THE EFFECTS OF EXERCISE DURING PREGNANCY ON INFANT NEUROMOTOR SKILLS

by

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In 2011-2012, the prevalence of obesity in children 2-19 years was 17% in the United States, and North Carolina was ranked fifth in the nation for childhood obesity. Researchers have attempted to prevent obesity by intervening at various times in a child's life, with limited success. Perhaps the earliest interventions to diminish the prevalence of childhood obesity would be those occurring before birth. Moderate to vigorous aerobic exercise during pregnancy has been shown to contribute to improved cardiovascular health in the offspring. To date research has not investigated the effects of maternal exercise on infants' neurobehavioral status. The purpose of this study was to determine the effects of maternal exercise during pregnancy on the neuromotor development of offspring. We hypothesized that exercise during pregnancy would be associated with improved neuromotor scores in infants at one and six months of age, based on standard pediatric assessment of motor skills and reflexes.

Eighty healthy, pregnant women between 18-35 years were recruited for this study from the Greenville, NC area. Eligible women were assigned to one of three exercise groups or to the control, non-exercise (CTRL) group. Exercise groups performed aerobic exercise, strengthening exercise, or circuit training 3 times per week under supervision, while those in CTRL group maintained usual activity and did not receive an exercise intervention.

Post-delivery, neurodevelopmental exams were performed on the infants at one and six months using the Peabody Developmental Motor Scales, 2nd Edition (PDMS-2) and the Alberta Infant Motor Scales (AIMS). Variables analyzed to determine differences between groups included: AIMS raw score: age ratio, and PDMS-2 subtest percentiles, subtest standard scores, and overall Gross Motor Quotient (GMQ) percentile.

Significant between-group differences were found as infants in exercise groups had higher GMQ than that of infants in CTRL group (Exercise mean 104.7 ± 4.31 vs. CTRL mean 100 ± 4; p=0.03). The GMQ percentile scores were also significantly greater in infants in exercise groups compared to those in CTRL group (Exercise mean=62.1 ± 10.9 vs. CTRL mean=50 ± 10; p=0.03). Stationary percentile scores were significantly greater in infants in exercise groups compared to those in CTRL group (Exercise mean= 49.5 ± 16.0 vs. CTRL mean=31.3 ± 12.5; p=0.02), as were the Stationary standard scores (Exercise mean= 9.9 ± 1.3 vs. CTRL mean= 8.5 ± 1.0; p=0.03). Locomotion percentile scores were significantly greater in infants in exercise groups compared to those in CTRL group (Exercise mean= 59.1 ± 7.5 vs. CTRL mean= 50 ± 10.6; p=0.03), as were Locomotion standard scores (Exercise mean= 10.6± 1.3 vs. CTRL mean= 10 ± 0.8; p=0.04).

The infants in this study appeared to benefit from maternal exercise during pregnancy. Infants with higher neurodevelopmental scores in infancy might be expected to have higher scores at later months as well, which may set them up to be “good movers” and more physically active in childhood and beyond. Furthermore, children who are physically active at an early age will likely continue to lead a physically active lifestyle into adulthood and reduce the risk of becoming overweight or obese.

Background

Obesity is a major health problem in the United States. More than one-third of all adults in the United States are obese, as defined by a body mass index (BMI) of 30 or greater. Furthermore, 17% of US children age 2-19 years old are considered obese, with a BMI at or above the 95th percentile of the gender-specific Center for Disease Control (CDC) BMI-for-age growth charts (Ogden et al. 2014). In a 2009 study titled, "The Burden of Obesity in North Carolina," 19.3% of children in North Carolina were reported to be obese, ranking NC as the fifth highest state in the nation for childhood obesity (NC Division of Public Health 2009). Children are three times more likely to be obese at three years of age if they are obese at one year, and one-half of children who are obese between three to six years of age will continue to be obese into adulthood (Lake 2012). These statistics raise concerns for health problems and risk factors associated with childhood and adult obesity.

The increasing prevalence of overweight and obesity in the United States also brings a prevalence of symptoms related to metabolic syndrome including hypertension, dyslipidemia, and high blood sugar, all precursors of serious conditions such as coronary artery disease, stroke, certain cancers, and Type II diabetes (Holterman 2012). Other physical and psychosocial comorbidities associated with obesity are sleep apnea, asthma, polycystic ovary syndrome (PCOS), low self-esteem, and depression (Holterman 2012). Until recently, all of these medical conditions were considered adult diagnoses. Type II diabetes, for example, was a diagnosis restricted to adults, but in recent years, more and more children are developing insulin resistance and can be diagnosed with Type II diabetes as early as 10 years old (Holterman 2012). In the past ten years, the diagnosis of new onset childhood diabetes increased from 2% to between 25-50% (Rosenbaum 2007). With an earlier diagnosis of Type II diabetes, one can also expect the health problems that accompany the disease (e.g., renal, cardiac, and ocular issues) to follow the child into adulthood unless treated (Holterman, 2012). Recent research studies have found that childhood obesity is a good predictor of increasingly severe obesity in adulthood. A US National Longitudinal Study of Adolescent Health found that 40% of 12-21 year olds classified as obese became or remained obese by 30 years of age. (The et al. 2010).

The alarming rise in childhood obesity cases has created a popular field of research for the prevention of obesity. Researchers are now investigating when interventions should occur to prevent obesity in infants and children. Some believe the intervention should begin while the fetus is still in-utero while others believe the intervention is not necessary until the child begins to develop quickly around age 5 (Clapp 1996, Whitaker 2014, IOM 2011). According to a study by Whitaker et al. (2014), the mean age at which children are first classified as obese is between 5-6 years. A strong recommendation was issued by the Institute of Medicine, which encouraged obesity prevention interventions for children age 0-5 years, stating that during these first five years the dietary and physical activity habits of children are established. These lifestyle habits become difficult to alter after the age of 5 years (IOM, 2011). Skinner et al. (2004) found that a child's BMI at age 2 was a positive predictor of BMI at age 8, and Siervogel et al. (1991) significantly correlated BMI at age 2 to BMI at age 18 (male $r = 0.31$, female $r = 0.22$). Others argue the earliest intervention begins during pregnancy. Clapp (1996) performed a longitudinal study on mothers and their offspring from pregnancy through the children's fifth birthday. The children of mothers who exercised during pregnancy were found to weigh less (18.0 kg±0.5 vs. 19.5 kg±0.6, $p = 0.01$) and had a lower sum of skinfold measures (37 mm vs. 44 mm, $p = 0.01$) compared to children of non-exercising mothers. While both methods described above have shown positive results for early interventions against childhood obesity, the question still remains as to which method is most effective for the prevention of childhood obesity. In summary, there is inconsistent evidence for when intervention aimed at preventing childhood obesity is most effective.

The cardiovascular effects of maternal exercise during pregnancy have been reported by May et al. (2014), who found that one month infants showed increased heart rate variability (HRV) in time and frequency if the mother performed aerobic exercise during pregnancy. Heart rate variability is the variation between intervals of heartbeats that is regulated by the sympathetic and parasympathetic domains of the autonomic nervous system (Xhyheri 2012). An increase in HRV is desirable as low HRV is associated with obesity in adults (Skrapari 2007). Metabolic impairment caused by metabolic syndrome also decreases HRV by damaging the myelin sheath and axon of the neurons, therefore impairing the autonomic nervous system and leaving the heart at greater risk for injury (Xhyheri 2012). May et al.'s (2014) findings suggest that moderate to vigorous aerobic exercise during pregnancy yields positive effects on offspring's cardiac autonomic control that carry on into infancy.

Effects of maternal exercise on other aspects of infant development have also been studied. Clapp (1996) reported that 5 year olds of mothers who exercised while pregnant showed promising trends on the Wechsler Preschool and Primary Scale of Intelligence - Revised (125 ± 2 vs. 116 ± 3) and on oral language tests (119 ± 2 vs. 109 ± 3, $p = 0.01$) compared to those whose mothers did not exercise during pregnancy. In a later study, Clapp (1998), focused on the neurodevelopment of one-year old infants whose mothers exercised while pregnant. It was noted that while the results of the psychomotor portion of the Bayley Scales of Infant Development were not found to be statistically significant (108 ± 1 vs. 101 ± 2, $p= 0.05$), both the exercise and non-exercise infants scored somewhat above the mean in motor performance (Clapp 1998).

Many studies have focused on the effects of exercise during pregnancy on infants' cardiovascular system, morphometric outcome, and later neuromotor development. However, no studies have looked specifically at the effects of maternal exercise on early neuromotor development of infants.

Study Aim

The purpose of this study was to determine the effects of maternal exercise during pregnancy on the early neuromotor development of offspring. We hypothesized that exercise during pregnancy would be associated with higher neuromotor scores in infants at one and six months of age, based on standard pediatric assessment of motor skills and reflexes.

Methods

Participants

Eighty healthy pregnant women from the Greenville, NC area were recruited for this study. Inclusion and exclusion criteria are shown in Table 1. All participants performed a peak maximal aerobic capacity treadmill test at 16 weeks gestation to determine VO_2 max and target heart rate. Afterwards, participants were randomly assigned to one of three exercise groups or the control (CTRL) group. Exercise groups performed aerobic exercise, strengthening exercise, or circuit training three times per week for at least 45 minutes under supervision. Each exercise session was performed at a moderate intensity. Those in CTRL group maintained usual activity with an additional option to participate in light yoga (designed to promote breathing and stretching, not raise the heart rate or build muscle). At 36 weeks gestation, the exercise groups ceased exercising and the control group was no longer offered yoga.

Data Collection

After delivering their babies, the mothers of both the exercise and control groups brought their infants for one and six month neurodevelopmental examinations using two different assessment tools. The first was the Peabody Developmental Motor Scales, 2nd edition (PDMS-2). The PDMS-2 is a standardized, norm-referenced assessment used to measure gross motor skills. For infants up to 12 months of age, the PDMS-2 includes three subtests: Reflexes, Stationary, and Locomotion. Each subtest provides a normalized standard score as well as percentile ranks (comparing infant's behavior to the normative sample). A composite score, the Gross Motor Quotient (GMQ), and a percentile ranking for this overall score, can also be determined (Folio 2000). The second measure used was the Alberta Infant Motor Scales (AIMS), a standardized gross motor assessment tool designed especially for the testing of birth-

18 month infants. The AIMS provides scores for the following categories: Prone, Supine, Sit, and Stand. A total score can be calculated from the four categories to determine the infant's percentile for their age group (Piper 1994). These assessments (PDMS-2 and AIMS) were performed by an experienced pediatric physical therapist during one session which took approximately 20 minutes. Each assessment was then scored according to the standardized protocols.

Data analysis

Between-group differences for PDMS-2 Subtest Standard Scores, PDMS-2 Percentiles, GMQ, GMQ Percentile, and AIMS raw score: age ratio at one month and six months were obtained using Student's t-tests and ANOVAS. The Student's t-tests were used to compare exercising groups vs. non-exercise (CTRL) group. ANOVAs compared differences across all groups. Statistical significance was defined as $\alpha < 0.05$.

Results

Preliminary PDMS-2 data for a subset of infants at one month are reported here. One month AIMS data, and 6 month PDMS-2 and AIMS data are still being collected and analyzed.

Maternal variables

While approximately eighty mothers participated overall, neuromotor assessments were added mid-study, using the PDMS-2, and the AIMS was added later. This report includes data on twenty-one infants' neuromotor testing. Detailed demographics for the maternal participants can be seen in Table 2. Information collected about the mothers included height, pre-pregnancy weight, BMI, number of pregnancies, and number children. It is important to note the pre-pregnancy weight was self-reported by each participant. There were no statistically significant differences between groups in any maternal demographic variables, including education. Six mothers performed moderate to vigorous aerobic exercise, four mothers performed moderate to vigorous circuit training, and seven mothers performed moderate to vigorous muscle strengthening. Four mothers made up the CTRL group that performed yoga, but did not receive an exercise intervention.

Infant variables

Detailed demographics for the infant participants at one month old can be seen in Table 3. Information collected about the infants included gestational age at birth (weeks), height, weight, and BMI.

Infant assessment results

The PDMS-2 overall GMQ and GMQ percentiles for one-month old infants in each group are shown in Table 4. Significant between-group differences were found as infants in exercise groups had higher GMQ scores than infants in CTRL group (Exercise mean = 104.7 ±

4.31, CTRL mean =100 ± 4; p=0.03). The GMQ percentile scores were also significantly greater in infants in exercise groups compared to those in CTRL group (Exercise mean=62.1 ± 10.9 vs. CTRL mean=50 ± 10; p=0.03). Differences among the four exercise groups were noted in the ANOVA, but did not reach statistical significance (p = 0.20).

Table 4 also contains the PDMS-2 Stationary, Reflex, and Locomotion subtest data for both groups. Stationary percentile scores were significantly greater in infants in exercise groups compared to those in CTRL group (Exercise mean= 49.5 ± 16.0 vs. CTRL mean=31.3 ± 12.5; p=0.02), as were the Stationary standard scores (Exercise mean= 9.9 ± 1.3 vs. CTRL mean= 8.5 ± 1.0; p=0.03). Locomotion percentile scores were significantly greater in infants in exercise groups compared to those in CTRL group (Exercise mean= 59.1 ± 7.5 vs. CTRL mean= 50 ± 10.6; p=0.03), as were Locomotion standard scores (Exercise mean= 10.6± 1.3 vs. CTRL mean= 10 ± 0.8; p=0.04).

The PDMS-2 Reflex subtest scores were not significantly different between exercise and CTRL groups.

Discussion

This data offers preliminary support for our hypothesis that infants of mothers who exercised during pregnancy would score higher on neuromotor exams at one and six months than infants of mothers who did not receive an exercise intervention during pregnancy. One-month PDMS-2 scores were higher for infants of mothers in the exercise groups compared to those in the CTRL group. Since there were no significant differences between groups on maternal variables, the only difference was the exercise intervention. Given the health status, prenatal care/attention, etc. of the moms in this study, the infants tested would likely have developed at a healthy, typical rate without any type of exercise interventions as even the CTRL group was above average when compared to other one month olds (in normative group). The fact that infants whose mothers received an exercise intervention scored even higher on neuromotor assessments shows a promising trend for the effect of exercise on the development of the neuromotor system. This along with findings of greater HRV may indicate greater neural maturation in infants if mothers exercised during pregnancy. Infants with higher neurodevelopmental scores in infancy might be expected to have higher scores at later months as well, which may set them up to be "good movers" and more physically active in childhood and beyond.

Limitations

The sample sizes for each group were very small, with the CTRL group having the lowest number of participants. This is partially due to the unwillingness or inability of some mothers to bring their infants back for neuromotor assessments. Another limitation was that some mothers were unable to come in for every exercise session, and therefore did not necessarily exercise three days per week. They were told to perform their exercises or yoga at home and return to the next exercise session as soon as possible, but we have no way of measuring their compliance other than self-report. Thus some infants in the "exercise" groups may not have received the full impact of prenatal exercise. Conversely, those in the CTRL group were told not to add exercise (other than the yoga sessions) to their routine, but they often saw others exercising and thus may have become more active themselves. Either of these scenarios would cause a blurring of the distinction between groups on the variables measured.

Conclusion

The infants in this study appeared to benefit from maternal exercise during pregnancy. If this prenatal maternal exercise continues to positively affect the gross motor skills of offspring, the children are likely to be more physically active. Children who experience neural maturation at a faster rate than children of the same age tend to be better movers, and therefore, it is easier for them to be physically active. The physical activity of children is critical to reduce their risk of pediatric obesity. Furthermore, children who are physically active at an early age will likely continue to lead a physically active lifestyle into adulthood, and again, reduce the risk of becoming overweight or obese.

Data collection and data analysis are continuing for this study. Future research should also include a more substantial control group to increase statistical power and provide a more balanced look at the effects of maternal exercise. These speak volumes and show a promising response to the offspring of mothers who exercise during pregnancy.

Tables

Table 1

Maternal Inclusion Criteria	
1	Age: 18 to 35 years
2	BMI between 18.5 - 34.9
3	Pregnancy: Singleton; between 13-16 wks. gestation (based on ultrasound dating)
4	Health Status: Healthy, no gestational or chronic illness that affects fetal growth
5	Communication: fluent in English, available contact by phone and email
Maternal Exclusion Criteria:	
1	Age: ≤ 17 or ≥ 36 years of age
2	BMI <18.49 or >35
3	Pregnancy: expecting multiples; or ≥16 wks.
4	Health Status: Any gestational (i.e. diabetes, hypertension) or chronic condition (HIV, substance abuse, depression) which may affect fetal development
5	Communication: unable to consent in English; No telephone/email contact
6	Taking medications known to affect fetal development and/or pregnancy outcomes

Table 2: Maternal participant demographics

Maternal Variables	**Control**	**Aerobic**	**Circuit**	**Resistance**
Number	4	6	4	7
Age (years)	30.5 ± 2.4	28.6 ± 4.3	30.8 ± 1.7	29.9 ± 3.4
Height (inches)	63.6 ± 2.4	67.1 ± 2.4	63.7 ± 1.4	64.1 ± 3.3
Pre-Pregnancy Weight (lb)	144.3 ± 16.1	145 ± 13.2	152.3 ± 16.2	167.9 ± 36.3
Pre-Pregnancy BMI	27.2 ± 0.14	25.2 ± 6.5	26.1 ± 3.3	28.6 ± 5.2
# Pregnancy	1.5 ± 0.6	2.2 ± 1.3	1.5 ± 0.6	2.6 ± 1.5
# Children	1.0 ± 0.8	1.0 ± 1.0	1.3 ± 0.5	1.9 ± 1.1

Table 3: Infant participant demographics at one-month

One-Month Variables	**Control**	**Aerobic**	**Circuit**	**Resistance**
Gestational Age (weeks)	38.4 ± 1.6	39.1 ± 1.1	39.7 ± 0.5	38.8 ± 2.2
Height (cm)	53.0 ± 0.1	54.8 ± 3.3	52.5 ± 2.9	52.1 ± 2.8
Weight (lbs)	10.0 ± 0.1	10.0 ± 1.2	8.7 ± 0.9	9.9 ± 2.0
BMI	15.9 ± 0.1	14.3 ± 1.5	14.7 ± 2.2	16.1 ± 3.1

Table 4: t-Test Results

PDMS-2 Subtest/GMQ	Control	Exercise	p-value
GMQ	100 ± 4	104.7 ± 4.3	*0.03*
GMQ Percentile	50 ± 10	62.1 ± 10.9	*0.03*
Stationary Standard Score	8.5 ± 1	9.9 ± 1.3	*0.03*
Stationary Percentile	31.3 ± 12.5	49.5 ± 16.0	*0.02*
Locomotion Standard Score	10 ± 0.8	10.6 ± 1.3	*0.04*
Locomotion Percentile	50 ± 10.6	59.1 ± 7.5	*0.03*
Reflex Standard Score	11.5 ± 0.6	11.6 ± 1.0	0.43
Reflex Percentile	69 ± 6.9	69.3 ± 10.9	0.48

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