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Brief Report

The Impact of Prenatal Yoga on Hip Mobility and Delivery Outcomes

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Abstract

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The purpose of this study was to test the effect of prenatal yoga on hip mobility. The secondary aim was to determine the relationship between hip mobility and additional pregnancy outcomes. Hip mobility (hip internal and external range of motion and hip flexor muscle length), pregnancy symptoms, anxiety (State Trait Anxiety Inventory Survey), and depression (and Perinatal/Postnatal Depression Scale Survey), were measured in pregnant women at baseline. All participants (N=20) were then randomly assigned to an experimental or control group. The intervention was a 6-week prenatal yoga program. At the end of six weeks, all baseline assessments were repeated. After delivery, the participants completed a survey on their birth outcomes. The prenatal yoga intervention did not have an impact on hip mobility, even when controlling for maternal parity. There was a trending negative correlation between hip mobility and gestation age at delivery (r=-0.385, p=0.085). After six weeks of yoga, the intervention group showed an improvement in anxiety (although not statistically significant) with a mean anxiety score of 36.8 (SD = 7.00). In contrast, the control group's score increased slightly to 37.9 (SD = 11.49, [$t(15.3) = 1.71$, p-value = 0.107]. After six weeks of yoga, the intervention group's depression score decreased to 6.1 (SD = 5.74) whereas the control group's score rose to 6.9 (SD = 3.70), [$t(16.8) = 1.26$, p-value = 0.226]; however, these data also did not achieve statistical significance as this pilot study was underpowered to detect differences in outcomes of interest. This study suggests that a larger sample size is needed, and the positive impact of prenatal yoga is worthy of future studies.

Keywords: Prenatal yoga, hip mobility, pregnancy

Introduction

Maternal morbidity and mortality have become a national health crisis, with rates in the United States (U.S.) nearly six times higher than those of other developed nations.[1] While this issue is certainly multifaceted, several key factors contribute to these high rates, including maternal obesity, physical inactivity, and poor mental health.[2] Depression, for example, affects up to 20% of women during pregnancy.[3] Substantial evidence exists that women diagnosed with anxiety, depression, and/or stress during pregnancy have an increased risk for preterm birth, lower neonatal birth weight, and adverse neurodevelopmental outcomes in infants and children.[4] Further research is needed to explore strategies that support maternal mental and physical health.[2]

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In addition to mental health, the adaptation of a pregnant woman's body to her developing fetus affects the function of the endocrine, respiratory, cardiovascular, and musculoskeletal systems.[5] As pregnancy progresses, an anterior shift of the body's center of gravity occurs, leading to alterations in posture such as increased lumbar lordosis and reduced flexibility in the hip flexor muscle group, primarily comprised of the iliopsoas group.[6] These biomechanical changes frequently contribute to lower back pain, with the maximum pain output found in the third trimester.[7]

Clinicians should note that managing maternal mental health, delivery outcomes, and physical pain is essential for improving the perinatal experience. One holistic approach that may address all these areas is prenatal yoga, which has been shown to improve both maternal mental well-being and delivery outcomes.[8] There is substantial evidence supporting the safety and benefits of prenatal yoga. A systematic review highlights improvements in autonomic nervous system function and key labor parameters, such as comfort and pain.[9] Additionally, a study suggests that prenatal yoga interventions were linked to a decreased risk of surgical delivery, a lower risk of premature birth, and healthier neonatal birth weights.[10]

While scientific literature supports the fact that there are many well-established benefits of yoga, the underlying mechanism by which yoga elicits these improvements is unclear. In non-pregnant women, research suggests that yoga enhances quality of life and mental health.[11] However, further research is needed to determine whether prenatal yoga similarly improves hip mobility, potentially contributing to enhanced maternal mental health and improved delivery outcomes.

The purpose of this pilot randomized controlled trial was to determine the impact of prenatal yoga on hip mobility, mental health, and delivery outcomes, as well as the relationships between these variables.

Methods

Participants

This randomized controlled trial investigated the effects of a 6-week prenatal yoga intervention on hip internal and external rotation range of motion (ROM), hip flexor muscle length (assessed using the Thomas Test), mental health (measured using the State Trait Anxiety Inventory, Pregnancy Symptom Inventory, Edinburgh Perinatal/Postnatal Depression Scale), and delivery outcomes (self-reported by patients). This research was approved by Western Kentucky University's Institutional Review Board (WKU#24-188). This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[12]

Participants included pregnant women aged 18 years and older between 12 to 28 weeks of gestation. This gestational period was selected to capture key pregnancy-related musculoskeletal changes, including changes to the spinal curvature and the tilting of the pelvis.[6] The sample size of 20 women was chosen due to feasibility and funding allotment for this pilot study. Previous work suggests that for a pilot study, a sample size as low as 10 people per group can be sufficient.[13] Additionally, this time period would allow women to complete the study before reaching full term. The participants were recruited through flyers at physician offices and at local businesses. Exclusion criteria included those who were not cleared for exercise by an obstetric provider, those who were pregnant with more than one baby, those who had orthopedic limitations prohibiting exercise, and those who had participated in yoga within the last 6 weeks.

Protocol

Ten pregnant women were randomized to the prenatal yoga intervention group utilizing computer-generated randomization. The intervention group's goal was to take at least one prenatal yoga class per week for a total of six weeks. The registered prenatal yoga instructor supervised and monitored the participants to ensure classes were attended during the duration of the intervention. The other ten participants remained in a control group with no prenatal yoga classes over the six weeks.

The prenatal yoga intervention and control groups attended two in-person sessions (one at baseline and one at the end of 6 weeks) for hip mobility testing, assessed by Doctor of Physical Therapy students accompanied by a current licensed Physical Therapist (details included below in Table 1). Baseline demographic data were collected including age, pre-pregnancy and current weight, body mass index (BMI), gestational age, and a variety of socioeconomic and lifestyle factors such as education, marital status, income, and self-reported physical activity.

Following the signing of the informed consent form, participants completed the following surveys: a Demographic Information Survey; the Edinburgh Postnatal Depression Scale (EPDS)[14]; the State-Trait Anxiety Inventory (STAI)[15]; and a Pregnancy Symptom Inventory pain[16]. Each participant was then randomly assigned to either the control or intervention group and completed pre-intervention hip mobility testing. Only the PI in the study knew the allocation of participants in each group by using a random number generator through Google prior to the baseline hip mobility testing. After six weeks, participants completed the same set of surveys and repeated the hip mobility tests. Within two weeks of delivery, participants were sent a delivery outcomes survey.

Hip mobility was assessed at each time point using two different positions to evaluate ROM across the hip joint. To assess hip flexor muscle length via the Thomas Test, participants began at the edge of a mat table and were assisted into a supine position with bilateral hip and knee flexion. One lower extremity was then lowered toward the mat while maintaining greater than 80 degrees of knee flexion, while the opposite leg remained supported in hip and knee flexion of at least 90 degrees using a towel. A goniometer was placed at the lateral hip to measure and record hip mobility. This procedure was then repeated for the opposite limb, with three trials recorded for each lower extremity, alternating to allow for rest breaks[22]. For the seated assessment of hip internal and external rotation ROM, participants began seated at the edge of a mat table with their legs unable to touch the floor and both hips and knees positioned at 90 degrees of flexion, utilizing a towel under the femur to ensure alignment of the lower extremity. Following a demonstration, the participants performed hip internal and external rotation actively while goniometric measurements were recorded. Following the active assessment, the same movements were performed passively by the co-investigator, and additional measurements were taken. The procedure was then repeated on the opposite leg. Three trials for both active and passive internal and external hip rotation were recorded on each side, alternating between legs to allow for a rest period of at least 30 seconds.

Table 1. Assessment Tools

Outcome Variable	Assessment tool	Details	Validity and /or reliability
Depression	*Edinburgh Perinatal/ Postnatal Depression Scale (EPDS)*	· 10-item self-report scale to look at depression during and after birth · Diagnosis of depressive illness was confirmed using the Research Diagnostic Criteria, through Goldberg's Standardized Psychiatric Interview · Sensitive to changes in the severity of depression over time · 5 minutes to complete with a simple scoring method	Diagnosis of depressive illness was confirmed using the Research Diagnostic Criteria, through Goldberg's Standardized Psychiatric Interview[14-16]
Anxiety	*State Trait Anxiety Inventory (STAI)*	· Widely used test to assess anxiety between state anxiety (temporary feelings of nervousness) to trait anxiety (a chronic tendency of anxiety) · The state anxiety portion assesses current feelings, like "I am tense" or "I am calm." · Trait anxiety is looking at responses pertaining to "I worry too much over something that doesn't matter	Demonstrates strong psychometric properties, with high internal consistency (Cronbach's alpha >0.85) and test-retest reliability[16-17]
Pregnancy Symptom Inventory		· Includes 41 items that cover pregnancy-related symptoms (fatigue, incontinence, poor sleep, and back pain) · Developed through a multi-phase process · Takes about 5-7 minutes to complete	High validity score of >70 for most items[18]
Hip Mobility	Hip Flexor Muscle Length: Goniometer with the Thomas Test Hip Internal and External Rotation Range of Motion: Goniometer	· Assesses hip flexor flexibility in a supine position by measuring hip extension of one lower extremity while maintaining > 80 degrees of knee flexion, all while the other leg is held in at least 90 degrees of hip flexion. Used to identify tightness in the iliopsoas and rectus femoris muscles · Hip internal and external rotation assessed in a seated position, both actively and passively, to evaluate joint ROM	Intraclass correlation coefficient (ICC) values typically range between 0.80-0.95 for experienced examiners[29-21]

The prenatal yoga classes were taught by a registered prenatal yoga instructor at Be Happy Yoga and Salt Cave and offered to the participants twice per week. Each class lasted 60 minutes, providing time for a warm-up, yoga poses, and guided relaxation. The sessions were designed to enhance flexibility, strength, and balance while minimizing the discomforts that the participants may have been experiencing. A variety of props were utilized throughout the classes to aid in participants' alignment and to provide additional support. The props included yoga mats, straps, bolsters, and blocks. The instructor integrated a variety of balance poses, static stretches, and dynamic movements which were demonstrated to modify different trimesters. Additionally, the instructor led a 10-to-15-minute guided relaxation at the end of class to encourage the participants to develop awareness of their bodies. These exercises also aimed to prepare the mothers for labor by focusing on controlled breathing and mental relaxation.

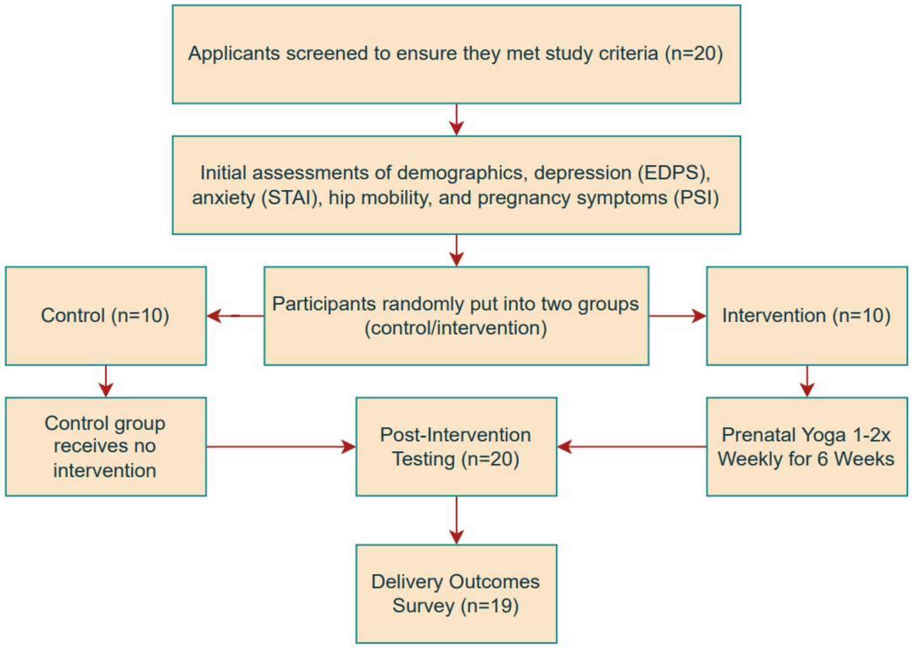

Figure 1. Summary of the study protocol.

Statistical Analysis

Given feasibility constraints, no power calculation was conducted; results are exploratory and hypothesis-generating. Differences in demographic characteristics were assessed using two-sample t-tests or Fisher's Exact tests, as appropriate. For depression scores, anxiety scores, and all hip mobility tests, two-sample t-tests on the change scores were conducted to determine changes from before and after the intervention. Additional covariates were considered in a linear regression setting to improve model fit, but group differences remained insignificant even with adjustments. For hip mobility scores, all post-intervention comparisons were adjusted for pre-intervention values. Two-sample t-tests and Fisher's Exact tests were conducted to determine differences in birth outcomes between groups, as appropriate. Pearson product moment correlation coefficients were used to assess the relationships between hip mobility measurements and pregnancy outcomes, along with 95% confidence intervals. Differences in Pregnancy Symptom Inventory responses were analyzed between groups and over time using repeated-measures ANOVAs.

All model assumptions, including normality, were assessed using visual plots, including residual plots after model fit. Across all analyses, statistical significance was set at $p<0.05$. All analyses were performed using R 4.3.1 (R Foundation for Statistical Computing; Vienna, Austria).

Results

Baseline demographic data are shown in Table 2.

Participant Adherence

Of the prenatal yoga intervention participants, only four completed the full intervention of six to 12 classes over six weeks. An additional four participants attended four to five classes, while two participants attended only three classes. Overall, the mean class attendance was five (SD = 2) sessions.

Prenatal Yoga and Mental Health

Before the prenatal yoga intervention, the intervention group had a mean anxiety score of 43.5 (SD = 13.1) on an 80-point scale, compared to the control group's mean of 37.2 (SD = 8.2). After six weeks of yoga, the intervention group showed an improvement, with a mean anxiety score of 36.8 (SD = 7.0), as illustrated in Figure 1 below. In contrast, the control group's score increased slightly to 37.9 (SD = 11.5). The difference in change scores between the control and intervention groups did not reach significance [$t(15.3) = 1.71$, p-value = 0.107], likely due to the large standard deviations and small sample size.

For depression, the intervention group's pre-intervention average was 8.9±5.2 on a 30-point scale, while the control group had an average score of 6.4±5.6. After six weeks of yoga, the intervention group's score decreased to 6.1±5.7, as seen in Figure 2, whereas the control group's score rose to 6.9±3.7. The difference in change scores between the control and intervention groups did not reach significance [$t(16.8) = 1.26$, p-value = 0.226], likely due to the large standard deviations and small sample size.

Prenatal Yoga and Hip Mobility

Yoga did not significantly change hip mobility compared to controls, but exploratory correlations suggest baseline and post- intervention hip mobility were associated with shorter labor. Table 3 presents right and left hip flexion muscle length outcomes for both the control and intervention groups at pre- and post-intervention timepoints, as well as the change scores for each outcome.

Table 2. Demographic Characteristics of Control and Intervention Participants.

	Control (n=10) **Mean ± SD**	**Intervention (n=10)** **Mean ± SD**	**Hypothesis**	**Test Results**
Age (years)	30.4 ± 3.5	28.2 ± 4.6	$t(18) = 1.20$,	$p = 0.245$
Pre-pregnancy weight (lbs)	176 ± 25	164 ± 48	$t(18) = 0.68$,	$p = 0.503$
Baseline Weight (lbs)	192 ± 29	173 ± 46	$t(18) = 1.09$,	$p = 0.289$
Height (in)	65.4 ± 2.2	65.5 ± 2.6	$t(18) = 0.09$,	$p = 0.927$
Pre-Pregnancy BMI	29.0 ± 3.9	26.9 ± 7.5	$t(18) = 0.78$,	$p = 0.447$
Baseline BMI	31.6 ± 4.4	28.4 ± 7.3	$t(18) = 1.21$,	$p = 0.244$
Gestation (weeks)	21.6 ± 5.3	22.1 ± 5.2	$t(18) = 0.19$,	$p = 0.850$
	Number of Women (%)	**Number of Women (%)**		
First pregnancy	Yes: 1 (10%) No: 9 (90%)	Yes: 6 (60%) No: 4 (40%)	Fisher's Exact	$p = 0.057$
Ethnicity	Caucasian: 8 (80%) Latino: 1 (10%) Asian: 1 (10%) African American: 0 (0%)	Caucasian: 7 (70%) Latino: 1 (10%) Asian: 1 (10%) African American: 1 (10%)	Fisher's Exact	$p = 1$
Education	Some College: 1 (10%) Technical/Trade School: 0 (0%) Associate's degree: 1 (10%) Bachelor's Degree: 4 (40%) Master's Degree: 3 (30%) PhD or Higher: 1 (10%)	Some College: 0 (0%) Technical/Trade School: 1 (10%) Associate's degree: 2 (20%) Bachelor's Degree: 3 (30%) Master's Degree: 2 (20%) PhD or Higher: 2 (20%)	Fisher's Exact	$p = 1$
Marital Status	Single: 1 (10%) Married: 9 (90%)	Single: 2 (20%) Married: 8 (80%)	Fisher's Exact	$p = 1$

Household Income	$20,001 to $40,000: 0 (0%) $40,001 to $60,000: 0 (0%) $60,001 to $80,000: 2 (20%) Greater than $80,001: 8 (80%)	$20,001 to $40,000: 2 (20%) $40,001 to $60,000: 1 (10%) $60,001 to $80,000: 4 (40%) Greater than $80,001: 3 (30%)	Fisher's Exact	$p = 0.095$
Self-report Health Status	Excellent: 1 (10%) Good: 7 (70%) Average: 2 (20%)	Excellent: 3 (30%) Good: 4 (40%) Average: 3 (30%)	Fisher's Exact	$p = 0.500$
Self-reported Physical Activity Frequency (days/ week)	Zero: 0 (0%) One-Two: 8 (80%) Three: 1 (10%) Four-Five: 0 (0%) Six-Seven: 1 (10%)	Zero: 2 (20%) One-Two: 5 (50%) Three: 2 (20%) Four-Five: 1 (10%) Six-Seven: 0 (0%)	Fisher's Exact	$p = 0.359$

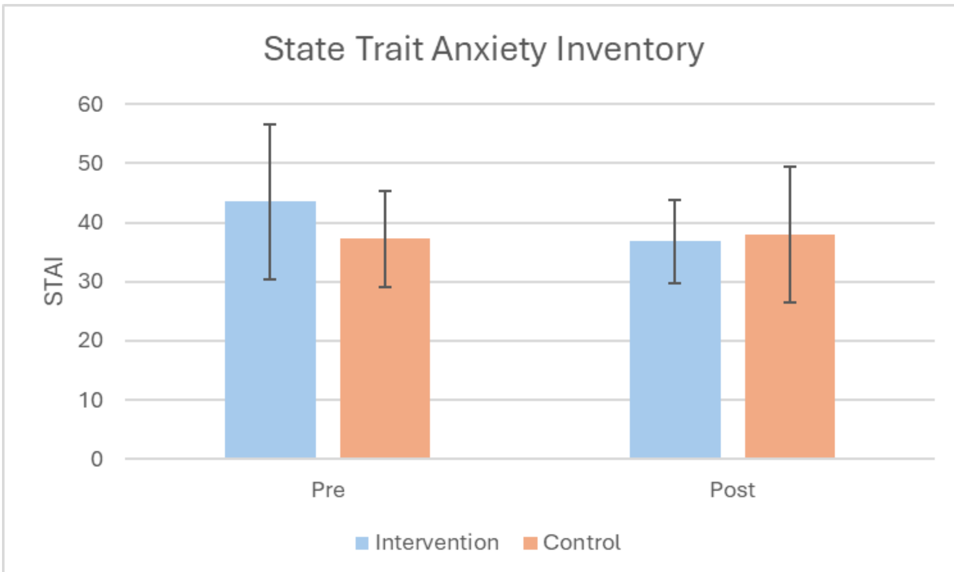

Figure 2. Anxiety scores (STAI) before and after the prenatal yoga Intervention.

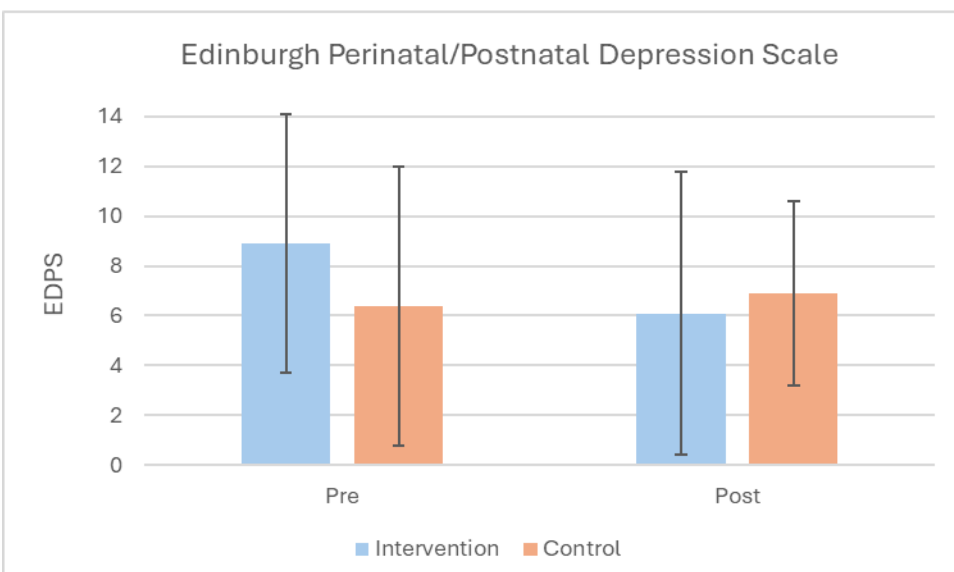

Figure 3. Depression scores (EDPS) before and after the prenatal yoga Intervention.

Table 3. Hip Flexor Muscle Length.

Outcome	Timepoint	Control	Intervention	Hypothesis Test Results
Right Hip Flexor	Pre	-0.3 ± 4.3	1.1 ± 2.3	$t(18) = 0.91$, $p = 0.375$
	Post	4.0 ± 2.5	4.3 ± 2.8	$F(1, 17) < 0.01$, $p = 0.980$#
	Change	4.3 ± 4.6	3.2 ± 2.7	$t(18) = 0.65$, $p = 0.525$
Left Hip Flexor	Pre	2.1 ± 3.1	2.3 ± 1.8	$t(18) = 0.21$, $p = 0.839$
	Post	5.1 ± 2.8	4.3 ± 3.1	$F(1, 17) = 0.44$, $p = 0.518$#
	Change	3.0 ± 4.0	2.0 ± 2.6	$t(18) = 0.69$, $p = 0.500$

– Post-intervention comparisons are adjusted for pre-intervention values.

Prenatal Yoga and Delivery Outcomes

When adjusting for parity and maternal body weight babies born to women in the intervention group had lower birthweight (control: 8.4±0.8 lbs vs. intervention: 6.9±1.0 lbs; $F(1, 15) = 10.94$, $p = 0.005$) and birth length (control: 20.6 ± 0.6 in vs. intervention: 19.3 ±1.2 in; $F(1, 15) = 6.47$, $p = 0.023$) despite being born at similar gestation weeks.

There were no other statistically significant differences between groups in birth outcomes (i.e. induction, mode of delivery, etc…). However, a trend emerged for time in labor as the control group spent 12.1± 6.8 hours in labor vs. only 7.6 ± 5.8 hours in the yoga group ($F(1, 16) = 1.64$, $p = 0.219$) (Table 4).

Table 4. Delivery Outcomes.

Outcome		Control (n = 10)	Intervention (n = 10)	Hypothesis Test Results
Gestational Age at Birth (weeks)		39.0 ± 1.1	39.1 ± 1.0	$F(1, 16) = 0.25$, $p = 0.621$^
Baby Birth Weight (lbs)		8.4 ± 0.8	6.9 ± 1.0	$F(1, 15) = 10.94$, $p = 0.005$*#
Baby Birth Length (in)		20.6 ± 0.6	19.3 ± 1.2	$F(1, 15) = 6.47$, $p = 0.023$*#
Induced	Yes	2 (20%)	5 (56%)	Fisher's Exact $p = 0.170$
	No	8 (80%)	4 (44%)	
Mode of Delivery	C-section	1 (10%)	2 (22%)	Fisher's Exact $p = 0.582$
	Vaginal	9 (90%)	7 (78%)	
Labor Time (hours)		12.1 ± 6.8	7.6 ± 5.8	$F(1, 16) = 1.64$, $p = 0.219$^
Epidural	Yes	7 (70%)	3 (33%)	Fisher's Exact $p = 0.179$
	No	3 (30%)	6 (67%)	
Meds during Labor	Yes	5 (50%)	6 (67%)	Fisher's Exact $p = 0.650$
	No	5 (50%)	3 (33%)	
NICU Baby	Yes	1 (10%)	0 (0%)	Fisher's Exact $p = 1$
	No	9 (90%)	9 (100%)	

#Comparison adjusted for parity and maternal body weight. ^ Comparison adjusted for parity only. *p<0.05.

Relationships between hip mobility and birth outcomes

Passive left external rotation (both pre and post intervention) were negatively correlated with time in labor (pre: r=-0.76 p<0.001; post: r=-0.60, p=0.006); thus, the more passive left external rotation present, the shorter the time in labor. Baseline right passive external rotation was also related to time in labor (r=-0.48, p=0.04). Change in right active internal rotation was also correlated to time in labor (r=-0.47, p=0.04). Taken together, these results suggest that hip mobility may be related to time in labor. Right passive external rotation was related to infant birthweight (r=-0.56, p=0.01), and change in left active internal rotation from pre-to-post intervention was also related to infant birthweight (r=-0.527, p=0.020) (Table 5).

Table 5. Hip Outcomes and Delivery

Hip Outcome	Gestational Age at Birth		Baby Birthweight		Baby Birth Length		Labor Time	
	Correlation (95% CI)	Hypothesis Test Results	Correlation (95% CI)	Hypothesis Test Results	Correlation (95% CI)	Hypothesis Test Results	Correlation (95% CI)	Hypothesis Test Results
Baseline Right Hip Flexor	-0.02 (-0.47 to 0.44)	$t(17) = 0.07$, $p = 0.95$	-0.16 (-0.57 to 0.32)	$t(17) = 0.67$, $p = 0.51$	-0.03 (-0.48 to 0.43)	$t(17) = 0.13$, $p = 0.90$	-0.32 (-0.67 to 0.16)	$t(17) = 1.38$, $p = 0.19$
Baseline Left Hip Flexor	0.09 (-0.38 to 0.52)	$t(17) = 0.38$, $p = 0.71$	-0.09 (-0.52 to 0.38)	$t(17) = 0.37$, $p = 0.71$	0.11 (-0.36 to 0.54)	$t(17) = 0.46$, $p = 0.65$	-0.17 (-0.58 to 0.31)	$t(17) = 0.69$, $p = 0.50$
Baseline Right Active Internal Rotation	0.04 (-0.43 to 0.48)	$t(17) = 0.15$, $p = 0.89$	0.00 (-0.45 to 0.46)	$t(17) = 0.02$, $p = 0.99$	-0.11 (-0.53 to 0.37)	$t(17) = 0.44$, $p = 0.67$	0.31 (-0.16 to 0.67)	$t(17) = 1.37$, $p = 0.19$
Baseline Left Active Internal Rotation	-0.02 (-0.47 to 0.44)	$t(17) = 0.09$, $p = 0.93$	0.28 (-0.20 to 0.65)	$t(17) = 1.22$, $p = 0.24$	0.25 (-0.23 to 0.63)	$t(17) = 1.05$, $p = 0.31$	0.32 (-0.15 to 0.68)	$t(17) = 1.41$, $p = 0.18$
Baseline Right Passive External Rotation	-0.02 (-0.47 to 0.44)	$t(17) = 0.08$, $p = 0.94$	-0.56 (-0.81 to -0.14)	$t(17) = 2.80$, $p = 0.01$*	-0.37 (-0.71 to 0.10)	$t(17) = 1.64$, $p = 0.12$	-0.48 (-0.76 to -0.03)	$t(17) = 2.23$, $p = 0.04$*
Baseline Left Passive External Rotation	-0.13 (-0.55 to 0.34)	$t(17) = 0.54$, $p = 0.60$	-0.28 (-0.65 to 0.20)	$t(17) = 1.21$, $p = 0.24$	-0.18 (-0.59 to 0.30)	$t(17) = 0.76$, $p = 0.46$	-0.76 (-0.90 to -0.47)	$t(17) = 4.83$, $p < 0.001$*
Baseline Right Passive Internal Rotation	-0.06 (-0.50 to 0.41)	$t(17) = 0.25$, $p = 0.81$	-0.03 (-0.48 to 0.43)	$t(17) = 0.14$, $p = 0.89$	-0.20 (-0.60 to 0.28)	$t(17) = 0.85$, $p = 0.41$	0.14 (-0.34 to 0.56)	$t(17) = 0.57$, $p = 0.57$
Baseline Left Passive Internal Rotation	0.16 (-0.32 to 0.57)	$t(17) = 0.65$, $p = 0.52$	-0.07 (-0.51 to 0.40)	$t(17) = 0.29$, $p = 0.78$	-0.27 (-0.64 to 0.21)	$t(17) = 1.14$, $p = 0.27$	0.45 (0.00 to 0.75)	$t(17) = 2.10$, $p = 0.051$
Post Intervention Right Hip Flexor	-0.37 (-0.71 to 0.10)	$t(17) = 1.66$, $p = 0.12$	-0.18 (-0.58 to 0.30)	$t(17) = 0.73$, $p = 0.47$	-0.07 (-0.51 to 0.39)	$t(17) = 0.30$, $p = 0.77$	-0.18 (-0.59 to 0.30)	$t(17) = 0.77$, $p = 0.45$
Post Intervention Left Hip Flexor	-0.23 (-0.62 to 0.25)	$t(17) = 0.96$, $p = 0.35$	0.21 (-0.27 to 0.61)	$t(17) = 0.89$, $p = 0.39$	0.17 (-0.31 to 0.58)	$t(17) = 0.71$, $p = 0.48$	-0.24 (-0.63 to 0.24)	$t(17) = 1.02$, $p = 0.32$
Post Intervention Right Active External Rotation	0.04 (-0.42 to 0.49)	$t(17) = 0.18$, $p = 0.86$	-0.34 (-0.69 to 0.14)	$t(17) = 1.48$, $p = 0.16$	-0.13 (-0.55 to 0.35)	$t(17) = 0.52$, $p = 0.61$	-0.17 (-0.58 to 0.31)	$t(17) = 0.69$, $p = 0.50$
Post Intervention Left Active External Rotation	-0.10 (-0.53 to 0.37)	$t(17) = 0.40$, $p = 0.70$	-0.34 (-0.69 to 0.13)	$t(17) = 1.50$, $p = 0.15$	-0.07 (-0.51 to 0.39)	$t(17) = 0.31$, $p = 0.76$	-0.40 (-0.73 to 0.06)	$t(17) = 1.82$, $p = 0.09$
Post Intervention Right Active Internal Rotation	0.12 (-0.36 to 0.54)	$t(17) = 0.49$, $p = 0.63$	0.03 (-0.43 to 0.48)	$t(17) = 0.12$, $p = 0.91$	-0.17 (-0.58 to 0.31)	$t(17) = 0.70$, $p = 0.49$	-0.02 (-0.47 to 0.44)	$t(17) = 0.09$, $p = 0.93$
Post Intervention Left Active Internal Rotation	-0.12 (-0.55 to 0.35)	$t(17) = 0.51$, $p = 0.62$	0.06 (-0.41 to 0.50)	$t(17) = 0.23$, $p = 0.82$	-0.07 (-0.51 to 0.40)	$t(17) = 0.29$, $p = 0.77$	0.13 (-0.34 to 0.55)	$t(17) = 0.55$, $p = 0.59$
Post Intervention Right Passive External Rotation	-0.08 (-0.52 to 0.39)	$t(17) = 0.34$, $p = 0.74$	-0.35 (-0.70 to 0.12)	$t(17) = 1.55$, $p = 0.14$	-0.14 (-0.56 to 0.33)	$t(17) = 0.59$, $p = 0.56$	-0.32 (-0.67 to 0.16)	$t(17) = 1.37$, $p = 0.19$

Post Intervention Left Passive External Rotation	-0.18 (-0.59 to 0.30)	$t(17) = 0.76$, $p = 0.46$	-0.14 (-0.56 to 0.33)	$t(17) = 0.59$, $p = 0.56$	-0.22 (-0.62 to 0.26)	$t(17) = 0.95$, $p = 0.35$	-0.60 (-0.83 to -0.21)	$t(17) = 3.13$, $p = 0.01$*
Post Intervention Right Passive Internal Rotation	-0.10 (-0.53 to 0.37)	$t(17) = 0.40$, $p = 0.70$	0.10 (-0.37 to 0.53)	$t(17) = 0.43$, $p = 0.67$	-0.19 (-0.59 to 0.29)	$t(17) = 0.79$, $p = 0.44$	0.19 (-0.29 to 0.59)	$t(17) = 0.79$, $p = 0.44$
Post Intervention Left Passive Internal Rotation	-0.28 (-0.65 to 0.20)	$t(17) = 1.20$, $p = 0.25$	0.15 (-0.33 to 0.56)	$t(17) = 0.61$, $p = 0.55$	0.01 (-0.45 to 0.46)	$t(17) = 0.04$, $p = 0.96$	0.23 (-0.25 to 0.62)	$t(17) = 0.96$, $p = 0.35$

* $p<0.05$

Women who had a vaginal delivery had more changes in right hip flexion from pre to post when compared with those who had a c-section/surgical delivery (vaginal delivery: 4.5 ± 3.4 vs. c-section: -1.0 ± 1.8; $t(17) = 2.67$, $p = 0.007$), irrespective of group (Table 6).

Pregnancy Symptom Inventory

The pregnancy symptom inventory addresses a wide array of pregnancy symptoms, many of which are unlikely to be impacted by prenatal yoga (ex: excessive saliva). For the present study, we focused on analyzing data related to pregnancy symptoms that could be improved or impacted directly by prenatal yoga (Supplementary Table 1).

Fatigue changed significantly over time ($F(1,18)=113.66$, $p<0.001$ (i.e. pregnant women become more tired over the course of 6 weeks)), but was not different between groups ($F(1,18)=0.093$, $p=0.764$). Trends in depression scores are consistent with the patterns noted in Edinberg Postpartum Depression survey ($F(1,18)=3.316$, $p=0.085$). Several other trends were noted; reports of restless legs improved in intervention group but stayed the same in control ($F(1,18)=2.436$, $p=0.136$), and reports of sciatica improved in the yoga group but worsened among controls ($F(1,18)=3.041$, $p=0.098$).

Table 6. Hip Outcomes and Mode of Delivery.

Hip Outcome	**Mode of Delivery**		**Hypothesis**	**Test Results**
	Vaginal (n=16)	**C-section (n=3)**		
Baseline Right Hip Flexor	-0.1 ± 3.2	3.9 ± 2.8	$t(17) = 1.99$,	$p = 0.063$
Baseline Left Hip Flexor	2.1 ± 2.4	2.9 ± 3.5	$t(17) = 0.49$,	$p = 0.628$
Post Intervention Right Hip Flexor	4.4 ± 2.78	2.9 ± 2.0	$t(17) = 0.90$,	$p = 0.383$
Post Intervention Left Hip Flexor	4.9 ± 3.1	3.6 ± 2.3	$t(17) = 0.68$,	$p = 0.506$
Change in Right Hip Flexor	4.5 ± 3.4	-1.0 ± 1.8	$t(17) = 2.67$,	$p = 0.016$*
Change in Left Hip Flexor	2.8 ± 3.5	0.7 ± 2.7	$t(17) = 0.99$,	$p = 0.337$

* $p<0.05$

Discussion

This pilot randomized controlled clinical trial aimed to determine whether a six-week prenatal yoga intervention could improve hip mobility, maternal mental health, and delivery outcomes. A secondary goal was to further evaluate the relationships between hip mobility and other health outcomes. With maternal mortality rates significantly higher in the U.S. than in other developed nations[1], it is important to research accessible interventions that can improve health outcomes for U.S. mothers.

Prenatal Yoga and Mental Health

The results from this six-week trial show that prenatal yoga may contribute to reducing anxiety and depressive symptoms, which may influence maternal and fetal health. These results are consistent with a randomized control trial that found that in a cohort of 102 pregnant women between 13-28 weeks' gestation who practiced yoga (30min sessions, six times per week) and mindfulness experienced reduced prenatal stress, anxiety, and depression. The intervention resulted in decreased perceived stress and an improvement in mental health, such as anxiety and depression.[23] A 2021 meta-analysis by Shuai et al looked at 48 studies and found that mental and physical training, such as relaxation and mind-body exercise, can reduce perinatal depression.[24]

Given the shorter intervention duration and frequency of our study compared with that of previous literature, along with a much smaller sample size, our findings suggest that prenatal yoga can improve mental health and reduce perceived stress for new and expecting mothers, which is consistent with previous literature. The breathing mechanics and pacing of yoga have the potential to activate the parasympathetic nervous system, prompting physical and, subsequently, mental relaxation.[11] This relaxation is key, as a physiologic hallmark of pregnancy is an increase in sympathetic activity, which leads to naturally increased stress on the body. It also stands to reason that this could be a major factor contributing to results from studies such as that of Rakhshani et al finding that high-risk pregnant women were significantly less likely to develop other pregnancy co-morbidities such as pre-eclampsia after a prenatal yoga intervention.[25]

Prenatal Yoga and Hip Mobility

In addition to the mental health benefits observed, changes in hip mobility, such as flexibility and ROM (movements that are essential during labor), were assessed. Prenatal yoga focuses on poses that open the hips such as yogi squats and low and high lunges, which can improve flexibility of the rectus femoris and iliopsoas. These movements may also improve pelvic alignment during pregnancy, contributing to more efficient positioning during labor.[11] Interestingly, participants in our prenatal yoga intervention group demonstrated significantly improved passive hip external rotation ROM in both legs. This improvement in passive external rotation yielded a significant negative correlation with labor time. We hypothesize that the improved external rotation ROM in addition to an increased posterior pelvic tilt that occurs with hip flexion during a traditional supine delivery position could lead to a more open pelvic inlet, allowing for more room for the baby to be delivered without complication.[26] However, this interpretation is speculative without biomechanical data to support the finding, which is an area to consider for future studies. In addition, our findings are inconsistent in connecting hip mobility with labor outcomes; these correlations are exploratory in nature and more work in this area could provide clarity on the relationship (causal or not) between the aforementioned variables.

The literature is limited on prenatal yoga's effect on hip mobility (thus, the rationale for the present study), but one randomized control trial by Luo et al found that a twice-weekly, 70-minute, 16-week yoga intervention could positively affect the balance and flexibility of 40 female college students.[27] While Luo's research looked at non-pregnant women, it demonstrates yoga's impact on lower extremity flexibility (primarily hip flexors and posterior chain musculature (i.e. hip extensors, hamstrings, and lower leg)) in young women of childbearing age.[27] When comparing these findings to those of our study, similar results were noted regarding mobility and flexibility, where the yoga intervention improved hip mobility overall. Even though most of these improvements were not statistically significant, they show a trend that might approach significance if a future trial can be performed with a larger sample.

Additionally, muscle flexibility and joint mobility are not going to have long-lasting changes without a considerable amount of time and consistency, as reflected with standardized recommendations for performing flexibility exercises.[28] Most sources recommend a minimum of two to three days with flexibility exercise for all major muscle groups, and this is simply for maintenance and prevention of loss of ROM.[28] Ideally, individuals would perform stretching exercises five to seven days per week to improve flexibility.[28] Our intervention was not this frequent, due to time and resource constraints of both the study and the pregnant participants, so hip mobility findings might have differed if the frequency and duration of the prenatal yoga intervention was increased, and if our adherence would have been better.

Prenatal Yoga and Delivery Outcomes

While most delivery outcomes did not show statistically significant differences, data such as lower epidural use and higher vaginal delivery rates in the intervention group compared to the control were noted. Similar findings were found in a systematic review that looked at five controlled studies, involving 689 participants highlighted that prenatal yoga was associated with improved autonomic nervous system function, which could contribute to a more calming labor experience for the mother.[11] A randomized controlled trial by Kuder et al suggests that prenatal yoga may reduce the likelihood of cesarean sections, decrease labor pain, and lower the use of epidural analgesia during labor.[29] This supports research by Zhang et al that looked at physical exercise and delivery outcomes, yielding similar results.[30]

Kuder et al conducted a single-blind, randomized, controlled clinical trial with 214 participants comparing yoga to standard obstetric care in pregnancy.[29] The intervention included weekly, 90-minute yoga classes led by a certified prenatal yoga teacher, similar to our 60-minute yoga classes. The results found that the yoga group had fewer cesarean sections and a higher rate of spontaneous vaginal birth. Additionally, the yoga group experienced less pain intensity during labor, although there were no differences in the requests for epidural use.

Although our results did not show statistically significant changes in delivery outcomes, the aforementioned previous literature suggests that so many aspects of labor and delivery can be impacted by physical activity and prenatal yoga interventions.[11, 29, 30] Due to the high variability in physiological presentation of labor between pregnant women, our small sample size could be a large contributor to the lack of significant findings.

An unexpected finding (and one that is unlikely to be explained by prenatal yoga given the sample size) in the present study was that babies born to women in the intervention group had lower birthweight and birth length, even when controlling for maternal BMI. Across all modes of exercise, a meta-analysis suggests that overall, maternal physical activity does not have a direct relationship to infant birthweight.[31] Generally speaking, especially in lieu of the obesity epidemic, the delivery of lighter infants (but not considered small-for-gestation-age) could be beneficial and contribute to a healthier body weight later in life, particularly in girls.[32] Babies born large-for-gestation-age (>90th percentile) or small-for-gestation-age (<10th percentile) are both at risk for future obesity.[32] However, this finding of the present study is challenging to interpret as previous research on prenatal yoga specifically has found women who regularly practice yoga to deliver infants with higher birthweight (albeit within healthy ranges). Infant birthweight and future obesity have a U-shaped curve with the extremes of birthweight posing the greatest risk of obesity in the future.[32] Because of this U-shaped curve, it is difficult to make any interpretations on increases or decreases in birthweight among such a small sample size, when it is unlikely the intervention elicited changes with a clinical impact. However, our findings suggest that it is important for future yoga interventions to carefully evaluate any impact on infant birthweight. This finding (although statistically significant) should be interpreted carefully given the small sample.

Compliance to Prenatal Yoga

A meta-analysis by Shuai et al demonstrated that there were challenges in finding ways to encourage pregnant women to maintain a consistent exercise routine.[24] We experienced a similar hurdle in our study, with only four of the ten participants completing the full prenatal yoga intervention of 12 sessions in the 6-week timeframe. Considering the innumerous changes that each expecting mother is undergoing in all facets of life, future interventions should be tailored in such a way that they are practical, accessible, time-efficient, and effective enough to elicit benefits. One way to accomplish these goals could be to create more digital tools to help with exercise engagement as they report relying heavily on websites and mobiles apps for key sources of exercise information.[33] The fitness world continues to find creative ways to digitize fitness programming that may allow for increased accessibility and compliance.[35] Findings ways to integrate prenatal yoga specifically into digital interventions may be valuable to increase compliance by allowing women to take classes from the comfort of home and on their own timeline. One such app that is evidence-based and contains prenatal yoga and should be considered in future interventions is BumptUp®.[34]

Other Pregnancy Symptoms

The Pregnancy Symptom Inventory suggested improvements in restless legs and sciatica among yoga participants. Kulkarni conducted a study with 100 women having sciatica pain during pregnancy and found that prenatal yoga is a safe and effective option for managing pregnancy-related sciatic pain, which is consistent with our.[37] Similarly, our study suggests prenatal yoga may help with symptoms of restless leg syndrome, and previous work is consistent with this suggesting prenatal yoga shows promise for helping women cope with the symptoms of restless leg syndrome.[38] Given the high levels of fatigue late in pregnancy (in our study and across the literature),[39] anything that can improve sleep for pregnant women is likely to be beneficial to overall maternal and infant health.

This study had several limitations that should be considered when interpreting the findings. First, the small sample size (n=20) of the study made it difficult to establish significant differences between the intervention and control groups. The present study design (small sample with multiple comparisons) increases the risk of Type I errors, which may have occurred (specifically for birth weight and birth length between intervention and control participants). With only 10 participants per arm, baseline imbalance was also a noteworthy limitation (e.g., parity difference approaches significance, which could confound outcomes like delivery mode and labor time). However, a randomized controlled clinical trial was conducted despite limited resources, which is a strength of the project. Another major limitation is participant adherence and intervention "dose", both of which may explain the lack of significant findings. The inconsistency in attendance may have impacted potential for improvements in hip mobility, mental health, and delivery outcomes. Another noteworthy limitation is that delivery outcome data was self-reported, which could lead to recall bias and misclassification. However, pregnant women tend to remember details of delivery and infant outcomes very well as it is a particularly salient time in their life.[40] Future work should consider ways to access verified medical chart data to avoid this limitation.

Another notable limitation is that we did not collect data on gestational weight gain, and thus we were not able to account for this in the analyses. Next, short duration of the six-week intervention may not have been long enough to elicit changes in hip flexor flexibility or overall hip mobility, as well as other labor and delivery outcomes. Finally, interrater reliability testing was not conducted prior to the start of the study; measurement differences between testers could have influenced the findings.

Future research should aim to investigate the connections between hip mobility and prenatal yoga, while attempting to increase participants' adherence to the intervention, potentially through digital and easily accessible strategies. Future work should also continue to involve clinicians (we have two physical therapists on our team) to differentiate statistical significance vs. clinically meaningful changes in outcomes. For example, an increase in flexion of five degrees may not meet statistical significance, but this change could result in clinical changes for the participant (e.g. reductions in pain, improved movement patterns). For results such as these, the clinical perspective is key to interpretation and should be carefully considered for any future studies examining the impact of prenatal yoga on hip mobility.

This pilot study explored the potential impacts of a 6-week prenatal yoga intervention for improving maternal mental health, hip mobility, and delivery outcomes. Although the findings on mental health were not statistically significant, pilot data suggests a potential trend to have a favorable impact on anxiety and depression. Similarly, trends in hip mobility scores suggest that prenatal yoga may play a role in labor, mitigated by changes in hip mobility; thus, future research should be conducted to support this hypothesis. While limitations, such as the small sample size and inconsistent class attendance impacted statistical significance, the positive findings observed suggest the need for longer and larger studies. Overall, our findings provide additional evidence that prenatal yoga may provide positive mental and physical benefits.

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Supplementary Table 1. Pregnancy Symptom Inventory.

	Intervention		*Control*		*Hypothesis Test Results*	
	Pre	**Post**	**Pre**	**Post**	**Change over time across groups**	**Difference between groups**
Fatigue						
Never	0	0	0	0	F(1, 18) = 113.66, p < 0.001*	F(1, 18) = 0.09, p = 0.764
Rarely	3	0	2	0		
Sometimes	7	6	7	3		
Often	0	4	1	7		
Sciatica						
Never	4	4	9	6	F(1, 18) = 0.06, p = 0.806	F(1, 18) = 3.04, p = 0.098
Rarely	1	3	0	3		
Sometimes	3	2	1	0		
Often	2	1	0	1		

Back Pain						
Never	0	0	1	1	F(1, 18) = 0.00, p = 1.000	F(1, 18) = 0.62, p = 0.441
Rarely	2	0	2	2		
Sometimes	5	8	5	6		
Often	3	2	2	1		
Constipation						
Never	4	4	2	4	F(1, 18) = 2.32, p = 0.145	F(1, 18) = 0.09, p = 0.764
Rarely	0	3	5	2		
Sometimes	5	2	2	4		
Often	1	1	1	0		
Nausea						
Never	4	4	3	3	F(1, 18) = 3.77, p = 0.068	F(1, 18) = 0.03, p = 0.862
Rarely	1	5	1	5		
Sometimes	2	2	5	2		
Often	3	0	1	0		
Anxiety						
Never	1	0	0	1	F(1, 18) = 1.11, p = 0.307	F(1, 18) = 0.28, p = 0.605
Rarely	4	8	5	5		
Sometimes	2	0	4	2		
Often	3	2	1	2		
Depression						
Never	6	7	7	5	F(1, 18) = 1.69, p = 0.210	F(1, 18) = 3.32, p = 0.085
Rarely	2	1	3	2		
Sometimes	2	2	0	2		
Often	0	0	0	1		
Hip Pain						
Never	0	1	4	3	F(1, 18) = 0.28, p = 0.600	F(1, 18) = 0.03, p = 0.861
Rarely	3	9	0	5		
Sometimes	4	0	5	2		
Often	3	0	1	0		
Restless Legs						
Never	6	9	9	9	F(1, 18) = 0.45, p = 0.512	F(1, 18) = 2.44, p = 0.136
Rarely	0	1	1	1		
Sometimes	2	0	0	0		
Often	2	0	0	0		
Leg Cramps						
Never	2	3	5	5	F(1, 18) = 0.85, p = 0.370	F(1, 18) = 0.21, p = 0.651
Rarely	2	2	3	3		
Sometimes	5	5	1	2		
Often	1	0	1	0		
Poor Sleep						
Never	0	0	3	1	F(1, 18) = 0.00, p = 1.000	F(1, 18) = 0.46, p = 0.506
Rarely	1	1	0	2		
Sometimes	3	4	3	4		
Often	6	5	4	3		
Body Image						
Never	2	5	0	2	F(1, 18) = 2.21, p = 0.154	F(1, 18) = 0.55, p = 0.466
Rarely	2	2	2	2		
Sometimes	4	1	8	4		
Often	2	2	0	2		

All data reported as number of participants; *p<0.05