2016

The Effect of Step Frequency Training on a Male Runner with Patellofemoral Pain

Shelley Payne Dr.
Otterbein University

Katelyn Barrett
Bowling Green State University

Joe Wilkins
Bowling Green State University

Payne, Barrett, Wilkins. Effect of step frequency on male with patellofemoral pain.
JSMAHS. 2016. 2(2)
Article 3

The Effect of Step Frequency Training on a Male with Patellofemoral Pain

Shelley Payne, Katelyn Barrett, Joe Wilkins
Otterbein University

Content: Running is a very popular form of exercise. The most common site of injury for runners is the knee with patellofemoral pain being the most common complaint. Patellofemoral pain is described as pain around the patella that is worse with activities such as running, squatting, ascending or descending stairs, or sitting for long periods. Much of the recent work with the treatment of patellofemoral pain has involved strengthening of the hip musculature to reduce pain about the knee. However, the ability of these strengthening programs to change lower extremity mechanics or sustain long-term pain reduction has been unproven. More recently, researchers have started to examine the impact of step frequency modification on the forces encountered in the lower extremity, and specifically about the patellofemoral joint. The purpose of this study was to examine the short term effects of step frequency training in a recreational runner with PFP. **Methods:** This was a single-subject case study design. The subject completed a pre- and post-training assessment to determine the preferred step frequency. The subject also completed a Visual Analog Scale (VAS) and a Lower Extremity Functional Scale (LEFS). **Results:** After the initial evaluation, the subject completed training 2 times per week for 4 weeks using auditory feedback to increase their step frequency by 5% above their preferred step frequency. The subject experienced a decrease in pain as measured by the VAS and an increase in function as measured by the LEFS across the 4-week training. **Discussion:** Although the results of this case study may not be generalized, the positive findings support additional research to determine both the short and long-term effects of step frequency training on PFP.

INTRODUCTION

Running is a popular form of exercise among the general population. The most common site of injury for runners is the knee, with patellofemoral pain being the most common complaint.[1]PFP is highly prevalent in recreational runners in particular. Recreational runners are typically defined as running 15-20 km/week.[1] According to the literature, patellofemoral pain (PFP) is defined as pain in the anterior knee due to overuse. Activities that cause pain include ascending and descending stairs, squatting, sitting for long periods of time, running, jumping--anything that increases the patellofemoral joint compressive forces.[2] Much of the recent work with the treatment of patellofemoral pain has involved strengthening of the hip musculature to reduce pain.[3,4] However, the ability of these strengthening programs to change lower extremity mechanics or sustain long-term pain reduction has been unproven. As a result, more recently, researchers have started to examine the impact of "retraining" strategies for runners in an attempt to reduce PFP and patellofemoral joint forces.[5,6]

Step frequency has been established as a contributing factor to increased ground reaction forces through the patellofemoral joint that may contribute to patellofemoral pain. Specifically, researchers found that increasing step rate to 110% of their preferred rate reduced peak patellofemoral joint force by 14%.[6] One method of treating patellofemoral pain involves increasing step frequency for those who have a low preferred stride frequency. Motion analysis research has found runners with a low preferred step frequency tend to land with their foot well out in front of their center of mass at initial contact. This "over-striding" effectively increases the vertical ground reaction forces that are experienced by the runner.[7]Additionally, runners that over-stride tend to land with a decreased knee flexion angle at initial contact, decreasing the ability of the quadriceps to dissipate the ground reaction forces about the patellofemoral joint.

As clinicians begin to examine the use of step frequency as a treatment strategy, it becomes important to examine the effect of increased frequency on joint load. Authors suggest that increasing a runner's preferred step rate by 10% or greater may reduce the load through the patellofemoral joint and other joints in order to reduce injury risk.[7] A follow-up study included 45 injury-free recreational runners. They had them run at their preferred stride frequency, 5% above preferred, and 10% above preferred; and then recorded 3-D motion data, ground reaction force data, and EMG data from the following muscles: rectus femoris, vastus lateralis, medial gastrocnemius, tibialis anterior, medial and lateral hamstrings, and gluteus medius and maximus. Results showed that muscle activity, specifically of the gluteus medius and gluteus maximus, increased in late swing phase of gait in anticipation of contact with the ground. Due to the anticipatory contraction of these muscles, the authors concluded that this type of muscle activity would be useful in reducing PFP that may be the result of an increased adduction and internal rotation moment about the knee.[8] The results of these studies are very informative, but it must be noted that their population included only healthy runners.

Other authors examined this type of training strategy in a study using 10 healthy males running at 2.5 m/s on a treadmill-mounted force platform and measured their lower extremity loading variables at five different step frequencies, controlled using a metronome.[9] The five step frequencies included preferred, 15% below preferred, 30% below preferred, 15 % above preferred, and 30% above preferred. The average preferred step frequency for runners in this study was 163 steps per minute. All subjects were allowed a 3-4 minute warm-up in order to become comfortable with the auditory feedback. Then, each subject ran for 30 seconds at each of the five step frequencies in a random order, with five minute break periods in between each step frequency. These researchers also concluded that training at a higher step frequency decreased lower extremity loading variables, and therefore, may be a good method in reducing risk of lower extremity running-related injuries, such as medial tibial stress syndrome, tibial stress fracture, or PFP. This study also supported the use of a metronome for step frequency training and found that each participant performed a step frequency within 5% of the designated metronome frequency, showing that runners adapted to the change in step frequency through auditory feedback via metronome to a significant degree .[9] However, this study did not follow the runners outside of the training environment or follow-up long-term to determine if the step frequency was maintained.

PFP is multi-factorial in nature and may be caused by issues with strength and neuromuscular control, flexibility, body structure, or due to issues in the selected running mechanics. Strengthening has been commonly used to treat PFP, focusing on quadriceps and hip strengthening protocols. However, recent literature has examined the effect of step frequency on the load through the patellofemoral joint and the neuromuscular adaptations that occur from increasing step frequency. Therefore, the purpose of this study was to examine the short term effects of step frequency training in a college-aged recreational runner with PFP.

METHODS

This study was a single-subject, case study design. The subject was a 19 year old male student at a Midwestern University who was a recreational runner running approximately 24 km/week. The subject was recruited through the use of a recruitment flyer. This

Payne, Barrett, Wilkins. Effect of step frequency on male with patellofemoral pain.
JSMAHS. 2016. 2(2)
Article 3

study was approved by the institutional review board. The criteria for PFP in this study were on the recruitment flyer and included: having anterior knee pain for at least 3 months, having anterior knee pain with 2 or more activities (ascending and descending stairs, squatting, kneeling, jumping, long periods of sitting).[10] The subject indicated that he had experienced knee pain for three months or longer and that he experienced pain with ascending stairs, squatting, kneeling on his knees, and sitting for long periods and thereby met the established inclusion criteria for this study.

The subject had a history of bilateral knee pain for 3-4 years. The subject had approximately one month of physical therapy intervention approximately 4 years ago for his knee pain. The subject reported running an average of 15-20 miles per week, typically 5 miles in 45-minute increments a few days a week. The subject was instructed to use the 2, 25-minute training sessions each week in place of two typical running days and was otherwise allowed to run outside of training like his typical routine.

At the first meeting, the subject signed an informed consent form. Additionally, the subject completed an initial Visual Analog Scale (VAS) and Lower Extremity Functional Scale (LEFS). The VAS has been repeatedly used in the literature as way to measure patient perceived pain. The VAS is a horizontal continuum from "no pain" to "very severe pain" and is 10 cm in length. The VAS score is measured in millimeters from the left hand end to the point where the patient marks. The Minimally Clinically Important Difference (MCID) in using the VAS in orthopedic populations undergoing conservative management of pain has been reported to be 1.4 cm.[11] The LEFS is another instrument that has been repeatedly used throughout the literature to measure function in the lower extremities. The LEFS lists 20 activities and patients indicate how much difficulty they have with each activity, from "extreme difficulty or unable to perform" to "no difficulty". Each level of difficulty is indicated by a number from 0 to 4 and these numbers are added in order to produce the LEFS score. A maximum score is 80 on the LEFS. Binkley, et al (1999) established a Minimally Clinically Important Difference (MCID) of 9 points for various lower extremity injuries and a Standard Error of Measurement (SEM) of 3.9 points.[12]

In order to assess the subject's preferred stride frequency, he was instructed to run at his normal, comfortable pace on the treadmill. As he ran at this self-selected pace, the primary investigator counted the steps taken by one foot for one minute and multiplied the number by two to calculate the preferred steps per minute. The subject's preferred stride frequency was 164 steps/minute. A 5% increase in preferred step frequency was 172 steps/minute for this subject.

The training took place over a 4 week period in the research lab. The instruments used included a Woodway PRO 27 (Waukesha, WI) treadmill and an iPad Air. The iPad was used to provide auditory feedback via a metronome application set to 172 steps/minute. The feedback schedule was similar to one established in visual retraining of runners with PFP [5], however, the 8 sessions were spread over a 4 week period in order to replicate a more typical physical therapy regime. The feedback schedule was as follows:
Week 1: 1 minute on, 1 minute off
Week 2: 1 minute on, 2 minutes off
Week 3: 1 minute on, 4 minutes off
Week 4: 1 minute on, 8 minutes off.

The subject was instructed to match pace set by the metronome and try to continue matching the pace when the metronome was off. During each training session, the subject first completed a warm-up run at a self-selected pace for 5 minutes. Next, the subject

was instructed to continue with a self-selected training pace and follow the feedback schedule as indicated for the remaining 20 minutes of training. Investigators did not provide verbal feedback regarding accuracy of matching the 172 steps/minute during the "on" or "off periods. The subject completed the VAS again at 2 weeks and at the end of the study at 4 weeks. The LEFS was also completed at 4 weeks. The initial VAS and LEFS were compared to the final VAS and LEFS to determine if the 5% increase in preferred stride frequency decreased the knee pain and increased function in this recreational runner. The VAS at 2 weeks was used simply to determine the subject's initial response to the training protocol.

RESULTS

The subject completed the study in full over the course of the 4 week training schedule. At the initial visit the subject completed the initial VAS and initial LEFS. Figure 1 represents the VAS scores at weeks 0, 2, and 4. The subjects VAS scores declined over the course of the study from 4.4 cm (0 weeks) to 1.8 cm (2 weeks) then to 0.5 cm (4 weeks). Figure 2 represents the LEFS scores for the subject. At the initial meeting the subject recoded a score of 57 on the LEFS. At 4 weeks, the LEFS score improved to 71.

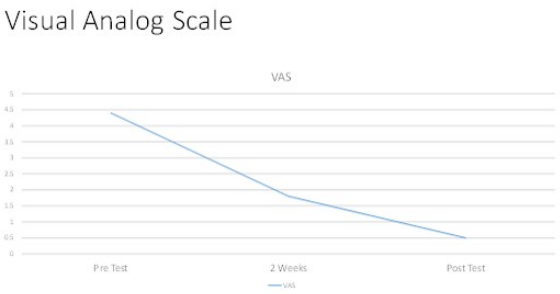

Figure 1: VAS data collected from the subject before the training schedule (pre-test), at 2 weeks into the training schedule, and after the 4-week training schedule (post-test).

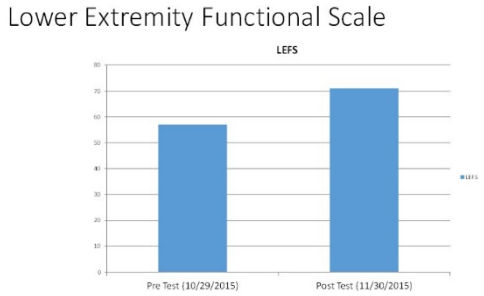

Figure 2: LEFS data collected from the subject before the 4 week training schedule (pre-test) and after the 4 week training schedule (post-test).

DISCUSSION

The results of this study supported the hypothesis that increasing a runner's preferred stride frequency by 5% during a 4 week training schedule would decrease their reported PFP as measured by a VAS. The drop of 3.9 cm was clinically significant given the MCID of 1.4 cm that has been reported.[11] The 14 point increase on the LEFS also exceeded the MCID of 9 points.[12]

The results of this case study support the theory that training a recreational runner with PFP at a step frequency 5% above (172 steps/minute) their preferred step frequency using an auditory feedback schedule supported by the literature over the course of 4 weeks will decrease their PFP and increase their function level. The process of using a metronome to provide auditory feedback was supported by the literature as well.[9]

Due to the single-subject design, further research is needed to allow the results to be generalized to recreational runners. The subject was not diagnosed with PFP through the use of any specific physical exam measures, but did meet the criteria for PFP as defined operationally in this study and in a manner that has been used in previous literature.[5] Additionally, examining the use of this treatment strategy between competitive and recreational runners as well as across a

Payne, Barrett, Wilkins. Effect of step frequency on male with patellofemoral pain.
JSMAHS. 2016. 2(2)
Article 3

wider age population are areas in which more research is needed. Long-term follow-up with subjects could be an area for further research as well. If it is determined that runners need intermittent "retraining", there are step frequency apps that could be used by these runners outside of a research facility. How often and for how long runners require feedback to maintain lower PFP levels has yet to be established. This runner also experienced pain in both of his knees, but was asked to complete the VAS and LEFS for the most symptomatic knee which may be a limitation of the study. The use of a symptom journal for runs outside of the training facility was not used, nor did this study employ any means to train frequency outside of the facility. Use of step frequency or cadence "applications" are widely available, and this could be an area for future research.

The data supports the development of further studies in the topic area of patellofemoral pain and stride frequency modification even if they cannot be generalized beyond this case report. The amount of time required for this patient was minimal to achieve the clinically important results with regard to decreasing PFP and increasing function as measured by the LEFS. Case studies such as this are important to validate these training strategies within populations suffering from PFP. Interventions that are functional in nature and go beyond treatment of PFP at the impairment level may be critical to the development of long-term solutions for PFP within the running community.

Areas for future research include studies involving both male and female runners and comparing the effectiveness of step frequency training on both recreational and competitive runners with PFP. A study that compared the use of this functional intervention against impairment-based interventions such as quadriceps and hip strengthening could be of benefit to determine if interventions employed in isolation are as effective as a combined, or multimodal rehabilitation program in the treatment of PFP.

REFERENCES

1. Taunton JE, Ryan MB, Clements DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A retrospective case-control analysis of 2002 running injuries. *Br J.Sports.Med*.2002;36:95-101. http://dx.doi.org/10.1136/bjsm.36.2.95
2. Witvrouw E, Callaghan M, Stefanik J, et al. Patellofemoral pain: consensus statement from the 3rd International Patellofemoral Pain Research Retreat held in Vancouver, September 2013. *Br J Sports Med*. 2014;48:411-414.
3. Ferber R, Noehren B, Hamill J, Davis IS. Competitive female runners with a history of iliotibial band syndrome demonstrate atypical hip and knee kinematics. *J Orthop Sports Phys Ther*. 2010;40:52-58.
4. Souza RB, Powers CM. Differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain. *J Orthop Sports Phys Ther*. 2009;39:12-19.
5. Willy RW, Scholz JP, Davis IS. Mirror gait retraining for the treatment of patellofemoral pain in female runners. *Clin Biomech (Bristol, Avon)*. 2012;27:1045-1051.
6. Lenhart RL, Thelen DG, Wille CM, Chumanov ES, Heiderscheit BC. Increasing running step rate reduces patellofemoral joint forces. *Med Sci Sports Exerc*. 2014;46(3):557-564.
7. Heiderscheit BC, Chumanov ES, Michalski MP, Wille CM, Ryan MB. Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc*. 2011;43:296-302.
8. Chumanov ES, Wille CM, Michalski MP, Heiderscheit BC. Changes in muscle activation patterns when running step rate is increased. *Gait Posture*. 2012;36:231-235.
9. Hobara H,Sato T, Sakaguchi M, Nakazawa K. Step frequency and lower extremity loading during running. *Int J Sports Med*. 2012;33:310-313.
10. dos Reis AC, Correa, JCF, Bley, AS, Rabelo ND, Fukuda, TY, Lucarelli, PG. Kinematic and kinetic analysis of the single-leg triple hop test in women with and without patellofemoral pain. *J Orthop.Sports.Phys.Ther*.2015;45(10):799-807.
11. Tashjian RZ, Deloach J, Porucznik CA, Powell AP. Minimal clinically important difference (MCID)

and patient acceptable symptomatic state (PASS) for visual analog scales (VAS) measuring pain in patients treated for rotator cuff disease. *J Shoulder Elbow Surg.* 2009;18:927-932.

12. Binkley JM, Stratford, PW, et al. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. *Phys Ther*. 1999;79(4): 371-383.

Payne, Barrett, Wilkins. Effect of step frequency on male with patellofemoral pain. JSMAHS. 2016. 2(2)
Article 3