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Does Maternal Exercise Program During Pregnancy Affect Infants Development? A Randomized Controlled Trial

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Abstract

This study was designed to determine whether the exercise program during pregnancy would be associated with motor, cognitive and social skills in infants at 1 and 3 months of age, based on standard developmental assessment tools. This study was a randomized controlled trial in which 40 healthy pregnant women were allocated 1:1 to an experimental or a control group. Eligible pregnant women in the experimental group performed 50 minutes structured exercise program, three times per week; those in control group just maintained usual activity and received standard clinical care. Baseline data of mothers were collected at enrolment and their infants were evaluated for gross and fine motor skills, developmental motor quotient, cognitive and social skills at ages of 1 and 3 months by Peabody Development Motor scale, and Ages and Stages Questionnaire. Thirty- six women completed the study. After birth, the significant differences were found for gross motor (p=.026) and personal-social skills (p=.001). Although there was no significant difference between the two groups in terms of fine motor skill (p=.214), developmental motor quotient (p=.149), problem solving skill (p=.207) and communication skill (p=.487), the skills in the infants of the experimental group increased compared to the control group. This trial suggests that exercise during pregnancy may provide an opportunity to develop the offspring's skills. Furthermore, maternal exercise also has long-lasting effects in the next months.

Keywords*:* Exercises, Pregnancy, Developmental Dimensions, Infancy.

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Introduction

The physiologic processes of pregnancy and childbirth can determine the future well-being of mothers and children. Unhealthy habits during pregnancy increases the risk of disease and delays in both the mother and the fetus (Barakat, 2021). The effect of maternal health behaviour on children's development is one of the interesting and important subject in recent years. Accordingly, there are some guidelines which recommend the physical activity in pregnancy and postpartum. Current recommendations suggest that in the absence of medical restrictions, pregnant women should engage in regular physical activity (American College of Obstetricians & Gynecologists, 2015; Barakat, 2021; Kuhrt, Hezelgrave, & Shennan, 2015; LeMoyne, Curnier, St-Jacques, & Ellemberg, 2012). Previous evidences show that maternal activities, such as maternal exercises (Kuhrt et al., 2015; Marlos Rodrigues Domingues et al., 2015) could have the short- and long-term effects on offspring. Although early studies were concerned about the harmful effects of prenatal exercises on the mother and fetal health, latest evidences have not been proven over time and more studies seem to be needed for greater understanding (Marlos Rodrigues Domingues et al., 2015).

Animal models support the effects of maternal physical activities in pregnancy with increase in BDNF (Brain-Derived Neurotrophic Factor) in neonates, which can help improve objective diagnostic memory, short-term memory and spatial learning; as well as increased neurogenesis (Labonte-Lemoyne, Curnier, & Ellemberg, 2017; Robinson & Bucci, 2014). Further, changes in maternal hormone levels including growth hormone (GH) and intrauterine growth factor-1 (IGF-1) (Mcmillan, May, Gaines, Isler, & Kuehn, 2019) consistently affect the function of the hypothalamus-pituitary-adrenal axis, limbic system, the prefrontal cortex, and autonomic nervous system in the offspring (Grace, Bulsara, Robinson, & Hands, 2016). Few studies have examined the association between exercises during pregnancy and cognitive development (Esteban-Cornejo et al., 2016; Robinson & Bucci, 2014), motor development (Clapp, Simonian, Lopez, Appleby-Wineberg, & Harcar-Sevcik, 1998), language development (Jukic et al., 2013), behavioural and emotional development (Clapp, Lopez, & Harcar-Sevcik, 1999), physical and neuromuscular maturation (Labonte-Lemoyne et al., 2017; Marlos R Domingues et al., 2014) . Some of these studies did not show the significant differences in motor indicators (Clapp et al., 2014, 1998), verbal development (Jukic et al., 2013) between active and inactive groups. Some evidences were derived from animal models (Robinson & Bucci, 2014) or had the methodological limitation, so it is necessary to examine effective methodological approaches in the field. Accordingly, the purpose of this study was to determine the effects of maternal prenatal exercise on the infants' development. Based on the previous studies and our findings, we hypothesized that maternal prenatal exercises would have an effect on "motor development" as indexed by gross and fine motor skills and developmental motor quotient scores, "cognitive development” as indexed by problem solving skill and “social development” as indexed by personal-social and communication skills on standardized tests. Moreover, in later months, this developmental promotion might be maintained among the infants, as these modifications are sustainable.

Materials & Methods

Trial Design

This study was a parallel-group randomized controlled trial (RCT) to investigate the effects of structured exercise program (SEP) during pregnancy on cognitive, motor, and social development of infants. The population were pregnant women who referred to health care centres and hospitals of Bojnourd, North Khorasan province, Iran between 2016 and 2017. The study was approved by the Medical and Health Research Ethics of North Khorasan University of Medical Sciences and registered in IRCT.ir (IRCT2017050133743N1) and was in accordance with the Helsinki Declaration.

Participants

Nulliparous women, with no history of pre-pregnancy exercise (Haakstad & Bø, 2011) who visited public hospitals and pregnancy care centres with normal pre-pregnancy BMI (20 to 24.9 kg/m2) (Ghodsi & Asltoghiri, 2012) and with gestational age of 23 to 34 weeks (Haakstad & Bø, 2011) were included. These housewives had singleton pregnancy at the term (37-41 weeks) with birth of a healthy baby (without any apparent malformation or preterm birth) (Marlos Rodrigues Domingues et al., 2015). The exclusion criteria were inability to read, history of pregnancy diseases or history of diseases that required hospital stays or follow-up to monitor their conditions (Haakstad & Bø, 2011; Marlos Rodrigues Domingues et al., 2015;). In addition, women were ineligible if they were not able to attend weekly exercise classes (Haakstad & Bø, 2011).

Table 1- Participants' characteristics in the experimental and control groups

Variables	Experimental Group M (SD)	Control Group M (SD)	P
Age (year)	25.7 (3.27)	26.3 (3.9)	.638
Height (cm)	158.6 (3.81)	158.9 (5.30)	.846
Weight (kg)	55.7 (2.93)	56.4 (3.64)	.528
BMI (kg/m^2)	22.2 (1.34)	22.3 (1.12)	.805
SES	19.7 (3.13)	19 (2.24)	.445
AHEMD	23.55 (2.28)	23.80 (2.58)	.758

Note. Variables were scaled and recoded. Missing values were not imputed. All analyses controlled for the mother age, Height, weight, Body Mass Index (BMI) and Socioeconomic Status (SES).

Recruitment, enrolment, and informed consent

Maternal information was received through the Integrated Health System and contacted the mothers via local obstetric clinics. The eligible participants who willing to join in the study were informed of the benefits and risks of participation, and they signed written consent. The basic questionnaires including demographic and socio-economic status were completed through interviews and participants were assigned into the experimental group (EG) and control group (CG). The EG were invited to the SEP. To limit bias, detailed test-protocols were used, and the study personnel performed the assessments in the trial.

Intervention

The SEP were selected based on mothers' abilities and were executable during the second and third trimesters of pregnancy. The EG were supervised twice weekly and invited to complete once weekly at home. The exercise time gradually increased from 35 minutes on the first day to 50 minutes in the last week. The exercise time consisted of two parts; the first part consisted of 5 minutes of warm-up, up to 40 minutes of selected exercises and 5 minutes of cooling down (American College of Obstetricians and Gynecologists, 2015; Tomić et al., 2013). The SEP included moderate-intensity walking (60-75% of the maximal heart rate) (Tomić et al., 2013). During 10 minutes of walking, the heart rate of the participants at different times was checked through the carotid pulse, and the exercise intensity was examined by Talk Test (American College of Obstetricians and Gynecologists, 2015; Hammer, Perkins, & Parr, 2000). Next, 20 minutes of massage (Tomić et al., 2013), relaxation (Haakstad & Bø, 2011) and flexibility training (Marlos Rodrigues Domingues et al., 2015) were performed to gain mental relaxation and reduce tensions. In the second part, 10 minutes of the postural correction was given for better blood circulation and decreasing mothers' fatigue (American College of Obstetricians and Gynecologists, 2015). All pregnant women had standard clinical care. The CG had not participated in any SEP from the beginning of pregnancy to the experiment enrolment.

Outcomes

After collecting the information of mothers (Table 1), their infants were evaluated in developmental dimensions. After delivery, the affordances in the home environment for motor development- infant scale (AHEMD-IS) was used to assess the effect of environmental factors on development in one-to-three-month-old infants. In this questionnaire, four dimensions of physical environment, types of stimuli, and toys for developing gross and fine movements were examined. The AHEMD-IS has both internal reliability (0.99) and internal stability value (0.89) (Caçola, Gabbard, Montebelo, & Santos, 2015). The results showed that the postnatal environmental conditions were similar in the two groups (Table 2). Assessments were undertaken by first author and trained midwives. To measure the dependent variables of a) motor development, b) cognitive development, and

c) social development during the first and third months by researchers, the following scales were used:

Peabody Developmental Motor Scales, Second Edition (PDMS-2): The Peabody Developmental Motor Scales are used to assess the development of motor skills from birth through 5 years. In this study, the gross motor skill (GMS) subscales including reflex, stationary, locomotion, and fine motor skill (FMS) subscales including grasping, and visual-motor integration were used (Folio & Fewell, 2000). Each infant's raw scores were eventually turned into standard scores and Development Motor Quotient (DMQ) (Table 2). found correlation coefficients between the test and the post-test for gross motor scale (0.9987) and for fine motor scale (0.9967) were confirmed by Folio and Fewell as the test developers. Also, the validity of this test was the same as that of the Bayley and West Haverstraw Motor Development tests (Folio & Fewell, 2000).

Ages and Stages Questionnaire (ASQ III): The third version of the Ages and Stages Questionnaire (ASQ) was also used to study the cognitive development" as indexed by problem solving skill and "social development" as indexed by personal-social and communication skills. The ASQ questionnaire is a developmental screening questionnaire which evaluates children in five developmental areas (gross and fine movements, communication, problem-solving, and personal-social area) between one month and 5½ years and captures the developmental status in relation to pre-determined cut-off points (Squires & Bricker, 2009). The questionnaire was completed by parents and supervised by the examiner. The ASQ III has a sensitivity of 0.86 and a characteristic of 0.85, which has adequate screening accuracy. The test-retest reliability was 0.75 and 0.82, and reliability was 0.93 (Squires & Bricker, 2009).

Table 2- Infants Characteristics in 1 and 3 months

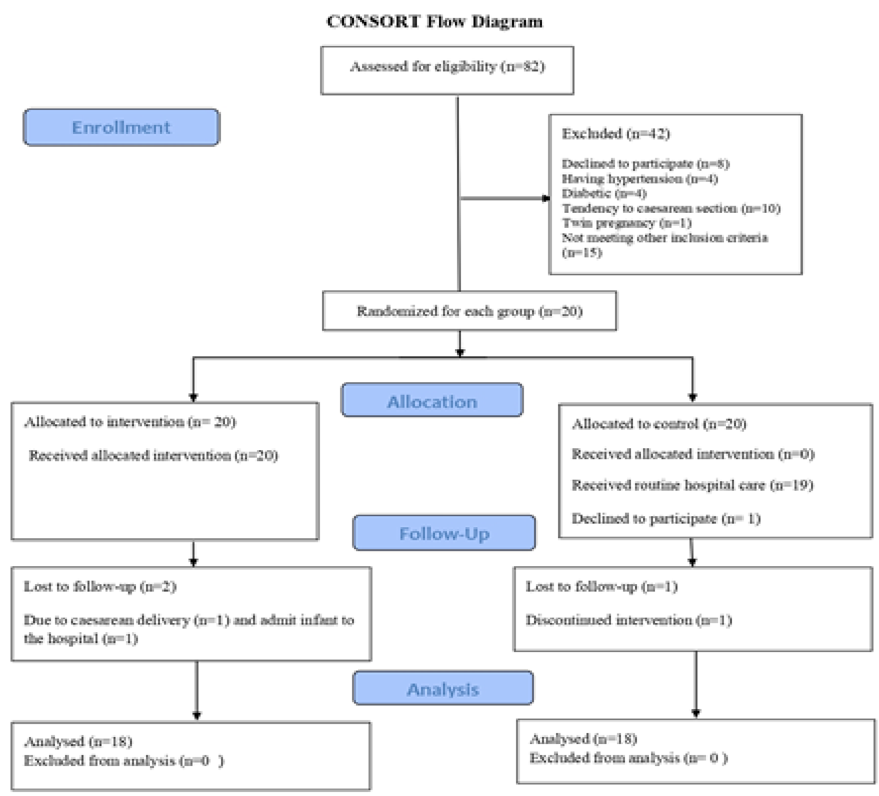
variables	**Experimental Group** ***M(SD)***		**Control Group** ***M(SD)***		**T test (*P*)**	
	1 month	**3 months**	**1 month**	**3 months**	**1month**	**3month**
Communication skill	47.52(6.69)	54.47(6.81)	30.51(10.92)	38.62(7.62)	5.59 (.000)	6.55 (.000)
Problem solving skill	45.27(5.27)	50.83(5.49)	*28.33(8.22)	36.94(6.88)	7.35 (.000)	6.68 (.000)
Personal-social skill	47.50(3.09)	53(4.55)	*34.46(9.32)	44.18(7.21)	5.61 (.001)	4.41 (.001)
Gross motor quotient	109.8(5.39)	112.44(3.43)	91.5(3.76)	92.61(3.44)	12.39 (.001)	16.53 (.001)
Fine motor quotient	105(4.36)	106(3.08)	87(3.08)	89.23(3.42)	14.28 (.000)	15.44 (.000)
Total motor quotient	109(5.04)	110.55(3.51)	88.77(3.33)	90.11(2.74)	14.19 (.000)	19.44 (.000)

Note: *N*= 18 Experimental and control groups are compared at ages 1 and 3 months. * It is close to the cutoff. It is recommended for the learning activities and monitoring. Cutoff point of each domain is personal-social=33.71, Communication=22.77, problem-solving=24.62, Gross Motor= 41.84, Fine Motor=30.16 respectively.

Sample size calculation and Randomization

According to the results of the study by Clapp et al. (1998) regarding the mental scores, exercise group (120 ± 1) and control group (118 ± 1), $\alpha = 0.05$, and power = 80% were calculated to be 16 (Clapp et al., 1998). Based on the results of Clapp et al. (1999) on the orientation behaviour in the exercise group (7.6 ± 0.2) and control group (6.5 ± 0.3), $\alpha = 0.05$ and power =80% was calculated to be 26 (Clapp et al., 1999). Since the sample size was calculated based on the related variables in the previous study which compared the active and inactive women, the final sample size was calculated to be 40. Further, the sample size was confirmed by G-Power software. Also, it assigned participants 1:1 to the EG (n=20) or the CG (n=20), using a computer random number generator. According to the considered criteria, the sample size was reduced to 36 pairs (10%) (Fig.1). Finally, two EG (n=18) and CG (n=18) remained and were compared in developmental variables.

Fig.1



Participation flow chart

Statistical Analysis

Shapiro–Wilk test was run to assess the normality. To determine the effect of the SEP, double assessments during 1 and 3 months were conducted by Repeated Measures Analysis of Variance (RM-ANOVA) 2 (two groups) ×2 (1 and 3 months). Using eta squared ($\eta 2$) as the measure of effect size, the interaction between time and group were accounted for all variables. In addition, independent t-test and paired-t test were used to examine the difference between two groups and the difference within the groups. The level of significance was set to 0.05 and analyses were performed using IBM SPSS Statistics 22 for outcome data.

Results

A total of 82 subjects volunteered to participate in this study from public health care centres and hospitals, the cases who had inclusion criteria were selected (Fig. 1). In Table 1, no statistically significant differences were observed between the two groups of mothers in demographic variables ($p > .05$). Based on the data in Table 2 and the cut-off points of the ASQ III questionnaire, none of the groups had scores lower than cut-off points in the subtests of communication skills, problem-solving skills and personal-social skills. However, the CG required further follow-up in personal-social skills with a cut-off point of 33.71 and in problem-solving with a cut-off point of 24.62 at one month of age. Based on the results of the PDMS-2 test, FMS scores were similar at each follow-up assessment, with no statistically significant difference.

RM-ANOVA of 2 ×2 revealed a significant difference between GMS in time ($F_{(1,34)}$=17.35, p=.001, $\eta 2$ =.338), and group ($F_{(1,34)}$=252.6, p=.001, $\eta 2$ =.881). In addition, there was a significant two-way interaction between time and group ($F_{(1,34)}$=5.45, p=.026, $\eta 2$=.138). Further analysis of the interactive effect indicated that SEP improve the GMS score in EG that were gained in 1 month ($t_{(34)}$ =12.39, p=.001) and continued in 3 months ($t_{(34)}$ =16.63, p=.001); also, paired t-test indicated that the SEP had a more lasting effect in the EG ($t_{(17)}$ =4.25, p=.001) than CG ($t_{(17)}$ =1.41, p=.174). Using $\eta 2$, the interaction between time and group accounted for about 14% of the total variability in the GMS score. In contrast, although the main effects were qualified by time ($F_{(1, 34)}$ =7.77, p=.009, $\eta 2$ =.186) and group ($F_{(1, 34)}$ =280.3, p=.001, $\eta 2$ =.892), FMS did not show significant two-way interaction between time and group ($F_{(1,34)}$=1.60, p=.214, $\eta 2$ = .045). Meanwhile, significant main effect of time ($F_{(1, 34)}$ =14.73, p=.001, $\eta 2$ =.302) and group ($F_{(1, 34)}$ =343.09, p=.001, $\eta 2$ =.910) were found in DMQ, but there was not a significant interaction between time and group ($F_{(1, 34)}$ =2.17, p=.149, $\eta 2$ =.060). Importantly, we found FMS and DMQ scores were lower in the CG but these differences were not significant (p >.05).

In addition, the finding of problem-solving subscale demonstrated that there was a significant main effect of group ($F_{(1, 34)}$ =78.13, p=.001, $\eta 2$ =.697) and time

($F_{(1, 34)}$ =27.55, p=.001, η2 =.448), but significant two-way interaction between group and time ($F_{(1, 34)}$=1.65, p=.207, η2 =.046) did not reveal. It means that the same changes occurred for both groups, as there was no statistically significant difference between them. The results of the communication subscale revealed that although the main effect was found for the group ($F_{(1,34)}$=39.4, p=.001, η2 =.535) and the time ($F_{(1,34)}$=90.13, p=.001, η2 =.726), no significant interaction was observed between the group and the time ($F_{(1,34)}$=0.495, p=.487, η2 =.014). Moreover, the personal-social skill subscale showed the main effect of group ($F_{(1,34)}$=29.53, p=.001, η2 =.465) and time ($F_{(1,34)}$=87.95, p=.001, η2 =.721) and their interactive effect were significant ($F_{(1,34)}$=6.54, p=.015, η2=.161). To clarify the difference between the two groups, independent t-test showed that there is a significant difference between the two groups at the age of 1 month ($t_{(34)}$ =5.611, p=.001) and 3 months ($t_{(34)}$=4.410, p=.001). In addition, paired t-test revealed that the SEP in the EG had a long lasting effect ($t_{(17)}$=6.21, p=.001) than the CG ($t_{(17)}$=7.13, p=.001).

Discussion

Maternal and their offspring's health is a serious public concern. The "developmental origins of health and disease" suggest that the intrauterine environment programs fetal organ/tissue development, projecting a trajectory of diseases and delays in the later life of offspring. Some previous studies have summarized that exercise in women with normal pregnancies also has no adverse effect on fetal heart rate, hyperthermia, neonatal morbidity or mortality (Chen et al., 2021). Notably, they showed that maternal exercise during pregnancy increases the health of children, but the programming impacts of exercise during pregnancy on infant's development is largely unknown. Accordingly, this trial was done and the results demonstrated that there was a significant difference between gross motor skills and personal-social skills among EG and CG. Overall, the results indicate that the SEP may affect the developmental skills in offspring. Although there is little evidence to support these claims, the findings corresponded with some previous studies and found that prenatal exercise promoted the development of motor, social (Clapp et al., 1999, 1998; Mcmillan et al., 2019), mental and cognitive skills (Clapp et al., 1998; Marlos R Domingues et al., 2014) in children. The results emphasize that the acquisition of GMS and FMS is influenced by interpersonal and intrapersonal changes (Piek, Dawson, Smith, & Gasson, 2008) as well as fluctuations in the speed of the emergence of skills (Souza et al., 2010). Similarly, it points out that although the acquisition of motor skills is stable and provides predictions of future conditions, it is not seen much in lower-age groups (Piek et al., 2008; Rosenbaum, 2006). In line with our results, infants of mothers who exercised during pregnancy scored higher on stationary and locomotion skills and on overall gross motor quotient at 1-month relative to infants of mothers who did not exercise during pregnancy (Mcmillan et al., 2019). In contrast, some studies reported that there was no significant difference between the scores of infants' motor skills (Clapp et al., 1998), motor organization and autonomic stability (Clapp et al., 1999) in both active and inactive groups. In addition, the main analysis of a study showed that motor skills did not differ between the active and inactive groups. However, in the subgroup analyses, children in the intervention group had slightly lower motor composite scores on the BSID-III, and boys in the intervention group had lower scores for fine motor skills than those in the control group (Hellenes et al., 2015). Another study found that child development depends on multiple factors in the complex relationship between genetic potential and environment. Regarding motor delay, the psychic risk of the infant was significantly associated with the GMS and FMS of premature and full-term infants. It was evident that good prenatal care, which prevents gestational complications are fundamental factors for the biological health of the infant and act as protective for motor delay. In social and economic terms, mothers who had higher education can better stimulate their child (Bortagarai, Moraes, Pichini, & Souza, 2021). Moreover, age and gender of infants and the mother's knowledge and awareness which is effective on the motivation of the participation, may be the reasons for the difference in the results (Bortagarai et al., 2021; Clapp et al., 1999, 1998; Hellenes et al., 2015).

Moreover, the results of problem-solving skills demonstrated that there is a difference between the two groups, though no statistically significant difference was reported. Along with these results, it was stated that low levels of maternal exercises both before and during pregnancy were associated with an increased risk of abnormal ASQ scores including FMS and problem-solving skills (Nakahara et al., 2021). Similarly, Clapp et al. (1998) stated that there was no significant difference in mental skills scores of infants between two groups (Clapp et al., 1998). It seems that other factors may affect the scores of problem-solving skill such as mother's level of education, SES, environmental stimuli and gender (Marlos R Domingues et al., 2014). Conservesly, some studies have claimed that there is a positive effect of maternal exercise on neurobehavior in newborns. Significant differences were also found in neuromotor skills within similar sexes associated with the exercise intervention (Mcmillan et al., 2019). Future studies should investigate the association between maternal physical activity before and during pregnancy and development in older children. There are several hypotheses on how maternal physical activity before and during pregnancy affects infant neuromotor development and cognitive skills. The first hypothesis states that maternal immune activation alone is sufficient to impart lifelong neuropathology and altered behaviors in offspring (Estes & Mcallister, 2016). Besides, it is mentioned that exercise intervention in pregnant women reduced inflammatory cytokines. Therefore, exercise-training programs could be a strategy to modulate immune responses in pregnant women and their fetuses (Acosta-Manzano et al., 2019). Another hypothesis is that maternal exercise directly affects neurodevelopment in infants. In an experiment with mice and rats, exercise during pregnancy improved neurogenesis in the hippocampus, memory, and learning outcomes (Labonte-Lemoyne et al., 2017; Robinson & Bucci, 2014). From this study, it can be inferred that for humans, exercise during pregnancy may have a beneficial influence on fetal neurodevelopment. And it also assume that maternal activity may stimulate fetal sensory systems, such as vestibular function. As fetal vestibular function develops from early pregnancy (Provasi, Blanc, & Carchon, 2021), maternal exercise may stimulate the fetal vestibular system to positively affect neurodevelopment (Nakahara et al., 2021).

Finally, although there was no statistically significant difference between the two groups in the communication skills, the mean of personal-social skill scores was different. In a trial, the offspring of the active women responded better to environmental stimuli at 5 days after birth (Clapp et al., 1999). In justification, Clapp et al. (1999) expressed that these behaviours are learned during fetal period through the mother's exercise (Clapp et al., 1999). The results of the above study are in line with the personal-social subscale hypotheses. In contrast, a study shows that low levels of maternal physical activity both before and during pregnancy were associated with an increased risk of abnormal ASQ scores in the fine motor skills, problem-solving and personal–social skills (Nakahara et al., 2021). Indeed, there is no association between exercise during pregnancy, motor function, and social skills (Álvarez-Bueno et al., 2018). Other studies have reported that there was an association between maternal exercise and child development but it was also insignificant (Jukic et al., 2013; Marlos R Domingues et al., 2014). Therefore, future studies should assess the effect of maternal execise during pregnancy on development of offspring.

To sum up, a possible explanation for the improvements in infant’s development exposed to maternal exercise could be the release of growth hormone (GH) as well as intrauterine growth factor-1 (IGF-1) (Mcmillan et al., 2019). Indeed, maternal circulating GH and IGF-1 may promote placental function and fetal growth and development (Tung et al., 2012). Moreover, prenatal exercise may impact fetal neuroplasticity, cerebral maturation and efficient nerve system (Labonte-Lemoyne et al., 2017; Nakahara et al., 2021). Cerebral maturation is associated with myelination and motor skills (Labonte-Lemoyne et al., 2017). This RCT is considerable evidence adding the growing body of knowledge to support the positive effects of maternal exercise on infants’ development. Choosing a prospective clinical trial plan, selecting and presenting a SEP and controlling environmental conditions at birth were considered in this study. The research protocol has had some limitations including different lifestyles such as eating habits, maternal postnatal activities and potential bias of the parents for responding the ASQ-III. It is recommended that future studies be conducted reassessing the developmental dimensions at older ages.

In conclusion, the results of this study support that exercise during pregnancy is a safe and beneficial nonpharmaceutical intervention for promoting the infants' developmental skills in a long run. Regarding the importance of this issue and efforts to improve lifestyle during reproduction, further studies are required in this area.

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