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Biomechanical Comparison of Pediatric Female Ballet Dancers With and Without Pain

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BACKGROUND: Across all genres of dance, studies have reported musculoskeletal injury in 20-84% of dancers with 95% reporting a history of musculoskeletal pain. Compared to other dance styles, ballet dancers specifically are most affected by musculoskeletal injuries. The purpose of this study is to compare movement patterns and muscle activity in pediatric female pre-professional dancers with and without self-reported pain, using the Patient-Reported Outcomes Measurement Information System pediatric numeric rating scale. We hypothesize dancers reporting pain will exhibit compensatory strategies, such as asymmetrical movement patterns and muscle activity, across a series of ballet movements.

METHODS: A total of 55 female ballet dancers who train *en pointe* were seen for testing (age 14.4±1.9 years), with 34 dancers (62%) self-reported pain in the 7 days preceding testing. Biomechanical testing, performed in *pointe* shoes, included performance of static (5 classical ballet positions) and dynamic ballet movements (*développé*, *arabesqué* and *grand jeté*) while instrumented with surface electromyography (EMG) to capture muscle activity and inertial measurement (IMU) dual sensors on the trunk and lower extremities to capture movement patterns. The experimental setup allowed for measurement of trunk and lower extremity muscle activity, as well as trunk, hip, knee, and ankle joint angles in the sagittal, coronal, and transverse planes. Student's t-test was used to compare the pain and no pain groups across all variables with statistical significance set to $\alpha=0.05$.

RESULTS: Movement patterns and EMG differences were seen between groups. During first and third positions, the right (non-barre sided) leg demonstrated less external knee rotation in the pain group ($p \leq 0.05$). In fifth position, the left (barre-sided) leg exhibited increased ankle flexion ($p=0.048$), reduced hip abduction ($p=0.027$), and reduced knee adduction ($p=0.026$) in the pain group. The pain group exhibited decreased trunk flexion/extension range of motion during the *grand jeté* ($p=0.004$), and increased trunk rotation range of motion when performing the *arabesqué en pointe* ($p=0.034$). Rectus femoris activation was reduced for the pain group on the left leg in fifth position ($p<0.03$). The up leg in the pain group during the *développé* (flat) showed increased hamstring activation ($p=0.04$).

CONCLUSION: Ballet dancers with pain exhibited differences in movement patterns while performing certain ballet movements, notably during fifth position, *grand jeté*, and *arabesqué* (*en pointe*). Additionally, dancers with pain exhibited reduced rectus femoris activation in fifth position and increased hamstring activation on the working leg during the *développé* (flat). Future work should investigate how movement patterns and muscle activation in ballet dancers vary by location and severity of reported pain.

INTRODUCTION

Approximately 3.5 million children receive specialized dance instruction across an estimated 32,000 private dance schools and studios within the United States.[1] Additionally, 29% of children aged 6-17 years of age participate in dance as an extracurricular activity.[2] Within the sport of dance, musculoskeletal injury has been reported in 20-84% of dancers with 95% reporting a history of musculoskeletal pain.[3-6] Ballet dancers specifically

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are most commonly affected by musculoskeletal injuries compared to other dance styles.[3] Lower extremity injuries vary in dancers, compared to other athletes, due to the repetitive performance demands of leaps and jumps, rotational movements, and skills. These distinct movements involve hip abduction, external rotation, flexion, and extension, which can cause unique axial loading to the trunk and lower extremity. These repetitive movements can lead to injuries including ankle/foot sprains, hip impingement, low back injuries and pain, and subsequent time away from activity.[7,8] Overall, there is a paucity of research looking specifically at the biomechanics of pediatric ballet dancers, specifically quantifying lower extremity movement patterns and muscle activity at peak growth times. However, more work in this area may contribute to the development of effective injury prevention programs geared specifically towards this high-risk population and may help contribute to a more standardized *en pointe* readiness assessment.

In pre-professional, pediatric ballet dancers, the majority of injuries occur within the lower extremity region, ranging from 69-91%, followed by the head, spine, and trunk (5-24%).[9-12] A systematic review found alignment as a common risk factor for lower extremity injury in recreational and elite ballet dancers, with pelvic alignment being more of a risk factor for the elite level dancers compared to spine alignment and scoliosis in the recreational group.[2] More specifically, in recreational ballet dancers, longer training hours and hypermobility of the hips and ankles were found to be additional risk factors for lower extremity injuries, whereas in elite ballet dancers, decreased aerobic fitness, lower-extremity strength, lumbopelvic stability and movement control, and inappropriate transversus abdominus muscle contraction were found to be additional risk factors for lower extremity injury.[2] Data regarding most common injury types are varied across studies, ranging from lower leg overuse, ankle tendinopathy, ankle and foot sprains, mechanical low back pain, knee strain, to stress-related injuries including stress fractures to spine and lower extremity, and posterior ankle impingement.[9] Specifically, overuse injuries from repeated hyperextension and torsion of the spine can result in spondylolysis and spondylolisthesis which have been documented to occur at an increased incidence in dancers presenting with back pain (15-20%), compared to 4% in children and 6% in general adult populations.[9] Within ballet, injury rates have been shown to be much higher in older adolescent girls (age 11-21) compared to younger girls (age ≤10), and history of previous lower limb injuries has been identified as a strong predictor for lower extremity injury in ballet and modern dancers.[9]

Furthermore, young ballet dancers who progress to pointe work without adequate strength, flexibility, proper technique, or years of training may exhibit poorer movement quality that greatly increases their likelihood of experiencing musculoskeletal pain or injury.[13,14] *Pointe* work requires the dancer to transfer their full body weight to the tips of their toes and due to inconsistent *pointe* readiness criteria, dancers often are not physically and mentally prepared for this advancement. Transitioning to dancing ballet *en pointe* generates substantially greater forces through the foot, approximately 12x body weight, compared to only 4x body weight when dancing in flat ballet slippers.[15] It is important for parents, instructors, and physicians to better understand the criteria and screening tests commonly used to determine a dancer's readiness to begin *pointe* work to establish safer and more evidence-based readiness criteria. In addition to providing education to the dance community, there is also a need to better understand movement patterns of young pre-professional ballet dancers with pain and/or prior history of injury to identify injury risk factors that may remain long-term.

Currently, there is limited knowledge pertaining to biomechanical risk factors in pediatric pre-professional ballet dancers who train *en pointe*. This study will provide a better understanding of movement patterns in pediatric ballet dancers and their association with reported pain. Additionally, this effort may impact future development of preventative programs for this population and ultimately may reduce risk of future injury. The purpose of the proposed study is to evaluate and analyze movement patterns and muscle activity in pediatric, female pre-professional ballet dancers with and without self-reported pain across a series of classical ballet movements. These ballet-specific movements include static postures (5 classical ballet

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positions), and low and high impact ballet specific movements (*développé*, *arabesqué* and *grand jeté*) that gradually increase in dynamic range of motion and movement difficulty. We hypothesize dancers reporting pain will exhibit decreased passive range of motion, compensatory strategies to successfully perform static postures, and asymmetrical movement patterns and muscle activity with dynamic tasks compared to dancers with no reported pain.

METHODS

Pediatric female, pre-professional ballet dancers were recruited from local dance studios in North Texas. A cross-sectional study design was used with inclusion criteria requiring dancers to currently train *en pointe* at a pre-professional level for classical ballet and be between 10 and 18 years of age. Dancers self-reported training at a pre-professional level with minimum of 3 years of classical ballet training and were required to be instructed by a classically trained ballet instructor at the time of testing. Dancers were excluded if they experienced a major injury to their spine or lower extremity within the previous six months that required activity restrictions for at least three months, or surgery.

This study was approved by a regional institutional review board and all participants provided informed assent/consent prior to participation. Eligible dancers were seen for a single assessment at their dance studio during scheduled testing sessions. Each dancer was asked to complete a survey capturing demographics, injury history, and dance information, as well as a series of questionnaires from the Patient-Reported Outcomes Measurement Information System (PROMIS) that focus on pain. Dance participation information was collected including, age they began ballet training and *pointe* work, training volume (hours/week, weeks/year), and whether they trained in other dance genres or sport(s). The PROMIS Pediatric Numeric Rating Scale was administered to establish the presence and intensity of pain within the past 7 days and was used to classify dancers into pain (pain ≥ 1) or no pain groups. The pain group was administered additional questionnaires, the PROMIS Pediatric Pain Quality (PPQ) Affective and Sensory, to gauge how the reported pain felt in terms of unpleasantness and intensity, respectively.

Data Collection

The movement assessment was conducted by a single research staff member with 12 years of experience (AE) and included collection of anthropometric measurements and performance of static and dynamic ballet movements. Each dancer was instrumented with Delsys surface electromyography (EMG) and inertial measurement (IMU) dual sensors (Delsys Trigno Wireless, Boston, MA, USA) on the trunk and lower extremities (Figure 1). Specifically, Delsys Avanti sensors, which are a single EMG/IMU dual-sensors (e.g., single muscle), were placed bilaterally on the major lower extremity muscle groups (rectus femoris, hamstring, tibialis anterior, gastrocnemius). Alternatively, Delsys Quattro sensors consist of four EMG electrodes and one IMU sensor, allowing for increased coverage to capture muscle activity data. A single Quattro sensor was positioned on the sacrum (IMU), with the EMG electrodes placed on the gluteus medius and lumbar erector spinae bilaterally (Figure 1). Additionally, three Avanti sensors were placed on the sternum and the dorsum of each foot to evaluate trunk and foot motion (IMU only). The experimental setup allowed for measurement of trunk and lower extremity muscle activity, as well as trunk, hip, knee, and ankle joint angles in the sagittal, coronal, and transverse planes. Functional calibration of the IMU sensors was used to align the sensor reference frame to the segment reference frame according to previously published methods.[16]

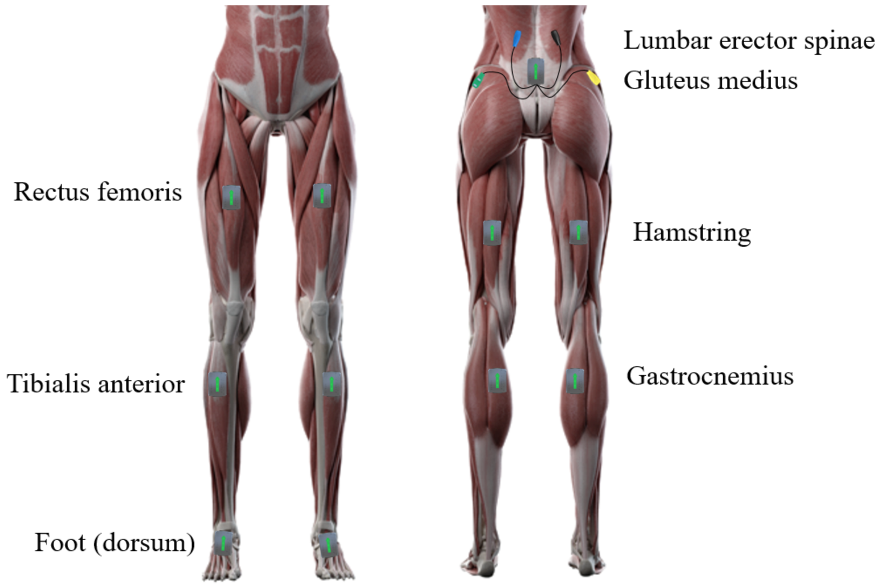

Figure 1. Electromyography (EMG) and inertial measurement (IMU) dual sensor placement. Dual sensors (EMG and IMU): Rectus femoris and tibialis anterior bilaterally; EMG only: Medial hamstrings and gastrocnemius bilaterally; IMU only: foot (dorsum), sternum (not pictured) and sacrum. A single Quattro sensor was placed posteriorly, with IMU collected with the sacrum sensor and 4 EMG leads on lumbar erector spinae and gluteus medius bilaterally

Biomechanical testing included collection of static postures of classical ballet (first through fifth positions), two low-impact dynamic movements (*développé* and *arabesqué*) and one high-impact, dynamic jump (*grand jeté*). A *développé* is a movement from a standing position in which the dancer draws the working leg up to the knee of the stance leg and then extends the knee with the thigh held out to the side, demonstrating muscle control and flexibility. The *arabesqué* requires the dancer to extend the working leg behind her with their weight supported on the stance leg, with both legs held straight in full extension. Lastly, the *grand jeté* is a jump, where the dancer takes off on from one leg and leaps into the air with one leg extended to the front and the opposite leg extended behind, similar to a split in the air and lands on the opposite leg. The *développé* and *arabesqué* were performed with a flat stance foot and repeated *en pointe*. To elicit natural mechanics and environment, dancers were asked to wear their personal *pointe* shoes, and all tasks were performed on a vinyl dance floor (e.g., Marley floor), which is utilized at most dance studios at the dancer's training studio. A single trial was analyzed for each static position and dynamic movement.

Data Analysis

Phases of interest were identified as the entire task for the five static positions (first through fifth; Figure 2), the up phase for the *grand jeté*, *développé* (flat and *en pointe*), and *arabesqué* (flat and *en pointe*) (Table 1). The up phase of the *développé* was defined from initiation of movement to time point of maximum hip flexion of the working leg. Furthermore, the up phase of the *développé* was divided into two sub-phases, from the beginning of the task to the point of max knee flexion (*passé*) and from the position of max knee flexion (*passé*) to full extension of the working leg (Figure 3). For the *arabesqué*, the up phase began with the initiation of movement, through the time point in which the trunk was at maximum forward flexion and the working leg was in maximum extension behind the dancer (Figure 4). The up phase for the *grand jeté* was defined as the period beginning immediately prior to the lead leg leaving the ground to the point of peak hip flexion of the lead leg (Figure 5). Joint angles were calculated from the IMU data as the

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average position during the five static positions, and range of motion for the dynamic tasks during the phases of interest for the working leg. EMG signals were rectified and filtered to compute a linear envelope, and average values were computed for each task. Average EMG data was analyzed during the task/phase of interest and normalized to the maximum activation during the task for dynamic tasks, and to the maximum activation of the stance leg during the *développé en pointe* for the static ballet positions. Given the primary analysis focused on the comparison between the pain and no pain groups across all kinematic and muscle activation variables, student's *t*-tests were used to compare groups with statistical significance set to *a*=0.05.

Table 1. Phases of interest for static positions and dynamic movements

Phase		*Start of Phase*	*End of Phase*
Static Positions			
Entire Task	Average	Once in position	Prior to moving out of position
Développé			
Up Phase	ROM	Initiation of movement	Maximum hip flexion
Up Sub-phase 1	ROM	Initiation of movement	Maximum knee flexion
Up Sub-phase 2	ROM	Maximum knee flexion	Maximum knee extension
Arabesqué			
Up Phase	ROM	Initiation of movement	Maximum trunk flexion/maximum extension of working leg
Grand Jeté			
Up Phase	ROM	Prior to lead leg leaving the ground	Maximum hip flexion of lead leg

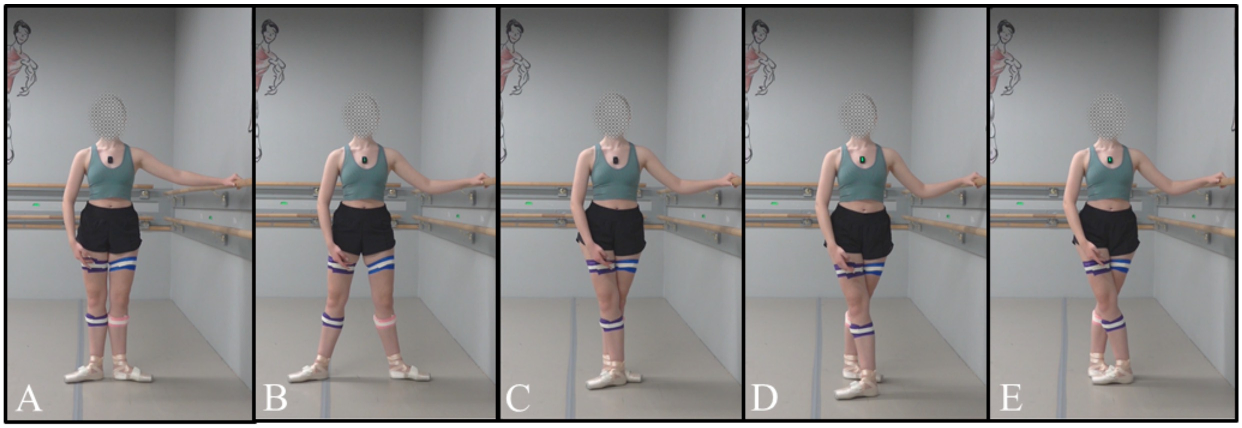

Figure 2. Static positions. A) First; B) Second; C) Third; D) Fourth; E) Fifth

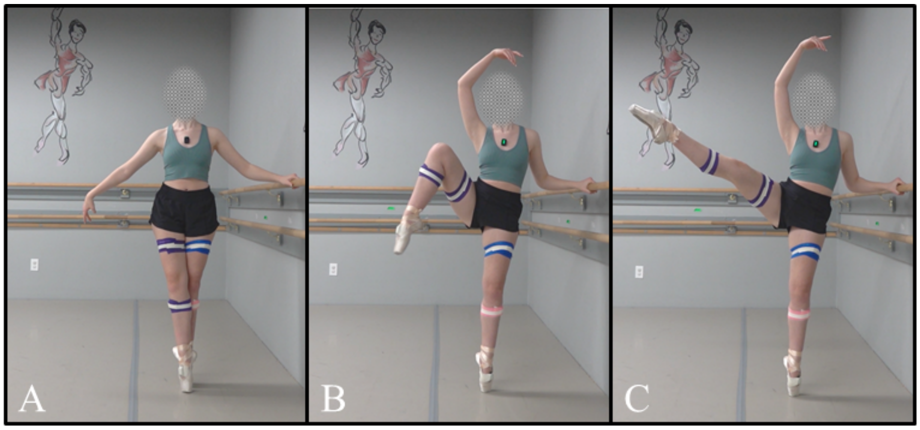

Figure 3. Sub-phases of the *Développé*. A) Initiation of movement; B) *Passé* (maximum knee flexion); C) Maximum knee extension of the working leg

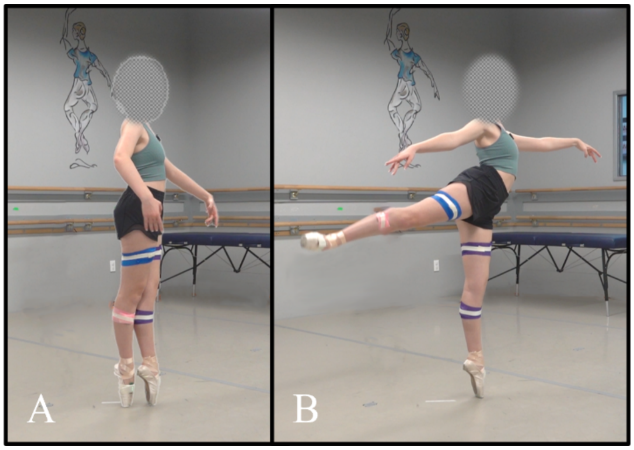

Figure 4. Up phase of the *Arabesqué*. A) Initiation of movement; B) Maximum trunk flexion/maximum extension of working leg

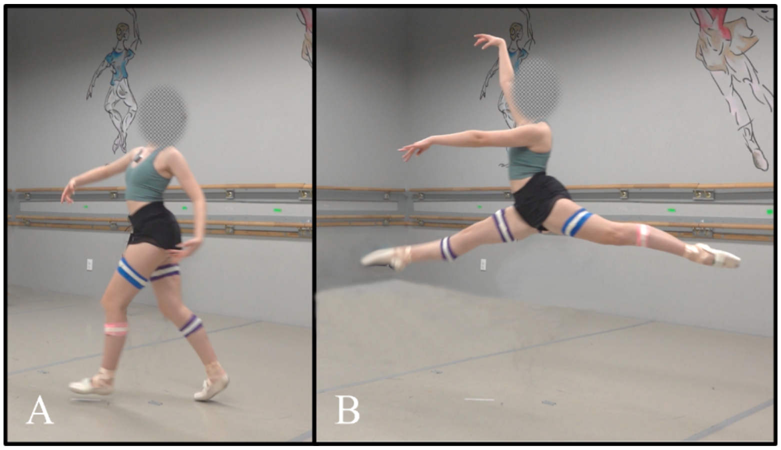

Figure 5. Up phase of the *Grand Jeté*. A) Prior to lead leg leaving the ground; B) Maximum hip flexion of lead leg

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Table 2. Dance participation and injury history for Pain and No Pain Groups

	Pain	*No Pain*	*p-value*
Age at testing (years)	14.5 ± 2.0	14.3 ± 1.7	0.69
Years participating in dance	10.5 ± 2.9	10.3 ± 2.9	0.81
Years dancing *en pointe*	3.4 ± 2.2	3.3 ± 1.7	0.97
Months per year participating in dance	11.9	11.5	**0.02**
Practices per week (> 1 hour)	6.2 ± 1.8	6.8 ± 1.3	0.16
Number of other dance styles	5.2 ± 1.8	4.7 ± 2.1	0.41
History of activity related injury	23 dancers (67.6%)	13 dancers (61.9%)	0.67
Activity related injury in past year	13 dancers (38.2%)	6 dancers (28.6%)	0.47

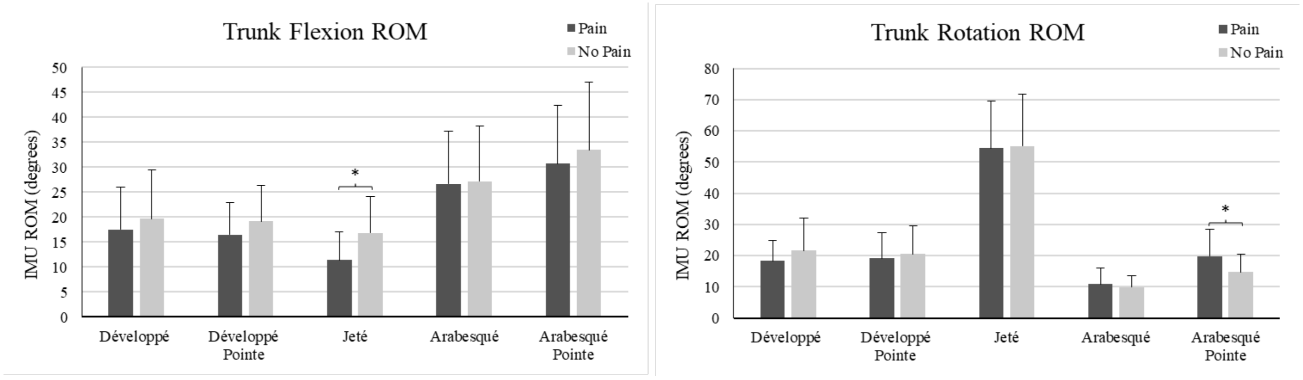

Figure 6. Static joint positions in the Pain and No Pain Groups. *IMU, inertial measurement; ROM, range of motion; Significance indicated with an asterisk (*)*

RESULTS

Demographics

A total of 55 pediatric female, pre-professional ballet dancers were seen for testing (age 14.4 ± 1.9 years, range 10.6 – 18.3 years), with 34 dancers (62%) self-reported pain in the past 7 days according to the PROMIS® Pediatric Numeric Rating Scale v.1.0 – Pain Intensity. Pain level was rated from 0-10 (0, “No pain”, to 10, “Worst pain you can think of”), with an average rating of 3.4 ± 2.0 (range 1-8). Dancers reported on average 10.5 ± 2.9 years of prior dance experience with 3.3 ± 2.1 years of *pointe* training. Additional dance participation information and injury history is presented in Table 2. The pain group indicated increased months per year of dance participation compared to the no pain group (p = 0.02). There were no other differences between the pain and no pain groups for any participation or injury metrics.

IMU Data

In the static positions, there were no significant findings for second or fourth positions when comparing the pain group to the no pain group. However, during first and third positions, the right leg (non-barre sided) demonstrated less external knee rotation in the pain group compared to the no pain group (mean difference 4.6° and 6.8°, respectively, $p \leq 0.05$; Figure 6). The left leg exhibited similar trends, however the differences were not significant. In third position, hip abduction was reduced in the pain group (mean difference 3.1°, p = 0.009; Figure 6). In fifth position, the left leg exhibited increased ankle flexion (mean difference 8.8°, p = 0.048), reduced hip abduction (mean difference 2.9°, p = 0.027; Figure 6), and reduced knee adduction (mean difference 7.2°, p = 0.026) in the pain group. During the dynamic tasks, no differences were observed during the *développé* (flat or *en pointe*) or the *arabesqué* (flat) tasks. The

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pain group exhibited decreased trunk flexion/extension range of motion during the *grand jeté* (up phase; mean difference 5.4°, p = 0.004; Figure 7), and increased trunk rotation range of motion in the *arabesqué en pointe* (mean difference 5.1°, p = 0.034; Figure 7).

EMG Data

During the static positions, the only significant difference in muscle activation was in fifth position, with the pain group exhibiting reduced rectus femoris activation on the left leg (mean difference 14.9%, p < 0.03; Figure 8). The up leg during the *développé* (flat) showed increased hamstring activation (mean difference 6.5%, p = 0.04; Figure 8) in the pain group, while no differences were observed on the stance leg. The remaining tasks did not yield any significant differences in muscle activation between the pain and no pain groups.

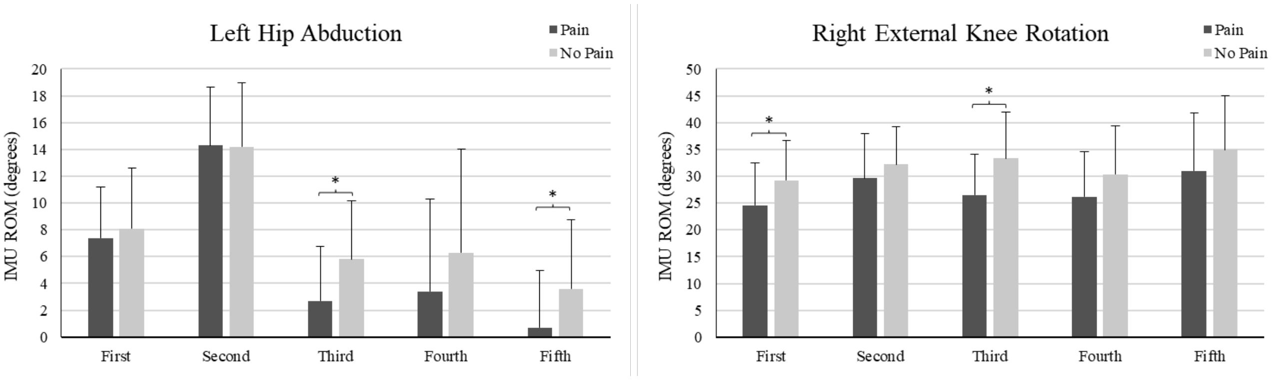

Figure 7. Dynamic task joint range of motion in the Pain and No Pain Groups. *IMU, inertial measurement; ROM, range of motion; Significance indicated with an asterisk (*)*

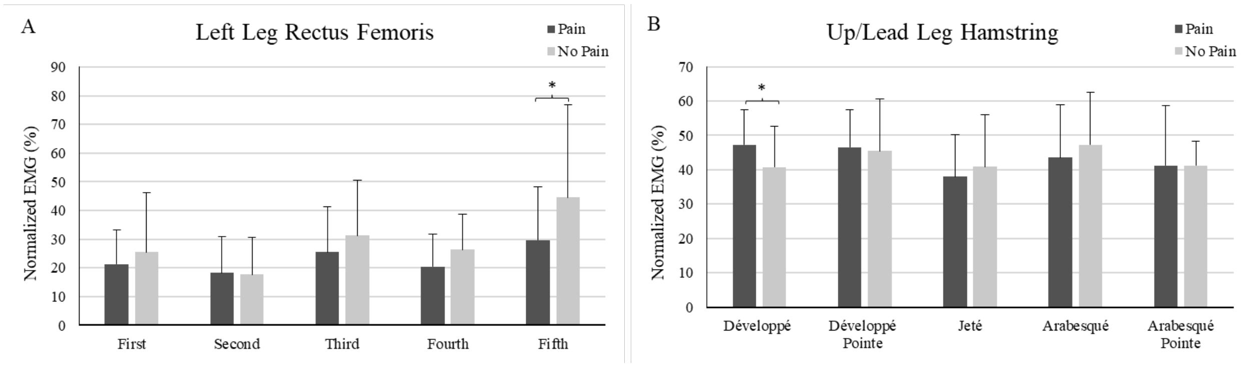

Figure 8. Normalized EMG in the Pain and No Pain groups for (A) Static Positions and (B) Dynamic Tasks. *EMG, electromyography. Significance indicated with an asterisk (*)*

DISCUSSION

The purpose of the current study was to evaluate movement patterns and muscle activation in pediatric female pre-professional ballet dancers with and without pain across a series of classical ballet movements. Key differences were observed in joint positions during first, third, and fifth static positions in dancers who had indicated pain. Findings included reduced knee rotation for the right (front) leg while standing in first and third position in the pain group. Additionally, the left (barre-sided, back) leg demonstrated increased ankle flexion and reduced hip abduction and knee adduction while in fifth position in the pain group. There were limited differences observed between dancers with and without pain during the dynamic tasks. Mainly, adaptations were observed in trunk motion during the *grand jeté* and *arabesqué en pointe*. Muscle activity findings were observed for fifth position, with the pain group exhibiting reduced rectus activation on the left (back) leg. Increased hamstring activation was measured on the working leg during the *développé* (flat), with no other significant findings with the remaining dynamic tasks.

Prior work has investigated the kinematics during certain ballet movements, including the five classical ballet positions.[17-22] Specifically, Gorwa et al. studied muscle activation and kinematics in 14 pre-professional adolescent ballet dancers (age 11-16) performing turnout of classical ballet positions who were categorized into groups based on the amount of passive external hip rotation achieved.[18] They found reduced external knee rotation during first, second, and fourth positions in dancers that had limited passive hip external rotation.[18] Additionally, during third, fourth, and fifth positions, external hip rotation was increased for the left (back) leg in the limited passive hip external rotation group.[18] In the current study, there were no significant findings observed for hip rotation, however, knee rotation was reduced in dancers in the pain group in first and third positions. Gorwa et al. evaluated dancers categorized by their amount of passive hip external rotation but all dancers were without injury, with no mention of the presence of pain. While our findings are not categorized in a similar manner, both studies illustrate potential alterations in movement strategies and altered movement patterns in pre-professional ballet dancers that may correspond to history and/or location of pain and reduced passive range of motion. Thus, our current findings show that dancers with pain demonstrate a weight shift toward the barre, resulting in a more dorsiflexed ankle and adducted hip on the left barre sided leg. This may imply dancers with pain tend to lean more into the barre on the left non-working leg, with the barre sided hip in a relative trendelenberg stance, suggesting weak gluteus medius and maximus muscle activation and strength. Additionally, the observation of decreased knee external rotation of the working leg and decreased knee adduction of the barre-sided leg may indicate a more valgus knee stance in the pain group, potentially resulting in increased risk of lower extremity injury.[23]

Additionally, previous work by Lin et al. analyzed lumbar motion in ballet dancers with low back pain and found reduced lumbar movement smoothness, defined as a movement quality related to continuality, compared to dancers without pain.[19] In the current study, adaptations in trunk range of motion were identified in the pain group when performing the *grande jeté* and *arabesqué en pointe*, which may be due to differences in movement quality or smoothness of dancers with pain while performing these particular tasks. While Lin et al. similarly investigated trunk kinematics according to the presense of pain, their study evaluated an adult cohort of ballet dancers performing a standing trunk flexion and extension range of motion task, which required dancers to move from full lumbar flexion to full lumbar extension and back to full flexion.[19] While it is feasible that adaptations observed during an end range of motion task, as utilized by Lin et al., would translate to dynamic ballet-specific movements, it is unclear if those adaptations in trunk motion would be sustained in a younger, less-experienced cohort of dancers. Our study demonstrated increased trunk rotation range of motion in the pain group performing *arabesqué en pointe*, suggesting the dancer was not able to keep their pelvis and hips in neutral alignment. Deficits in pelvic, hip, and core stability and strength may contribute to increased strain and stress on the lumbar spine, resulting in a potential risk for developing bone stress injuries of the lumbar spine. The pain group also demonstrated decreased trunk flexion/extension range of motion resulting in a more erect trunk position during the *grande jeté*. This suggests possible decreased hip mobility and flexibility. Greater hip mobility allows for increased hip flexion of lead leg in flight, which in turn should result in increased trunk flexion/extension range of motion to allow support and momentum of the rapid dynamic movement in the air.

Previous studies have investigated the use of EMG to measure muscle activation in ballet dancers during various ballet specific

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movement tasks.[17,18,24-26] Gorwa et al. studied muscle activation in pre-professional, adolescent ballet dancers performing classical ballet positions.[18] They found dancers with less passive hip external rotation activated their ankle and back muscles more to force turnout, whereas dancers with greater passive external hip rotation activated and engaged more core and hip muscles. Their study found no differences for first through fifth position in activation of the rectus femoris, vastus medialis, semitendinosus, or gastrocnemius when comparing dancers according to their passive hip rotation. Alternatively, in the current study, rectus femoris activity was decreased on the left (back) leg during fifth position in dancers with pain, while no differences were observed in erector spinae activation with any of the classical ballet positions. Gorwa et al. classified their dancers according to the amount of passive external hip rotation, therefore, findings may not be translatable to the current study cohort. Furthermore, similar to kinematic findings during fifth position in our study, dancers in the pain group may be shifting their weight toward the barre as a compensatory movement pattern of using the barre to stabilize the body in fifth position, therefore requiring less activation of the rectus femoris on the left leg in order to stabilize and hold that static position.

Finally, a study by Trepman et al. found that EMG activity of the vastus lateralis and medialis during a *grand-plie* performed by ballet dancers was significantly less compared to modern dancers, despite a similar degree of knee flexion.[24] These variations suggest that ballet dancers use muscles differently with various dance movements compared to dancers of other styles. In the current study, dancers in the pain group showed greater hamstring activation compared to dancers without pain when performing the *développé* (flat stance foot) on the working leg. Greater hamstring activation on the working leg is likely aiding in stabilizing the hip, pelvis, spine, and knee as the dancer moves from their starting position up to maximum hip flexion. While the reason for this is unclear, it is possible that the pain group is demanding greater hamstring activation to compensate for deficiencies elsewhere. It was noted, although not statistically significant, that the pain group exhibited decreased gluteus medius and erector spinae muscle activation compared to the no pain group, suggesting decreased posterior chain and gluteus activation in this group. Strength deficits in the posterior chain and spine have been indicated as risk factors for low back injuries and back pain.[11,27-29] Furthermore, previous studies have suggested high recruitment of lumbar spine muscles during ballet movements that demand hip and spine hyperextension, and therefore, weak abdominal muscles may negatively affect lumbar flexibility.[27,30,31] No other significant findings were observed in the current study in muscle activation for any other dynamic tasks.

The current study has a few limitations that should be noted. First, due to inherent limitations of using IMU's for measuring joint kinematics, accuracy could not be guaranteed for absolute joint position. Therefore, joint range of motion was used for analysis of movement patterns rather than capturing specific joint angles at timepoints of interest. Second, joint kinematics and muscle activation were not investigated based on the location or level of pain reported. Future work should investigate differences in ballet specific movements according to location and level of pain. Another limitation was the inability to establish causality as to whether movement pattern and muscle activation differences seen are compensatory due to pain or contributory leading to the development of pain. While all dancers studied were 18 years of age or younger, data were not normalized according to developmental maturity, nor were structural abnormalities considered which may have contributed to differences in movement patterns. Lastly, given the homogenous cohort tested for the current study, the results may not be generalizable to other dance styles or to male dancers. Future work could be conducted to explore movement patterns and muscle activation in other dance styles as well as for male ballet dancers.

CONCLUSION

Our findings demonstrate the ability to quantify alterations in movement patterns and muscle activation in pediatric female, pre-professional ballet dancers with and without pain. Ballet dancers with self-reported pain exhibited differences performing certain ballet movements, notably during static fifth position, *grand jeté*, and *arabesqué* (*en pointe*). Additionally, dancers with pain exhibited reduced rectus femoris activation in fifth position and increased hamstring activation on the working leg during the *développé* (flat). Future work should investigate how movement patterns and muscle activation in pediatric female, pre-professional ballet dancers vary by the location and severity of reported pain. This work provides the research and dance community with information that may aid in the development of effective injury prevention strategies and more standardized guidelines for *pointe* readiness criteria to assess young dancers, ultimately leading to the reduction of injury risk for this population.

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Conflicts of Interest

The authors declare no conflicts of interest with the contents of this study.

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