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# Findings of the Lower Extremity Dynamic Screen in Patients with Patellofemoral Pain Syndrome: A Pilot Study

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# FINDINGS OF THE LOWER EXTREMITY DYNAMIC SCREEN IN PATIENTS WITH PATELLOFEMORAL PAIN SYNDROME: A PILOT STUDY

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## Abstract

**Study Design:** Case control study.

**Background and Purpose**: Research has shown that patients with patellofemoral pain syndrome (PFPS) have altered frontal plane hip and knee kinematics. Multiple factors have been hypothesized to contribute to these altered movement patterns. The Lower Extremity Dynamic Screen (LEDS) is a previously-developed instrument used to visually assess hip and knee kinematics during dynamic activities. The purpose of this study was to compare LEDS scores between a patient population with PFPS and healthy control subjects.

**Methods**: Ten subjects with PFPS and thirty-eight control subjects were recruited from a local outpatient clinic and the St. Catherine University Doctor of Physical Therapy program, respectively. Hip and knee kinematics were evaluated and quantified while performing the seven different components of the LEDS (including a double leg squat, double leg squat-jump, bilateral single leg squats, bilateral single leg squat-jumps, and a leaping task). The graded tasks were scored on a zero to three scale and individual task scores were summed to obtain a total possible score of 21 points. In this screen, higher numerical scores represent better lower extremity kinematics. The case subjects were matched with controls by gender. The total and component LEDS scores of the control subjects were compared to those of the case subjects using separate t-tests. Significance level was determined using $p<.05$.

**Results**: Results showed that subjects with pain had a lower mean score (13.9) than that of their gender-matched counterparts (16.5; $p=.02$). The individual task scores of Double-Leg Jump and Leap were also found to be significantly reduced in the patient population ($p=.005$ and $p=.003$, respectively). No other individual task was found to be significantly different.

**Conclusions**: The results of this study indicate that subjects with PFPS scored significantly less overall than subjects without pain on the LEDS. Our results support that patients with patellofemoral pain demonstrate abnormal lower extremity kinematics when compared to controls. Due to the small sample size, further research is necessary to investigate whether the LEDS is a useful screening tool for patients with PFPS.

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## Advisor's Signature Page

The undersigned certify that they have read, and recommended approval of the research project entitled

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in partial fulfillment of the requirements for the
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## Introduction

Knee pain, specifically patellofemoral pain syndrome (PFPS), is a common diagnosis for patients in the physical therapy settings of orthopedics and sports medicine. Research has shown that patients with PFPS have altered frontal plane hip and knee kinematics. Multiple factors have been hypothesized to contribute to these altered movement patterns. The Lower Extremity Dynamic Screen (LEDS) is a previously-developed instrument used to visually assess hip and knee kinematics during dynamic activities. The purpose of this study was to compare LEDS scores between a patient population with PFPS and healthy control subjects.

## Review of the Literature

Patellofemoral pain syndrome is a common source of knee pain that has been estimated to comprise approximately 25-40% of knee ailments observed in orthopedic and sport medicine physical therapy settings.[1,2] This condition occurs when the patellofemoral joint is affected by some type of pathology which results in excessive stress placed on the joint that can lead to extreme wear on the cartilage.[3,4] Patellofemoral pain is also commonly referred to as anterior or retropatellar knee pain. It is often defined as being aggravated by a combination of at least two of the following activities: ascending and/or descending stairs, squatting, kneeling, and prolonged sitting, among others.[2,5,6,7] Some factors that may lead or contribute to the development of PFPS include poor patellar position and tracking, decreased quadriceps strength and control, lack of quadricep and hamstring flexibility, proximal weakness specifically in the external rotators and abductors of the hip, and excessive pronation of the foot.[1,2]

Patellofemoral pain is often multifactorial in origin. Factors that have been postulated to correlate with an increased risk of PFPS include high body mass index (BMI), altered foot structure and/or mechanics, hip and quadricep weakness, joint laxity, abnormal patellar tilt and tracking, female gender, and knee extension peak torque, among others.[1,7-9] In addition, other risk factors for developing PFPS include decreased knee flexion angle, decreased vertical ground reaction force, and increased hip internal rotation angle during a jump-landing task.[7] Research has demonstrated that excessive tightness in soft tissue surrounding the patella, an increased Q angle, altered foot mechanics[1,8] and excessive exercise[1] can lead to increased compression on the patella. This consequence can result in abnormal tracking of the patella in the femoral groove, another mechanism thought to be contributory to PFPS. The multitude of risk factors that lead to PFPS are important to recognize when conducting a physical therapy evaluation.

A typical evaluation of a patient with PFPS includes both a subjective and objective examination. Objective examination should include measurement of Q-angle, palpation of ligamentous laxity, mobility and tenderness of the lateral patellar retinaculum, patellar tilt and placement, and manual muscle testing of both the hip and knee musculature with emphasis on the quadriceps, hip abductors, and external rotators.[10,11] In addition to these assessments, muscle flexibility is also important to incorporate because differences exist between groups. Patients with PFPS often demonstrate significantly less flexibility of the gastrocnemius, soleus, quadriceps, and hamstrings compared to healthy control subjects.[12] Along with these measurements, it has become increasingly important to observe the quality of dynamic aspects of the knee during movement; decreases in dynamic neuromuscular control of the knee are often found in individuals with PFPS.[7,13-15]

Hip strength is an important factor to consider in populations with PFPS. Individuals with PFPS have been shown to demonstrate hip weakness when compared to those without pain.[13,14,16-20] Decreased strength in hip abduction[14,16-23] and hip external rotation[14,16-20,22-24] are the most strongly supported motions demonstrating strength deficits in PFPS. Weakness in hip internal rotation,[18] hip extension,[22] and hip flexion[24] have been shown as well. Decreased strength has also been observed when comparing hip flexion and abduction between the involved and uninvolved knee in those with knee pain,[20,25] as well as global hip weakness when compared to sport-matched asymptomatic controls.[20] Additionally, deficits in eccentric strength have also been observed in hip abduction and external and internal rotation in a population with PFPS.[26]

When weakness is observed in hip musculature, dynamic changes can be observed further down the kinetic chain, such as at the knee and ankle. In 2000, Fredericson and colleagues[11] observed runners with iliotibial band syndrome, which was one of the first studies that examined the potential association between hip dysfunction and distal symptoms. This relationship was termed the "lower extremity chain," demonstrating that dysfunction in one joint of the lower extremity could potentially lead to dysfunction, proximally or distally. One example of this link is the correlation found between an increase in frontal plane valgus movements at the knee (whether hip adduction, knee abduction, or a combination of both) and hip weakness.[16,18,24] It has been hypothesized that this may be explained by a significant change in the ratio of hip adductor to hip abductor strength.[26] This abnormality could be the result of frontal plane movement deviations, or altered kinematics, such as excessive knee valgus, which are often due to abnormal joint control proximal to the knee. Increased knee valgus has been linked with the development and progression of PFPS.[7]

When compared to control subjects, individuals with PFPS also demonstrate other examples of altered kinematics, including a significantly increased amount of hip adduction excursion,[2,13,14,19,27,28] hip internal rotation,[6,14,15,27-29] knee abduction,[13,14,30] knee flexion,[31] greater contralateral pelvic drop,[13,14,28] and greater ipsilateral trunk lean[13,14] during dynamic activities such as: single leg squats, stair descent, and/or jump-landing tasks. Conversely, subjects with PFPS have been found to have similar hip internal rotation and adduction kinematic motion to that of controls during stair descent.[5]

The aforementioned findings regarding lower extremity strength, flexibility, and kinematics are important to this current study because the intention of the Lower Extremity Dynamic Screen (LEDS) is to specifically assess hip and knee strength, as well as neuromuscular control, during various dynamic tasks through qualitative observation. The LEDS was developed to observe qualities of dynamic control during single and double-legged movements that may have an increased likelihood of demonstrating decreases in hip strength. Previous research regarding the LEDS has shown it to have moderate to good reliability between raters, tasks, and overall LEDS score.[32]

Due to the high prevalence of patellofemoral pain in a rather specific population, pre-participation screening for risk factors associated with PFPS may be a quick, feasible way to identify those at risk for developing PFPS and potentially prevent injury through hip strengthening. As such, one of the main purposes of this screen is to identify the potential risk for future lower extremity injury via examination and evaluation of kinematics and dynamic strength. The use of a pre-participation screen in order to assess the quality of functional movements has been investigated. Performance of such fundamental movements, like squatting and lunging, may assist in determining if athletes are able to participate in their sport with a decreased risk for injury. When a pre-season functional movement screen was used to identify if a relationship existed between football players' scores on the screen and the likelihood of injury, it was found that a significant difference in scores existed between players who suffered an injury during the season and those who did not. Additionally, decreased performance and fundamental movements may be associated with an increased risk of injury.[33]

Considering the present body of literature, the purpose of this study is to compare and describe findings from the Lower Extremity Dynamic Screen in a patient population receiving physical therapy treatment for a diagnosis of PFPS to healthy individuals without symptoms of PFPS. Our primary hypothesis is that patients with knee pain will have lower scores on the LEDS than those from the control group. The null hypothesis is that there will be no difference between LEDS scores for subjects who have patellofemoral pain and those who do not. Our secondary hypothesis is that single-legged tasks would have lower scores than double-legged tasks.  The null hypothesis is that there will be no difference between scores of single and double-legged tasks.

# Methods

*Training*

Student researchers completed training taught by Dr. Paul Niemuth on how to administer the LEDS using previously recorded subject trials. Inter-rater reliability between researchers was established using these videos. The researchers watched the entire screening sequence while scoring each task using a zero to three scale to obtain a total score. Reliability for LEDS testing was found to have an intraclass correlation coefficient (ICC) of .88 for total scores in past research while reliability for the current researchers was determined to be excellent with an ICC of .96. Researchers then processed to train the assisting clinicians at Accelerated Therapy and Fitness, University Orthopaedics Physical Therapy, and Institute of Athletic Medicine Stadium Village Clinic on the administration of the LEDS with the guidance from Dr. Paul Niemuth.

*Subjects*

Male and female subjects between the ages of 18 and 55 years not currently seeking medical intervention for knee pain were recruited from St. Catherine University Doctor of Physical Therapy (DPT) program classes of 2013, 2014, and 2015 through an informational email and flyer to serve as a control group (Appendix A). Exclusion criteria for participating in this study included hip, knee, or ankle surgery or trauma within the past year, current pregnancy, and knee pain. Participation in this study was voluntary and the participants were informed that it would not affect their current or future academic standing. Control subjects were tested by the LEDS by the student researchers.

Case subjects who were currently experiencing patellofemoral pain were recruited by assisting physical therapists from the Institute of Athletic Medicine Stadium Village clinic. Male and female subjects were included if they were seeking medical intervention due to patellofemoral pain and were between the ages of 18 and 55 years. Exclusion criteria for participating in this study again included recent lower extremity surgery or trauma and current pregnancy. The treating physical therapists approached their patients who met study criteria about participating in the study and distributed an informational flyer (Appendix B). If the subject elected to participate, the LEDS was performed by the treating physical therapist at the clinic. Subjects were tested as close to the onset of physical therapy as possible in order to ensure that strengthening from the exercise program did not affect their muscle strength or lower extremity kinematics in relation to this screening tool. Participation in this study was voluntary and the participants were informed that it would not affect the treatment provided by the treating therapist.

Institutional Review Board approval was obtained from both St. Catherine University and the University of Minnesota for Fairview Health System Services. Each subject was provided with a letter of consent which described the details of the study including their responsibilities as a participant, risks and benefits, and study confidentiality (Appendix C). All subjects also completed a questionnaire regarding demographics and past or current lower extremity injuries (Appendix D). Each participant was also assigned a subject number to maintain confidentiality of their data.

*Testing Procedure*

Lower Extremity Dynamic Screen testing took place at Institute of Athletic Medicine Stadium Village clinic for case subjects seeking medical intervention and St. Catherine University for control subjects. The testing sequence for all five tasks included the subject was read directions of the task using a standardized script (Appendix E), watched a demonstration of the task, practiced the task one time, asked any questions s/he had, and performed the task three consecutive times for the graded trial. The total testing sequence took between five and ten minutes.

*Scoring of Subjects*

Subjects were scored by the student researchers for control subjects and assisting treating clinicians for case subjects. Each of the five graded LEDS tasks was scored on a four point scale, from zero to three, as follows:

0 = Cannot complete movement or loss of balance

1 = Completed with two or more faults

2 = Completed with one fault

3 = Completed with no major faults

Component scores were summed in order to obtain a total score out of a maximum 21 points. A higher score demonstrates better lower extremity kinematics and potentially, a lower risk of injury.

*Grading Criteria*

Prior to this current research, criteria for the five tasks in the testing sequence was developed by a previous research group with consultation from an expert clinician, Paul Solie, PT, SCS. The criteria identified biomechanical faults in the lower extremities while performing each specific task (Appendix E). The following are criteria for each of the five components of the LEDS:

<u>Double-leg Squat:</u>

1) Equal weight bearing.

2) Maintain knee control in all three planes.

3) Must squat with thighs parallel to the floor or knee flexion to 90-degrees.

<u>Double-leg Jump:</u>

1) Equal weight bearing at take-off and landing.

2) Maintain knee control in all three planes at take-off and landing.

3) Upon landing, must squat with knee flexion between 45-degrees to 90-degrees.

<u>Single-leg Squat on the right/left:</u>

1) Maintain hip control and balance with no visible hip hike, drop, or rotation.

2) Maintain knee control in all three planes.

3) Must squat so the left/right knee drops below half the height of the right/left leg shin length.

Single-leg Hop on the right/left:

1) Maintain hip control and balance with no visible hip hike, drop, or rotation at take-off and landing.

2) Maintain knee control in all three planes at take-off and landing.

3) Upon landing, must squat so the left/right knee drops below half the height of the right/left leg shin length.

Leap:

1) Maintain hip control and balance with no visible hip hike, drop, or rotation.

2) Maintain knee control in all three planes.

3) Upon landing, maintain foot position.

*Lower Extremity Dynamic Screen Tasks*

The five LEDS tasks in the testing sequence included a Double-leg Squat, Double-leg Jump, Single-leg Squat on the right and left lower extremity, Single-leg Hop on the right and left lower extremity, and six dynamic Leaps. A description of each task is as follows:

Double-leg Squat: The subject stood on both legs with their feet shoulder-width apart and their arms raised to 90-degrees of flexion. The subjects was then asked to squat down until their thighs were parallel with the ground.

Double-leg Jump: The subjects stood on both legs with their feet shoulder-width apart and both their arms extended behind. The subject was then asked to jump vertically from a partial-squat position while raising their arms overhead. As s/he lands, the subject was asked to descend into a double-leg squat position.

Single-leg Squat right/left: The subject stood on their stance leg with their opposite knee flexed. The subject was then asked to squat down until their flexed knee drops below mid-shin of their stance leg, while using a reciprocating arm swing.

Single-leg Hop right/left: The subjects stood on their stance leg with their opposite knee flexed and both of their arms extended behind them. The subject was then asked to jump vertically from a partial single-leg squat position while raising their arms overhead. Upon landing, s/he was asked to descend into a single-leg squat position.

Leap: The subject stood on their right leg with their left knee flexed and their left arm flexed forward. The subject was then asked to leap at a 45 degree angle onto their left leg using a reciprocating arm swing. From there, they lept onto their right leg using a reciprocating arm swing and continued through a total of six leaps.

Every subject completed all five tasks in this sequence, regardless of success.

*Statistical Analysis*

Statistical analysis was performed using Number Cruncher Statistical Software 8 (Kaysville, Utah). Median values were used for analyzing individual task scores due to the ordinal nature of the data, while mean values were used for analyzing the total score due its continuous nature. Statistical significance was set at a level of .05.

## Outcomes

*Demographics*

Participant demographics can be found in Table 1. A total of 10 case subjects with anterior knee pain volunteered for this study, including six females and four males. For the control group, a total of 38 participants, 28 females and 10 males, whose ages ranged from 21 to 38 years were assessed. In order to create a 2:1 ratio of control to case subjects for analysis purposes, 20 gender-matched controls were randomly selected. The resulting 20 control subjects included 12 females and eight males. The mean age was 25.15 with a standard deviation of 3.67 years for selected control subjects and 24.5 with a standard deviation of 4.95 years for case subjects. Independent t-tests revealed no significant differences between control and case groups for neither age nor gender.

For the case group, the mean duration of knee pain experienced was 18.45 months with a standard deviation of 32.56 months. This data was not normally distributed which is likely due to two patients reporting a knee pain duration of 60 and 96 months compared to the remaining eight patients reporting one to six months of knee pain. Both pain at rest and with activity for this group using the Numeric Pain Rating Score (NPRS) had a normal distribution. At rest, the mean was 1.6 with a standard deviation of 2.12. With activity, the mean was 5.0 with a standard deviation of 2.31.

Table 1. Participant Demographics.

| Patient Description | Control (n=20) | PFPS (n=10) |
|---|---|---|
| Age (y)* | 25.15 (22-38) | 24.5 (19-33) |
| Females | 12 | 6 |
| Symptom Duration (mo)* | n/a | 18.45 (1-96) |
| NPRS at Rest*# | n/a | 1.6 (0-7) |
| NPRS with Activity*# | n/a | 5 (2-8) |

Abbreviations: PFPS = patellofemoral pain syndrome; n/a = not applicable

*Mean (range)

*#NPRS= Numeric Pain Rating Score (range, 0-10, subjective outcome measure with higher numbers indicating greater pain)

*Primary Results*

Statistical analysis revealed subjects with pain earned a lower mean total score on the Lower Extremity Dynamic Screen of 13.9 compared to that of their gender-matched counterparts of 16.5 (p=0.02). In addition to the significant total scores, the median individual task scores of Double-leg Jump (p=0.005) and Leap (p=0.003) were also found to be significantly reduced in the case population. No other individual task was found to be significantly different;

however, the right Single-leg Hop task demonstrated a trend towards significance (p= 0.06). These findings are reported in Table 2.

Table 2. Primary Results.

| | Total (mean) | DLS | DLJ | SLS R | SLS L | SLH R | SLH L | Leap |
|---|---|---|---|---|---|---|---|---|
| Control | 16.5 | 3 | 3 | 2 | 2 | 2 | 2 | 3 |
| Case | 13.9 | 3 | 2 | 2 | 2 | 1 | 1 | 3 |
| p-Value | .02* | .48 | .006* | .65 | .40 | .06** | .21 | .003* |

*Statistical significance, $p<0.05$

**Approaching statistical significance

*Secondary Results*

Statistical analysis was performed to examine potential secondary findings. Two sample t-tests were calculated between total LEDS score and gender for both the control and case groups; both of which could not reject normality. A significant p-value of 0.016 for the case group was found where the mean total LEDS score for females was 12.0 with a standard deviation of 1.67 and a mean for males of 16.75 with a standard deviation of 3.30. For the control group, a non-significant p-value of 0.13 was found where the total LEDS score mean for females was 15.83 with a standard deviation of 2.41 and the mean for males was 17.5 with a standard deviation of 2.2.

Pearson correlations were performed within the case group between both pain at rest and total score and pain with activity and total score. The correlation was found to be -0.24 between pain at rest and total score, and -0.14 between pain with activity and total score. Each of these secondary findings are reported in Table 3 and Table 4, respectively.

Table 3. Secondary Results: Total LEDS Score vs. Gender.

| | Females | Males | p-Value |
|---|---|---|---|
| Case Group | 12.0 (1.67)* | 16.75 (3.30)* | 0.016** |
| Control Group | 15.83 (2.41)* | 17.5 (2.2)* | 0.13 |

*Mean (standard deviation)

**Statistical significance, p value<0.05

Table 4. Secondary Results: Total LEDS Score vs. Pain in Case Subjects.

| | Pearson Correlation Coefficient |
|---|---|
| Pain Rating at Rest | -0.24 |
| Pain Rating with Activity | -0.14 |

## Discussion

The results of this study confirmed the original hypothesis that patients seeking treatment for patellofemoral pain do, in fact, have significantly lower mean scores on the Lower Extremity Dynamic Screen than their gender-matched counterparts. This screening tool, designed to quantify qualitative observations of faulty lower extremity kinematics, has demonstrated that case subjects have altered movement patterns when compared to healthy gender matched control subjects. Results of this study have also demonstrated that case subjects achieved significantly lower median scores for the Double-leg Jump and Leap tasks, as well as a trend toward a significantly lower median value for the Single-leg Hop on the right.

The case-control comparison of total LEDS scores is congruent with what the literature reports regarding patellofemoral pain and lower extremity kinematics. Recent studies by Nakagawa et al[13,14] and Noehren et al[27] have found that individuals with patellofemoral pain demonstrate various kinematic faults when performing dynamic activities such as single-leg squats, jump landings, and stair descent, as well as stepping and running. The significant differences in total scores calculated between the control group and subjects with PFPS in this study demonstrate that there is an overall change in lower extremity kinematics during dynamic tasks. However, when comparing groups on each specific task, only the Double-leg Squat and Leap tasks were determined to be significantly different.

Two recent cross-sectional studies by Nakagawa et al[13,14] compared, among other things, lower extremity kinematics between male and female subjects with and without PFPS, which produced clinically significant findings relevant to this study. The research findings demonstrated that during stepping[13] and single-leg squats,[14] subjects with PFPS displayed multiple differences in lower extremity and trunk kinematics, including greater ipsilateral trunk lean, contralateral pelvic drop, and increased hip adduction and knee abduction, than gender-matched subjects without PFPS symptoms. Similarly, differences in hip and knee kinematics between healthy controls and subjects with pain were found in this study as well. Contrary to the aforementioned articles, this present study did not find significant differences in any single-legged tasks; however, a trend towards significance was present in the Single-leg Hop.

It should be noted that not all of the results of this study agreed with the original hypotheses and current research. Since kinematic variances have been observed in continuous dynamic activities such as running and isolated dynamic tasks such as single-leg squats,[6,13,14,19,34] it can then be postulated that there would be significant differences in all tasks of the LEDS. However, it was hypothesized that single-legged tasks would likely tend to have significantly worse kinematics than double-legged tasks due to findings in the literature. The literature would suggest that patients would score significantly lower on the LEDS tasks of Single-leg Squat and Single-leg Hop compared to their gender matched controls. This is because recent studies by Willson and Davis[19] and Souza and

Powers[6] have shown that females with patellofemoral pain demonstrate increased hip adduction and internal rotation, markers of faulty lower extremity kinematics, during jump landing tasks. A trend towards significance for the right Single-leg Hop task was present; however, it is important to note that significant results in these similar tasks were not found.

Based on studies by Nakagawa et al[13,14] and McKenzie et al[2] that evaluated lower extremity kinematics during single-leg squats and stair descent, an additional hypothesis was formed that there would be a significant difference in the Single-leg Squat tasks between the case and control groups. However, data from this current study did not support this hypothesis when a comparison was performed. Perhaps, this is due to the screening nature of this tool, in which an assessment of more dynamic activities is required to uncover statistically significant variations in lower extremity movement patterns.

A significant difference was found between the case and control groups in this study when comparing the Leap task. The goal of this component of the LEDS was to observe a more continuous, multi-component dynamic activity, whereas the other tasks of the LEDS observe single, isolated dynamic tasks. The Leap task was incorporated into the screen because research has demonstrated that significant changes in kinematics have been found in continuous dynamic activities, i.e. running. In a 2011 study by Noehren and colleagues[27] which compared lower extremity kinematics in subjects with PFPS to a control group during running, the experimental group with PFPS exhibited significantly greater hip adduction and internal rotation ROM. The experimental group also displayed significantly greater shank internal rotation. Additionally, a trend toward decreased contralateral trunk lean was found in this group. Significantly lower scores in the case subjects during the Leap task seems to be supported by literature indicating a potential strength and/or neuromuscular control deficit that is required for such repetitive dynamic tasks such as leaping and running.

There was a significant difference ($p < .05$) found when comparing total LEDS scores between males and females in the case group. There was not a significant difference when comparing males and females in the control group; however, the female control group primarily consisted of healthy, active individuals. These results could suggest that females may be weaker than males and therefore may be more likely to suffer from patellofemoral pain.

The correlation values found in this study demonstrate that there is neither a significant relationship between Numeric Pain Rating Score at rest, nor with activity, and total LEDS scores. This is likely a result of a small case group population . The lack of correlation may demonstrate that lower LEDS scores are potentially a result of biomechanical faults rather than pain limiting performance on tasks. However, this may also mean that pain level at rest or with activity cannot be used as a predictor of a subject’s LEDS score.

These results, in addition to future research, may be early evidence for the utility of the LEDS as a prevention tool in pre-participation screening for certain at-risk populations, such as young athletes. According to the findings of this study, participants who score lower on the screen could potentially be at a higher risk for sustaining a lower extremity injury, including developing patellofemoral pain. As such, subjects who score lower may benefit from a prescriptive program focusing on hip strengthening and improving lower extremity mechanics during dynamic activities in order to potentially decrease the chance of lower extremity injury.

The statistically significant findings from this research are encouraging; however, this present study has multiple limitations. It should be reiterated that this was a pilot study with a small sample size. Additionally, the control and case populations possess a potentially low generalizability to a clinic population as the majority of the control subjects were healthy graduate students. Also, the case subjects did not include the adolescent female population, which is known to have a high prevalence of PFPS. Furthermore, despite multiple clinics showing interest in assisting with this study and training being completed by physical therapists at each of these clinics, control subjects were only able to be recruited from one of the clinics. This ultimately narrowed the data pool.

As evident by these limitations, there are topics related to this study that need further research. Specifically, based on the pilot nature of this study and small number of subjects, future investigations should be directed at determining whether or not the LEDS is a valid screening tool in patients with patellofemoral pain on a larger scale. A control group that is more characteristic of the general population should be included. Also, additional studies should include adolescent females with PFPS, as anterior knee pain is a common complaint in this population.

Further research should be completed to investigate if there is a difference in functional strength and muscle group strength testing. This could suggest whether an association exists between functional dynamic faults and strength deficits. Additionally, research in this area may indicate whether interventions should focus on improving strength with functional activities, specific single muscle group strengthening, and/or neuromuscular re-education.

Similarly, potential differences in strength and kinematics between men and women with PFPS should be examined in future research. This research may indicate whether PFPS intervention should be sex-specific for patients.

## Conclusion

The results of this study indicate that subjects with PFPS had significantly lower mean scores on the Lower Extremity Dynamic Screen than their healthy counterparts. This finding suggests that patients with patellofemoral pain demonstrate abnormal lower extremity kinematics when compared to gender-matched controls. Additionally, the LEDS may be an appropriate screening tool for the population with patellofemoral pain.

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**Table of Tables**

Table 1. Participant Demographics.

| Patient Description | Control (n=20) | PFPS (n=10) |
|---|---|---|
| Age (y)* | 25.15 (22-38) | 24.5 (19-33) |
| Females | 12 | 6 |
| Symptom Duration (mo)* | n/a | 18.45 (1-96) |
| NPRS at Rest*# | n/a | 1.6 (0-7) |
| NPRS with Activity*# | n/a | 5 (2-8) |

Abbreviations: PFPS = patellofemoral pain syndrome; n/a = not applicable
*Mean (range)
*#NPRS= Numeric Pain Rating Score (range, 0-10, subjective outcome measure with higher numbers indicating greater pain)

Table 2. Primary Results.

| | Total (mean) | DLS | DLJ | SLS R | SLS L | SLH R | SLH L | Leap |
|---|---|---|---|---|---|---|---|---|
| Control | 16.5 | 3 | 3 | 2 | 2 | 2 | 2 | 3 |
| Case | 13.9 | 3 | 2 | 2 | 2 | 1 | 1 | 3 |
| p-Value | .02* | .48 | .006* | .65 | .40 | .06** | .21 | .003* |

*Statistical significance, $p<0.05$
**Approaching statistical significance

Table 3. Secondary Results: Total LEDS Score vs. Gender.

| | Females | Males | p-Value |
|---|---|---|---|
| Case Group | 12.0 (1.67)* | 16.75 (3.30)* | 0.016** |
| Control Group | 15.83 (2.41)* | 17.5 (2.2)* | 0.13 |

*Mean (standard deviation)

**Statistical significance, p value<0.05

Table 4. Secondary Results: Total LEDS Score vs. Pain in Case Subjects.

| | Pearson Correlation Coefficient |
|---|---|
| Pain Rating at Rest | -0.24 |
| Pain Rating with Activity | -0.14 |

# Appendices

**Appendix A.** Informational Flyer for Control Subjects.

Attention
1st and 2nd year DPT students!

For our research project we are comparing lower extremity dynamic screen (LEDS) scores between a patient population and a control group.

We are currently in need of control subjects who are not seeking medical attention for knee pain.
Exclusion to participation is:

- previous hip, knee or ankle surgery or trauma within the past year (ask Paul if you have any specific questions)
- pregnancy

This is a quick 5-10 minute screen that will assess 5 different movements.

A sign-up sheet with participation slots will be posted outside of Dr. Niemuth's office. Testing will be conducted on Monday's from September 17- October 22th, and then from October 29th- November 9th.

Your decision whether or not to participate in this research study will not affect your standing in the DPT program in any way.

If you choose to volunteer your time, please wear **athletic shorts** (so we can see your knees) **and running shoes** for testing.

Thank you very much

Jake, Meghan, Lindsey, Elizabeth
Class of 2013

**Appendix B.** Informational Flyer for Case Subjects.

**Would You Like to Participate in a Research Project? It Only Takes a Few Minutes**

You are invited to participate in a research study on leg testing for patients with patellofemoral knee pain syndrome by Physical Therapists here at the physical therapy clinic and Physical Therapy Graduate Students from St. Catherine University, under the supervision of Paul Niemuth, PT, DSc, Doctor of Physical Therapy program faculty member.

You were selected as a possible participant in this research because you are currently seeing a physical therapist for knee pain.

Eligible Participants
Active adults between the age 18 and 55 with patellofemoral knee pain.
Must not have previous hip, knee, or ankle surgery or trauma or are pregnant

Study Options

1. 5 Minutes Today or next visit with Your Physical Therapist

2. No Thank You

**Appendix C.** Subject Consent Form.

**Fairview Stadium Village Clinic/University Orthopaedic Therapy Center**

**Information and Consent Form**

**Introduction:**
You are invited to a research study on leg testing for patients with patellofemoral pain syndrome by Lindsey Halcrow and physical therapists here at the Stadium Village Clinic/Orthopaedic Therapy Center/West Health/Minnetonka and Doctor of Physical Therapy graduate students from St. Catherine University, under the supervision of Paul Niemuth, PT, DSc, OSC, SCS, ATC, Doctor of Physical Therapy program faculty member. You were selected as a possible participant in this research because you are either currently seeing a physical therapist involved in this study for knee pain or are a current St. Catherine DPT student with no current knee pain. Please read this form and ask questions before you agree to be in the study.

**Background:**
The purpose of this study is to describe findings in the Lower Extremity Dynamic Screen (LEDS) in a patient population with patellofemoral knee pain and compare it to a healthy control population. An additional purpose of this research is to correlate low scores in the LEDS with hip weakness and impaired balance performance.

**Procedure:**
If you decide to participate, you will be asked to first fill out a brief questionnaire about history of your knee pain, if applicable. You will then perform a series of five squatting, jumping, or hopping activities. You may also perform a balance test and have your leg muscle strength tested. The process will take between 5-30 minutes.

**Risks and Benefits:**
There are no benefits for participating in this study. The risks are minimal due to the physical requirements of data collection such as losing your balance. Demonstration and practice time is given to minimize injury risk. In the event that this research activity results in an injury, we will assist you. For example, if you suffer a fall while performing a hopping activity we will assess the injury, apply ice, and refer you for the proper medical care. Any medical care for research-related injuries should be paid by you or your insurance company. If you think you have suffered a research-related injury, please let us know right away.

**Confidentiality:**
Any information obtained in connection with this research study that could identify you will

not be disclosed. Participants will be assigned a research number. The number will be used for identification. Study information will be kept in a locked file in the office of the primary research advisor at St. Catherine University and will only be assessable to the researchers. Upon completion of the project in May of 2013, we will destroy all personal information and records.

**Voluntary nature:**
Participation in this study is voluntary. Your decision whether or not to participate will not affect your current and future relations with your physical therapist. If you decide to participate you are free to discontinue participation at any time without affecting these relationships.

**Contacts and Questions:**
You are encouraged to ask the researchers any questions about this study at any time. You may also contact Paul Niemuth, DPT program faculty, if you have any questions at any time (see contact information below). If you have other questions or concerns regarding the study and would like to talk to someone other than the researchers, you may also contact Lynne Linder, IRB administrative assistant, (lelinder@stkate.edu) at 651-690-6203. You may keep a copy of this consent form for your records.

**Statement of Consent:**
You are making a decision whether or not to participate in this study. Your signature indicates that you have read this information and your questions have been answered. Even after signing this form please know that you may discontinue your participation at any time.

I agree to participate in this study Yes_______ No_______

Signature of subject___________________________________ Date______________

Signature of researcher_________________________________ Date______________

Lead Investigator and supervising faculty member

Paul Neimuth, PT, DSc, OSC, SCS, ATC
Doctor of Physical Therapy Program
St. Catherine University
601 25th Avenue South
Minneapolis, MN 55454
Phone: 651-690-7981

**Appendix D.** Subject Questionnaire.

**Findings of the Lower Extremity Dynamic Screen in Patients with Patellofemoral Pain Syndrome: A Pilot Study**
**Questionnaire**

Subject # ___________ Date ____________

1. What is your Gender? Please circle one.
   **Male Female**
2. If female, are you currently pregnant?
   **Yes No**
3. What is your age? _________
4. Duration of current knee pain? _______
5. Pain rating (0 = no pain, 5 = moderate pain, 10 = extreme pain)
   **At rest: ______ With activity: ______**
6. Have you had a previous lower extremity surgery (hip, knee, and/or ankle)? Please circle one.
   **Yes No**
7. Have you had a previous lower extremity trauma (hip, knee, and/or ankle)? Please circle one.
   **Yes No**

**Appendix E.** Testing Sequence and Grading Form.

Participant # ___________ Date ________________________

**Description introduction:** *"I will first read you a description of the task. Next, I will demonstrate the task and you will be able to perform a practice trial. I will ask if you have any questions. Then you will perform the task for a graded trial. You will do each task 3 times in a row."*

| Task | Description | Criterion | Score |
|---|---|---|---|
| **Double-Leg Squat** | *You will be performing a double- leg squat. Stand with your feet shoulder width apart and your arms raised in front of you to 90°. Squat down until your thighs are parallel with the ground.* | • Equal weight bearing<br>• Maintain knee control in all 3 planes<br>• Must squat with thighs parallel to the floor or knee flexion to 90-degrees | 3 2 1 0 |
| **Double- Leg Jump** | *You will be performing a double- leg jump. Stand with your feet shoulder width apart and your arms extended behind you. Jump raising your arms overhead landing in a double-leg squat position each time. Try to land in the same place each time.* | • Equal weight bearing at take-off and landing<br>• Maintain knee control in all 3 planes at take-off and landing<br>• Upon landing, must squat with knee flexion from 45-degrees to 90-degrees | 3 2 1 0 |
| **Single-Leg Squat** | *You will be performing a single-leg squat. Stand on your R (L) leg with your opposite knee bent. Have your R (L) arm forward. Squat down until* | • Maintain hip control and balance (no visible hip hike, drop, or rotation) | R 3 2 1 0<br>L 3 2 1 0 |

| | | | |
|---|---|---|---|
| | *your bent knee drops below mid-shin of your stance leg using a reciprocating arm swing.* | • Maintain knee control in all 3 planes<br>• Must squat so the L (R) knee drops below half the height of the R (L) leg shin length | |
| **Single-Leg Hop** | *You will be performing a single-leg hop. Stand on your R (L) leg with your opposite knee bent and your arms extended behind you. Jump raising your arms overhead landing in a single-leg squat position each time. Try to land in the same place each time.* | • Maintain hip control and balance (no significant hip hike, drop, or rotation) at take-off and landing<br>• Maintain knee control in all 3 planes at take-off and landing<br>• Upon landing, must squat so the L (R) knee drops below half the height of the R (L) leg shin length | R 3 2 1 0<br><br>L 3 2 1 0 |
| **Leap** | *You will be performing 6 alternating leaps. Stand on your R leg with your opposite knee bent. Have your L arm forward. As you leap onto your L leg at a 45° angle use a reciprocating arm swing. Continue through 6 leaps* | • Maintain hip control and balance (no visible hip hike, drop, or rotation) with no toe touch<br>• Maintain knee control in all 3 planes<br>• Upon landing, maintain foot position | 3 2 1 0 |

**Total ____________/21**