Orthopaedic Section of the APTA
Grant Program
Final Report Form

Date: 7/1/18
Name of Investigators: Jennifer Bagwell, Julie Peterson, Joanne Smith
Name of Grant: Lower Extremity Joint Loading and Trunk and Lower Extremity Muscle Activation Adaptation during Gait in Pregnant, Post-partum, and Control Participants
Award Period: 5/4/2016 to 5/3/2018
The final report is due no later than 60 days after the end of the award date.

1. Briefly summarize major accomplishments of this project (2-4 pages)

Summary of data collection and analysis progress

The overall purpose of this project was to determine neuromuscular adaptations in trunk kinematics and in trunk and lower extremity (LE) joint loading during gait in pregnant, post-partum, and nulliparous females. Specifically, this objective supports the APTA orthopedic section objective of **identifying biomechanical mechanisms of injury to facilitate the development of improved, evidence-based orthopedic evaluation, intervention, and injury prevention techniques.** Funding from this grant supported the collection and analysis of data from females in the second and third trimesters of pregnancy and of matched, nulliparous females to serve as a "control" group. We met our timeframe of successfully recruiting and testing 23 pregnant participants in the second trimester (24 were recruited, but one withdrew due to medical complications during the first data collection). Twenty-two of these females returned for testing during the third trimester of pregnancy (one female declined to participate in third trimester testing due to significant low back pain). We also successfully recruited and tested 23 nulliparous females who were matched to the pregnant participants by age and pre-pregnancy body mass index.

In addition to the procedures which were funded by this grant, funding from another grant was secured to allow for post-partum testing 4-6 months after birth. As of today, 16 of the pregnant participants have returned to repeat testing procedures during the post-partum period. We anticipate the return of another five post-partum participants as they enter the appropriate post-partum testing time-frame, for a total of 21 post-partum testing sessions (91% completion rate). These numbers exceed our anticipated completion rate of 80% among post-partum participants due to the demands of the post-partum period.

The data collected during each testing session included the following: basic patient demographics, reports of orthopedic pain and/or difficulties including numerical pain rating scores, brief medical and pregnancy background, vitals, completion of the International Physical Activity Questionnaire, the Pain Catastrophizing Scale, the Depression Anxiety Stress Scales (DASS-21), and the Quebec Back Pain Disability Scale, several pain provocation tests (including posterior pelvic pain provocation test and active straight leg raise), and completion of biomechanical testing using electromyography and motion analysis. Specifically, walking (purposeful, self-selected and at a set pace of 1.5 m/s), single leg stance with eyes open and eyes closed, and running (self-selected) were performed. Additionally, we recorded data regarding urinary incontinence and nursing status.

Data analysis is ongoing (and post-partum data collections will continue through October or November 2018). Four abstracts from the initial results of this study were submitted to the 2019 combined sections meeting. Two additional abstracts will be submitted to the 2019 World Congress of Physiotherapy. Preparation of manuscripts has begun and is anticipated to continue through 2019. Target journals for the various manuscripts include Gait and Posture, Journal of Clinical Biomechanics, and Journal of Orthopaedic and Sports Physical Therapy.

Summary of primary accomplishments and results to date

The primary results of this research to date are that 1) pregnant females demonstrate increased LE frontal and sagittal plane joint loading during gait and 2) pregnant females who develop low back or posterior pelvic pain later in pregnancy demonstrate decreased utilization of the hip and increased reliance on the ankle early in pregnancy. We are in the process of analyzing the results from the sway characteristics of single limb stance (eyes open and closed) and running mechanics. The specific findings to date and the implications for physical therapy interventions and prevention techniques are delineated below.

1) **Pregnant females demonstrate increased LE frontal and sagittal plane joint loading during gait**

Most previous studies investigating LE joint loading during pregnancy report LE kinetics as normalized to body weight. The primary purpose of most of the previous research was to assess changes related to dynamic stability. While this method is logical when comparing individuals of different masses, it does not accurately reflect changes in joint loading within an individual. To better understand the increasing demand placed on the body during pregnancy, joint moments and power were not normalized to body weight in our analyses. To avoid potential complications related to utilizing non-body weight normalized moments, we matched nulliparous females to pregnant females' pre-pregnancy body mass indices (there were no significant differences between nulliparous females and pregnant females with respect to height or weight as compared to pre-pregnancy weight).

Using these non-body weight normalized forces, we found elevated peak hip abductor and ankle plantarflexor moments during second trimester of pregnancy (78.4$\pm$17.2 vs 67.5$\pm$14.7N; p=0.03 and -107.5$\pm$17.1 vs -95.3$\pm$18.9N; p=0.03) and ankle negative work (-11.8$\pm$3.7 vs -9.2$\pm$3.5J; p=0.02) compared to the nulliparous females. As expected, later in pregnancy, these kinetics remained altered and there were additional increases in frontal plane knee and sagittal plane loading across the LE joints (specifically, increased peak hip abductor (84.6$\pm$21.6 vs 67.5$\pm$14.7N; p<0.01), knee extensor and abductor (-57.9$\pm$17.5 vs -46.0$\pm$16.7N; p=0.02 and 43.7$\pm$12.3 vs 35.9$\pm$9.6N; p=0.02), and ankle dorsiflexor and plantarflexor moments (26.0$\pm$6.2 vs 20.6$\pm$5.2N; p<0.01 and -116.0$\pm$18.8 vs -95.3$\pm$18.7N; p<0.01) and hip, knee, and ankle sagittal positive work (9.5$\pm$2.9 vs 7.7$\pm$2.7J; p=0.03, 17.5$\pm$7.6 vs 13.2$\pm$4.1 J; p=0.02, and 25.7$\pm$7.2 vs 20.8$\pm$5.0J; p=0.01), ankle sagittal negative work (-12.4$\pm$3.6 vs -9.2$\pm$3.5J; p<0.01) and knee and ankle sagittal total work (26.0$\pm$8.9 vs 20.7$\pm$7.0J; p=0.03 and 38.1$\pm$8.7 vs 29.9$\pm$7.5J; p<0.01)) compared to nulliparous females.

LE loading during gait increases early in pregnancy and continues to increase as pregnancy progresses. Concurrently, pregnant females often experience low back, pelvic, and LE pain. It is possible that interventions to increase strength and muscle activation of the trunk and lower extremities may better prepare pregnant females to adapt to increasing joint demands, though this is not currently addressed in standard care of pregnant females.

Interestingly, during the second trimester of pregnancy the percent contribution of the ankle to energy absorption increased and the percent contribution of the hip to energy absorption decreased. However, during third trimester the percent contribution of each of the three LE joints to energy generation, absorption, and total energy were similar to that of the control group. This indicates that early on pregnant participants may alter their strategy to accommodate increasing loads and increased body mass; however, over time pregnant females adapt to these increasing demands and the relative distribution across the LE joints becomes more similar to the nulliparous females.

2) **Pregnant females who develop low back or posterior pelvic pain later in pregnancy demonstrate decreased utilization of the hip and increased reliance on the ankle early in pregnancy**

The Quebec Back Pain Disability Scale (QBPDS) was utilized to assess low back or posterior pelvic pain in our pregnant females. Pregnant participants were classified in the pain (QBPDS $\geq$ 15[6]) or no pain group (QBPDS < 15) based on QBPDS scores during the third trimester of pregnancy. 10 participants met the pain criteria and 13 did not (QBPDS 31$\pm$12 vs 5$\pm$4). During second trimester testing, females in the pain group demonstrated smaller hip flexor moments (46.7$\pm$9.9 vs 64.9$\pm$15.3N; p=<0.01), hip negative and total work (5.4$\pm$1.5 vs -10.3$\pm$6.8J; p=0.04 and 13.7$\pm$3.5 vs 19.4$\pm$7.7J; p=0.02), a smaller percent contribution of the hip to LE negative and total work (23$\pm$6 vs 33$\pm$5%; p<0.01 and 21$\pm$4 vs .25$\pm$3%; p=0.02), greater ankle negative work (-13.3$\pm$3.0 vs -10.6$\pm$3.9J; p=0.04), and a greater percent contribution of the ankle to total work (51$\pm$6 vs 44$\pm$6%; p<0.01) compared to the no pain group. During the third trimester testing, the only kinetic difference was that females with pain demonstrated smaller ankle dorsiflexor moments (22.1$\pm$5.3 vs 28.5$\pm$5.5N; p<0.01).

These data suggest that females who redistribute load to the ankle relative to the hip early in pregnancy may be more likely to develop LB/PPP later in pregnancy. Interestingly, load distribution was similar between groups 3T. This may be attributed to the need for participants to increase loading throughout the LE to accommodate increased body mass. Previous research has linked LBP and hip weakness. It is possible that females who utilize the ankle more than the hip early in pregnancy are more susceptible to LB/PPP as body mass and joint laxity increase. The hip and trunk muscles of these females may be ill equipped to accommodate the changes associated with pregnancy. Future research should investigate whether targeted strengthening programs may better prepare pregnant females to adapt to increasing LE joint loads.

2. Provide a one-paragraph summary of results or abstract suitable for posting on the Orthopaedic Section website.

Background: Low back and posterior pelvic pain (LB/PPP) are common during pregnancy. Few studies have evaluated lower extremity (LE) kinetics in pregnant females and it is unknown if joint loading differs between pregnant females with and without LB/PPP. The purposes of this study were to assess adaptations in LE joint loading during pregnancy and to compare LE joint loading between pregnant females with and without LB/PPP.
Methods: Motion capture and force data were collected on 23 pregnant females and 23 nulliparous females (matched to pregnant females by age and body mass index prior to current pregnancy) during stance phase of walking. Pregnant participants were tested during the second and third trimesters. Pregnant females completed the Quebec Back Pain Disability Scale (QBPDS) and were classified in the pain (QBPDS $\geq$ 15) or no pain group (QBPDS < 15) based on scores collected during third trimester of pregnancy. Independent t-tests were conducted between pregnant females and nulliparous females and between pain and no pain pregnant female groups at both time points.
Results: Compared to nulliparous females, during the second trimester pregnant females demonstrated increased peak hip abductor and ankle plantarflexor moments and increased ankle negative work. Compared to nulliparous females, during the third trimester pregnant females demonstrated increased peak hip abductor, knee extensor and abductor, and ankle dorsiflexor and plantarflexor moments and increased hip, knee, and ankle sagittal positive work, ankle sagittal negative work, and knee and ankle sagittal total work. Ten participants met the

pain criteria and the other 13 did not. During second trimester, pregnant females in the pain group demonstrated smaller hip flexor moments, hip negative and total work, a smaller percent contribution of the hip to LE negative and total work, greater ankle negative work, and a greater percent contribution of the ankle to total work compared to pregnant females who did not develop LB/PPP. During third trimester, females with pain demonstrated smaller ankle dorsiflexor moments as compared to those without LB/PPP.
Discussion: LE loading increases significantly during pregnancy. Currently, standard care for pregnant females does not include strengthening or skilled care to prepare females for these increased demands. These data suggest that females who utilize the ankle more than the hip early in pregnancy may be more likely to develop LB/PPP later in pregnancy. It is possible that the hip and trunk muscles of these females are weaker or are ill equipped to accommodate the changes associated with pregnancy. Future research should investigate whether targeted strengthening programs may better prepare pregnant females to adapt to increasing LE joint loads.

3. Attach a list of your publications published or accepted during the past year, or currently being written. Send reprints when available. List presentations made and abstracts accepted for presentation based on this work. Indicate with an asterisk (*) those publications supported by Orthopaedic Section funding.

PUBLICATIONS IN THE PAST YEAR

1. **Bagwell JJ**, Reynolds N, Walaszek M, Runez H, Lam K, Katsavelis D. Lower extremity joint loading during gait and running is increased during pregnancy. Manuscript in preparation.*
2. **Bagwell JJ**, Reynolds N, Walaszek M, Runez H, Lam K, Katsavelis D. Lower extremity joint load and load distribution during gait differ between pregnant females with and without low back and posterior pelvic pain. Manuscript in preparation.*
3. **Bagwell JJ**, Lam K, Runez H, Reynolds N, Walaszek M, Katsavelis D, Kyvelidou N. Single limb balance times and sway characteristics differ throughout pregnancy. Manuscript in preparation.*
4. **Bagwell JJ**, Powers CM. Persons with cam femoroacetabular impingement exhibit altered sagittal pelvifemoral coordination during weightbearing and non-weightbearing tasks. Manuscript in preparation.
5. **Bagwell JJ,** Ho KY, Powers CM. Finite element analysis of the tibial tuberosity anteromedialization procedure for patella instability. Manuscript in preparation.
6. Bauer LE, Gradoz MC, Grindstaff TL, **Bagwell JJ**. Popliteal angle measurements are more reliable than passive straight leg raise to assess hamstring length. Manuscript in preparation.
7. Grindstaff TL, Palimenia M, Franco M, Anderson D, **Bagwell JJ**, Katsavelis D. Optimizing between-session reliability for quadriceps peak torque and rate of torque development measures. Submitted.
8. Chaput M, Palimenia M, Egeland B, Katsavelis D, **Bagwell JJ**, Grindstaff TL. Clinical measures to predict patient function when considering return to sport following ACL reconstruction. Submitted.
9. White AK, Klemetson CJ, Egeland B, Katsavelis D, **Bagwell JJ**, Grindstaff TL. Clinical tests to evaluate the impact of fatigue on hip performance in healthy individuals. *Int J Sports Phys Ther*. In Press.
10. Gradoz MC, Bauer LE, Grindstaff TL, **Bagwell JJ**. Reliability of hip rotation range of motion in supine and seated positions. *J Sport Rehabil*. 2018; 24:1-17.

11. **Bagwell JJ**, Powers CM. Joint stress differences between people with and without cam femoroacetabular impingement during a deep squat task. *Arthroscopy*. 2017; 33(10):1797-1803.

INVITED SPEAKER AT SCIENTIFIC MEETINGS IN THE PAST YEAR

1. **Bagwell JJ**, Powers CM, Weber AE. The problem of femoroacetabular impingement: A theoretical framework to guide clinical practice. *Proceedings of the Combined Sections Meeting of the American Physical Therapy Association*. New Orleans, LA. February 2018.
2. **Bagwell JJ**. Femoroacetabular impingement: An evidence-based approach to rehabilitation. *Proceedings of the Mid-America Athletic Training Association.* Omaha, NE. March 2017.

RESEARCH PRESENTATIONS AT SCIENTIFIC MEETINGS IN THE PAST YEAR

1. **Bagwell JJ**, Lam K, Runez H, Reynolds N, Walaszek M, Katsavelis D, Kyvelidou N. Single limb balance sway characteristics differ throughout pregnancy. Abstract in preparation.*
2. **Bagwell JJ**, Reynolds N, Walaszek M, Runez H, Lam K, Katsavelis D. Lower extremity joint loading is increased during pregnancy. Submitted.*
3. **Bagwell JJ**, Reynolds N, Walaszek M, Runez H, Lam K, Katsavelis D. Lower extremity joint load and load distribution differ between pregnant females with and without low back and posterior pelvic pain. Submitted.*
4. Walaszek M, Lam K, Runez H, Reynolds N, **Bagwell JJ**. Spatiotemporal Characteristics of Walking and Running in Pregnant Females During Second and Third Trimester. Submitted.*
5. Lam K, Runez H, Reynolds N, Walaszek M, **Bagwell JJ**. Single limb balance times with eyes closed differ throughout pregnancy. Submitted.*
6. Katsavelis D, **Bagwell JJ**, Durand L, Clysdale A, Kyvelidou A. The effect of different types of high heel shoes on joint loading and kinematics during walking. Submitted.
7. Anderson D, Farmer B, Turman K, Katsavelis D, **Bagwell JJ**, Grindstaff TL. Limb preference impacts strength and jumping limb symmetry index values following ACL reconstruction. Submitted.
8. McAndrew DP, Farmer B, **Bagwell JJ**, Katsavelis D, Grindstaff TL. Effect if auditory cues on running biomechanics in healthy individuals. Submitted.
9. Klemetson C, Knight E, Farmer B, Katsavelis D, **Bagwell JJ**, Grindstaff TL. Fatigue negatively impacts single leg forward hip performance and biomechanics in individuals with a history of ACL reconstruction. Submitted.
10. Pilsbury L, McHough, **Bagwell JJ**, Furze J. Innovative treatment for children with SMA type I receiving SPINRAZA: a case series. Submitted.
11. Bauer LE, Gradoz MC, Grindstaff TL, **Bagwell JJ**. Reliability of passive straight leg raise vs. passive popliteal angle. *Proceedings of the Combined Sections Meeting of the American Physical Therapy Association*. New Orleans, LA. February 2018.
12. White AK, Klemetson CJ, Egeland B, Katsavelis D, **Bagwell JJ**, Grindstaff TL. Clinical test to evaluate the impact of fatigue on hop performance in healthy individuals. *Proceedings of the Combined Sections Meeting of the American Physical Therapy Association.* New Orleans, LA. February 2018.
13. **Bagwell JJ,** Ho KY, Powers CM. Finite element analysis of the tibial tuberosity osteotomy with anteromedialization procedure for patella instability. *Proceedings of the Annual Meeting of the American Society of Biomechanics*. Boulder, CO. August 2017.

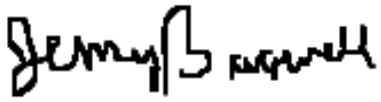
Budget:

4. Provide a budget, using the original approved budget. Indicate total funds spent to date per major categories. If there was > 25% deviation (greater or less spent) of use of funds for any of the budget category, please BRIEFLY indicate the rationale.

	Year 1 Budget	**Year 1 Actual**	**Year 2**	**Year 2 Actual**	
	5/3/16 - 5/3/17		5/3/17 - 5/3/18		
Compensation					
Principal Investigator	$2,015	$2045	$2,000	$1,893.44	
Research Assistant ($15/hr x 270 hrs)	$1,600	$327.50	$2,450	$1,839.75	
Total Compensation	**$3,615**	**$2,372.50**	**$4,450**	**$3,733.19**	
Software					
MATLAB	$500	$124.96	$500	$299.96	
Total Software	**$500**	**$124.96**	**$500**	**$299.96**	**Reduced rate available through Creighton**
Materials & Supplies					
5mm Electrode Collar Packages ($5.85 x 100)	$351	$406.18	$234	$0	
Disposable EMG Electrodes	$200	$550	$200	$240	
Optoreflective Markers and Plates (Full Body Set)	$500	$212.96	$0	$0	
Thigh and Shank Straps ($20 x 4)	$80	$0	$0	$0	
Data Collection Shorts/Tops ($40 x 8)	$320	$317.98	$0	$0	
Miscellaneous Supplies	$200	$185.54	$100	$175.98	
Total Materials	**$1,651**	**$1,672.66**	**$534**	**$315.98**	**Some anticipated supply needs were**

					covered through another grant
Other Expenses					
Participant Compensation ($50 x 75 visits)	$1,750	$550	$2,000	$2,600	
Total Other Expenses	**$1,750**	**$550**	**$2,000**	**$2,600**	**Additional funds spent during this budget year due to fewer subjects than anticipated tested last year**
Total Direct Costs	**$7,516**	**$4,720.13**	**$7,484**	**$6,949.13**	

5. Budget: please send out a final print-out from your institution indicating monies spent per major categories.



7/2/18

Your Signature Date

Return to:
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