accessible (Poyatos-León et al., 2022).

This study aimed to address these gaps by evaluating the impact of an early, structured exercise intervention on GWG and fetal outcomes in a diverse cohort of pregnant women. By incorporating rigorous methodological approaches and assessing a comprehensive range of maternal and neonatal outcomes, this research seeks to provide robust evidence to inform clinical guidelines and public health strategies. Furthermore, this study contributes novel insights into the timing and mechanisms of exercise benefits during pregnancy, offering a foundation for future research and intervention development.

Methodology

This randomized controlled trial was conducted at Lady willingdon hospital/King Edward medical university from June 2023 to July 2024 to evaluate the effect of an early structured exercise intervention on gestational weight gain (GWG) and fetal outcomes. A total of 200 pregnant women were recruited from antenatal clinics between gestational weeks 8 and 10. Participants were randomly assigned to either an intervention group (n=100) or a control group (n=100) using computer-generated randomization. The intervention group participated in supervised aerobic and resistance training sessions three times weekly from weeks 12 to 36 of gestation, while the control group received standard antenatal care.

The sample size was calculated using Epi Info software, assuming a 5% significance level, 80% power, and an effect size based on previous studies evaluating GWG outcomes. The inclusion criteria were: singleton pregnancy, BMI between 18.5 and 30 kg/m², and absence of medical or obstetric contraindications to exercise. Exclusion criteria included pre-existing diabetes,

hypertension, or any condition limiting physical activity. Verbal and written informed consent were obtained from all participants prior to enrollment.

The intervention included moderate-intensity aerobic exercises such as walking and cycling, combined with resistance training targeting major muscle groups. Each session lasted 60 minutes and was supervised by certified trainers. Adherence was monitored through attendance logs. Data on GWG were collected at baseline and every four weeks until delivery. Fetal outcomes, including birth weight, Apgar scores, and incidence of macrosomia, were recorded at delivery.

Statistical analyses were performed using SPSS software. Continuous variables were compared using t-tests, while categorical outcomes were analyzed using chi-square tests. Statistical significance was set at $p < 0.05$.

Results

Table 1. Demographic and Baseline Characteristics of Participants

Characteristic	Intervention Group (n=100)	Control Group (n=100)	p-value
Age (years, mean \pm SD)	28.5 \pm 3.6	29.1 \pm 4.0	0.423
Pre-pregnancy BMI (kg/m ²)	24.8 \pm 2.6	25.1 \pm 2.9	0.314
Nulliparity (%)	56	58	0.735
Education level (% tertiary)	72	69	0.651
Smoking status (%)	10	12	0.682

Explanation: The demographic data demonstrate no significant differences between groups in baseline characteristics, ensuring comparability and minimizing confounding variables.

Table 2. Comparison of Gestational Weight Gain (GWG) and Neonatal Outcomes

Outcome	Intervention Group (n=100)	Control Group (n=100)	p-value
GWG (kg, mean \pm SD)	10.4 \pm 2.5	13.1 \pm 3.2	<0.001
Incidence of macrosomia (%)	6	14	0.032

Neonatal birth weight (g, mean \pm SD)	3205 \pm 435	3310 \pm 455	0.291
5-minute Apgar score (≥ 8 , %)	98	97	0.730

Explanation: The intervention group exhibited significantly reduced GWG and lower incidence of macrosomia. Other neonatal outcomes, such as birth weight and Apgar scores, were within normal ranges for both groups, underscoring the safety and efficacy of the intervention.

Table 3. Adherence to Exercise Intervention and Maternal Metabolic Outcomes

Parameter	Intervention Group (n=100)	Control Group (n=100)	p-value
Adherence to sessions (%)	85	N/A	N/A
Gestational diabetes incidence (%)	8	16	0.047
Maternal systolic BP (mmHg)	118.4 \pm 8.6	122.1 \pm 9.3	0.021
Maternal diastolic BP (mmHg)	76.2 \pm 6.7	79.4 \pm 7.2	0.018

Explanation: High adherence rates in the intervention group underscore the feasibility of the program. Improved metabolic outcomes, including reduced incidence of gestational diabetes and lower blood pressure, indicate additional maternal health benefits of the intervention.

Discussion

Excessive gestational weight gain (GWG) remains a significant public health concern due to its adverse implications for both maternal and fetal outcomes. This randomized controlled trial (RCT) provides robust evidence supporting the role of early, structured exercise interventions in mitigating excessive GWG and improving neonatal outcomes. The findings align with contemporary research while addressing gaps in existing literature concerning the timing, adherence, and mechanisms of exercise benefits during pregnancy.

Gestational Weight Gain

Our results demonstrated that the intervention group experienced a significantly lower GWG compared to the control group (-3.7 kg, $p < 0.001$). This reduction is consistent with prior studies highlighting the role of exercise in curbing excessive GWG (Harrison et al., 2023). By

commencing the intervention early (at 12 weeks gestation), this study underscores the importance of timing in optimizing outcomes, corroborating the findings of Luo et al. (2023), which identified the first trimester as a critical window for metabolic adaptation. The structured nature of the program, combining aerobic and resistance exercises, likely contributed to these results by enhancing energy expenditure and maintaining muscle mass, as suggested by Barakat et al. (2022).

Fetal Outcomes

A notable reduction in macrosomia incidence (6% vs. 14%, $p=0.032$) was observed in the intervention group, consistent with findings by Fernandes et al. (2021). Exercise-induced improvements in uteroplacental blood flow and insulin sensitivity may underpin these outcomes, as hypothesized by Hopkins et al. (2021). Importantly, other neonatal parameters, including Apgar scores and birth weight, remained within healthy ranges across both groups, reaffirming the safety of moderate-intensity exercise during pregnancy (May et al., 2023).

Maternal Metabolic Health

The intervention group demonstrated significant reductions in systolic and diastolic blood pressure, alongside a lower incidence of gestational diabetes mellitus (GDM). These findings align with those of Davenport et al. (2022), who reported improved maternal cardiovascular and metabolic profiles following prenatal exercise programs. The physiological mechanisms include enhanced endothelial function and reduced systemic inflammation, as proposed by Nascimento et al. (2022). High adherence rates (85%) highlight the program's feasibility, addressing concerns raised in prior studies regarding exercise barriers during pregnancy (Poyatos-León et al., 2022).

Comparison with Existing Literature

While prior research has extensively documented the benefits of prenatal exercise, our study stands out due to its rigorous design and focus on early intervention. Existing meta-analyses, such as those by Nascimento et al. (2022), emphasize the heterogeneity in intervention timing and modalities, limiting the generalizability of their conclusions. This trial's emphasis on early and structured exercise aligns with emerging consensus but provides more targeted insights into the critical period of gestational weeks 12 to 36.

Strengths and Limitations

The study's strengths include its randomized design, adequately powered sample size, and comprehensive assessment of maternal and neonatal outcomes. The inclusion of diverse participants enhances the generalizability of findings. However, limitations include reliance on self-reported pre-pregnancy BMI, which may introduce recall bias, and the exclusion of participants with higher BMI categories, limiting applicability to obese populations. Future research should explore the scalability of such interventions in real-world settings, including culturally tailored modifications.

Implications for Clinical Practice

These findings underscore the necessity of integrating structured exercise into routine antenatal care. Guidelines should emphasize early initiation and provide specific recommendations regarding frequency, intensity, and type of exercise, as suggested by Mottola et al. (2021). Addressing logistical and cultural barriers to exercise adherence remains a critical priority for healthcare providers and policymakers.

Conclusion

This study provides compelling evidence that early, structured exercise interventions significantly reduce excessive GWG and improve fetal outcomes, particularly the incidence of macrosomia. By addressing critical gaps in the timing and comprehensive evaluation of prenatal exercise, this research advances understanding of its multifaceted benefits. Future studies should focus on the scalability of such interventions and their long-term impact on maternal and child health.

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