

[CASE REPORT]

ROY T.H. CHEUNG, PT, PhD¹ • IRENE S. DAVIS, PT, PhD²

Landing Pattern Modification to Improve Patellofemoral Pain in Runners: A Case Series

Patellofemoral pain (PFP) is one of the most common overuse injuries of the lower extremity. It affects 10% to 20% of the general population¹⁸ and is associated with higher risk of injury in active females.³⁴ The findings of a previous study suggested that a history of PFP increases the risk for subsequent development of patellofemoral osteoarthritis.³⁵ The nature of PFP is multifactorial, and many risk factors have been associated with this condition.^{5,10} Locally,

imbalance of the quadriceps musculature²⁵ and maltracking of the patella²⁴ are 2 potential factors that may lead to

PFP. Through the linkage of the kinetic chain, hip muscle weakness^{11,29} and excessive foot pronation²⁰ have also been

proposed to lead to the development of PFP. Therefore, different treatment approaches^{6,11} have been evaluated in the management of PFP.

Running is a popular sport worldwide. According to an epidemiological study,³⁶ the overall annual rate of running injury ranges from 37% to 56%. The incidence rate, calculated according to running time, is between 2.5 to 12.1 injuries per 1000 hours of running, with the knee being the most vulnerable joint. Among those knee injuries, PFP is the most common condition. PFP in runners has been linked to abnormal lower extremity movement patterns^{4,22} and weaknesses of hip muscles.³³ However, the role of abnormal kinetics in the development of PFP has not been fully examined. Vertical impact loading has been associated with a number of conditions, including plantar fasciitis,²⁷ tibial stress fractures,²⁸ and knee osteoarthritis.^{13,23} A recent pilot study suggested that runners with a history of PFP may exhibit a higher impact peak and loading rate than healthy runners.⁹

Approximately 75% of runners make initial contact with the ground using a rearfoot strike pattern (ie, they land on their heels).¹² This rearfoot strike pattern results in a very distinct vertical impact peak, which may be eliminated or signifi-

● **STUDY DESIGN:** Case series.

● **BACKGROUND:** Patellofemoral pain is a common overuse injury in runners. Recent findings suggest that patellofemoral pain is related to high-impact loading associated with a rearfoot strike pattern. This case series describes the potential training effects of a landing pattern modification program to manage patellofemoral pain in runners.

● **CASE DESCRIPTION:** Three female runners with unilateral patellofemoral pain who initially presented with a rearfoot strike pattern underwent 8 sessions of landing pattern modification program using real-time audio feedback from a force sensor placed within the shoe. Ground reaction forces during running were assessed with an instrumented treadmill. Patellofemoral pain symptoms were assessed using 2 validated questionnaires. Finally, running performance was measured by self-reported best time to complete a 10-km run in the previous month. The runners were assessed before, immediately after, and 3

months following training.

● **OUTCOMES:** The landing pattern of runners was successfully changed from a rearfoot to a non-rearfoot strike pattern after training. This new pattern was maintained 3 months after the program. The vertical impact peak and rates of loading were shown to be reduced. Likewise, the symptoms related to patellofemoral pain and associated functional limitations were improved. However, only 1 of the participants reported improved running performance after the training.

● **DISCUSSION:** This case series provided preliminary data to support further investigation of interventions leading to landing pattern modification in runners with patellofemoral pain.

● **LEVEL OF EVIDENCE:** Therapy, level 4. *J Orthop Sports Phys Ther* 2011;41(12):914-919, Epub 25 October 2011. doi:10.2519/jospt.2011.3771

● **KEY WORDS:** biofeedback, gait retraining, impact peak, impact rate, landing pattern

¹Research Associate, Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hung Hom, Hong Kong, China; Postdoctoral Fellow, Department of Physical Medicine and Rehabilitation, Harvard Medical School, Harvard University, Cambridge, MA. ²Director, Spaulding National Running Center, Department of Physical Medicine and Rehabilitation, Harvard Medical School, Harvard University, Cambridge, MA. The experimental protocol of this study was reviewed and approved by The Ethics Review Committee of the Hong Kong Polytechnic University. Address correspondence to Dr Roy Cheung, Spaulding National Running Center, Department of Physical Medicine and Rehabilitation, Harvard Medical School, Harvard University, Cambridge, MA 02138. Email: RTCheung@partners.org

cantly reduced with a midfoot strike or forefoot strike landing pattern. Previous studies have reported that vertical impact peak (VIP), average vertical loading rate (AVLR), and instantaneous vertical loading rate (IVLR) are lower in runners with midfoot and forefoot strike patterns than those with a rearfoot strike pattern.^{1,2}

It has also been shown that the peak knee joint net extensor moment is reduced when running with a midfoot strike compared to a rearfoot strike pattern.³⁷ Consequently, this may have the effect of reducing the magnitude of patellofemoral joint contact force. Additionally, the reduced load rate of the vertical ground reaction force may translate into lower rates of loading at the patellofemoral joint. Because human tissue is viscoelastic, its loading response is time dependent and less prone to injury at lower rates of loading.^{17,30} For these reasons, a midfoot or forefoot strike pattern may be beneficial in reducing symptoms in runners with PFP.

The purpose of this case series was to examine the effect of a novel intervention on reducing vertical load rates and improving pain and function in runners with PFP. If high rates of loading are associated with PFP, it is logical to expect PFP to diminish with changes in landing pattern that reduce loading magnitude and rates. To date, there are no data to support the use of landing pattern modification training in runners with PFP.

CASE DESCRIPTION

THREE FEMALE RUNNERS BETWEEN the ages of 26 and 32 years, who ran between 20 and 30 km per week, were recruited from a local running club. All were diagnosed with PFP by an orthopaedic surgeon. The participants were screened by a physical therapist to exclude any symptoms attributable to ligament, meniscus, tendon, or other soft tissue lesions. All 3 runners reported the presence of symptoms related to PFP for at least 12 months prior to beginning the gait retraining program, and

TABLE 1		PARTICIPANT DEMOGRAPHICS		
Characteristics	Runner 1	Runner 2	Runner 3	
Height, m	1.62	1.70	1.68	
Mass, kg	45.0	51.2	48.0	
BMI, kg/m ²	17.1	17.6	17.0	
Running experience, y	3	5	5	
Average running distance, km/wk	20	30	30	
Duration of patellofemoral pain symptoms, y	2.5	4.0	3.5	
Affected side	Right	Right	Left	

Abbreviation: BMI, body mass index.

all 3 failed to improve when previously treated with a more traditional physical therapy program consisting of quadriceps training, hip strengthening, and electrotherapy. Data from insole sensors (Pedar Novel GmbH, Munich, Germany), worn while running on a treadmill, were used to confirm that the 3 runners used a rearfoot strike pattern when running. In addition, all the participants were free from any cardiovascular or orthopaedic condition except PFP. Their demographics, running experience, regular training mileage, and information about PFP are provided in **TABLE 1**. The experimental procedures were reviewed and approved by The Ethics Review Committee of the Hong Kong Polytechnic University, and all the participants provided written informed consent before participation.

Evaluation

All 3 runners were invited to our laboratory for 3 identical testing sessions. In addition to the pretraining and post-training testing sessions, the participants were evaluated at a 3-month follow-up. Participants did not receive any other treatment or rehabilitation program throughout the duration of the study.

In each testing session, runners performed a standardized warm-up, including lower extremity stretching exercises and 15 minutes of light-resistance cycling before the running evaluation. They then ran on an instrumented treadmill (Zebris FDM; Zebris Medical GmbH, Allgäu, Germany) at 10 km/h, while wearing

standardized test shoes (Supernova Cushion; Adidas, Portland, OR). The treadmill had an embedded pressure mat containing more than 15 000 pressure sensors, from which data were integrated to produce the vertical ground reaction force. Once the runners demonstrated a stable running pattern, data were sampled at 200 Hz for 10 seconds. Though this sampling frequency was relatively low compared to other studies of ground reaction forces, the focus of this study was on the vertical ground reaction force during the impact phase, which typically lasts 20 to 30 milliseconds and occurs at a frequency of 30 to 50 Hz.^{3,15} The Nyquist-Shannon sampling theorem recommends that data be sampled at a rate of at least twice the frequency of the signal of interest.³¹ Therefore, a sampling rate of 200 Hz (4 times the signal frequency) should have adequately protected against signal aliasing. Ground reaction force data were filtered using a 50-Hz low-pass Butterworth filter. The VIP, AVLR, and IVLR were obtained by the method described by Crowell and Davis.⁸ These early impact variables were chosen for their demonstrated association with various running injuries, including PFP.^{9,13,23,27,28} All variables were averaged across 12 contacts from the symptomatic lower extremity within a 10-second window. Two validated questionnaires were used to assess pain and function. The first, the Kujala Scale,¹⁶ consisted of 13 multiple-choice questions that measured the severity of signs and symptoms and

[CASE REPORT]



FIGURE 1. Audio biofeedback device and force transducer affixed to the rearfoot area of the shoe insole.

the extent of limitations in functional activities related to PFP. An overall score of 0 (worst) to 100 (normal knee without symptoms and no restriction to daily functions) indicated the severity of PFP. The second measure of pain and function was the PFP Scale. Designed by Laprade and Culham,¹⁹ this scale encompassed 10 statements presented in a visual analog format, regarding patellofemoral pain. An overall score of 0 (no pain) to 100 (worst pain imaginable) indicated the severity of PFP. The excellent reliability of these 2 instruments has been established by previous studies.^{19,32} The minimal clinically important difference (MCID) of the Kujala Scale is 8 to 10 points, according to a database containing 20 individuals with PFP.⁷ Unfortunately, there is no reported MCID value for the PFP Scale. To assess running performance, the participants also reported their best time to complete a 10-km run in the previous month.

Gait Retraining

The runners participated in 8 sessions of landing pattern modification training over 2 weeks (4 sessions per week). A force transducer (Digi-Key Corp, Thief River Falls, MN), connected to an audible buzzer and synchronized with the instrumented treadmill, was used to generate feedback. The transducer was placed inside the shoe of the symptomatic lower extremity (FIGURE 1), under the calcaneus, and issued a warning beep when the individual landed

TABLE 2		RESULTS OF RETRAINING		
Measure	Runner 1	Runner 2	Runner 3	
Landing pattern accuracy, % of nonrearfoot strike				
Pretraining	0	0	0	
Posttraining	93	100	100	
3-mo follow-up	100	100	93	
Kinetics (mean ± SD)				
Vertical impact peak, BW				
Pretraining	1.7 ± 0.1	1.7 ± 0.2	1.3 ± 0.1	
Posttraining	1.4 ± 0.1	1.5 ± 0.1	1.1 ± 0.1	
3-mo follow-up	1.4 ± 0.2	1.5 ± 0.1	1.1 ± 0.2	
Average loading rate, BW/s				
Pretraining	48.2 ± 6.9	55.8 ± 7.6	41.4 ± 8.5	
Posttraining	37.7 ± 7.7	38.7 ± 8.3	35.2 ± 8.6	
3-mo follow-up	35.5 ± 7.6	36.2 ± 8.0	34.9 ± 8.2	
Instantaneous loading rate, BW/s				
Pretraining	69.6 ± 7.0	72.3 ± 7.9	60.8 ± 8.1	
Posttraining	51.7 ± 7.5	52.2 ± 7.9	50.8 ± 8.7	
3-mo follow-up	50.7 ± 7.8	49.0 ± 8.0	52.4 ± 8.8	
Symptoms, %				
Kujala Scale*				
Pretraining	87	72	85	
Posttraining	94	85	96	
3-mo follow-up	94	90	95	
Patellofemoral Pain Scale [†]				
Pretraining	29.7	41.0	22.7	
Posttraining	10.2	30.6	9.1	
3-mo follow-up	8.8	25.9	7.8	
Running performance, min				
Self-reported best 10-km time in recent month				
Pretraining	62	67	61	
Posttraining	62	66	60	
3-mo follow-up	62	62	61	

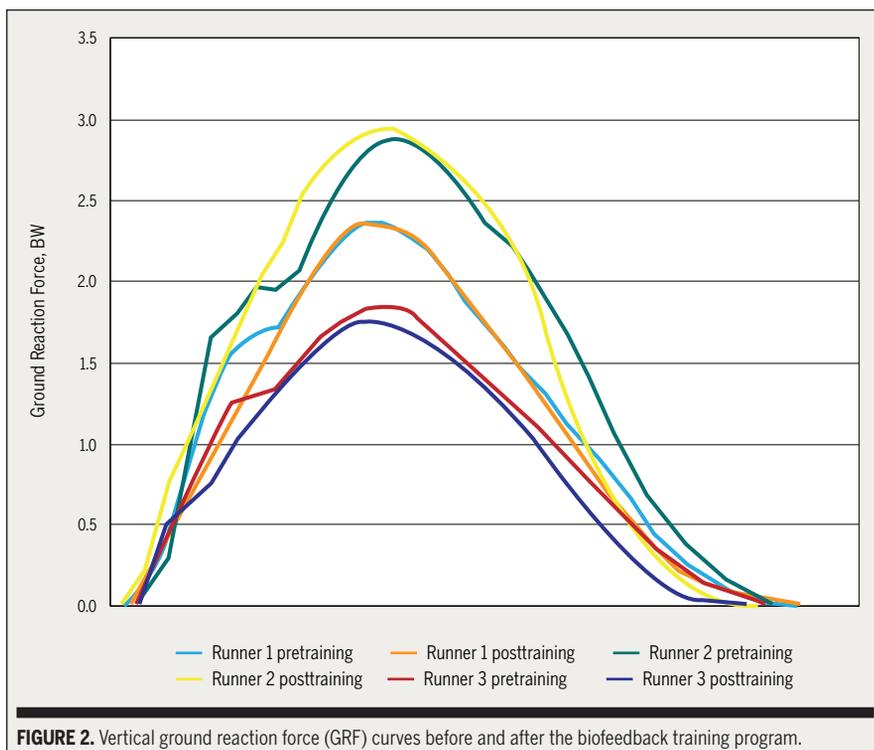
Abbreviation: BW, participant's body weight.
 *Lower number indicates greater functional limitations associated with patellofemoral pain.
 †Lower number indicates less patellofemoral pain.

on the heel. During the training, the participants were asked to run on a treadmill at their self-selected pace. Runners were instructed to eliminate the buzzer noise by shortening their stride length and avoiding a rearfoot strike landing. The run time and feedback schedule described by Crowell and Davis⁸ was followed. The run time was incrementally increased from 15 minutes to 30 minutes over the 8 sessions. The audio feedback was progressively removed in the last 4 sessions. The ground reaction forces were again assessed fol-

lowing the end of training. The runners were also advised to maintain their new running pattern during their regular running practice after the training. They returned to complete another gait analysis assessment 3 months following the end of their training.

OUTCOMES

AFTER THE LANDING PATTERN MODIFICATION program, the runners were able to eliminate heel strike in 90%



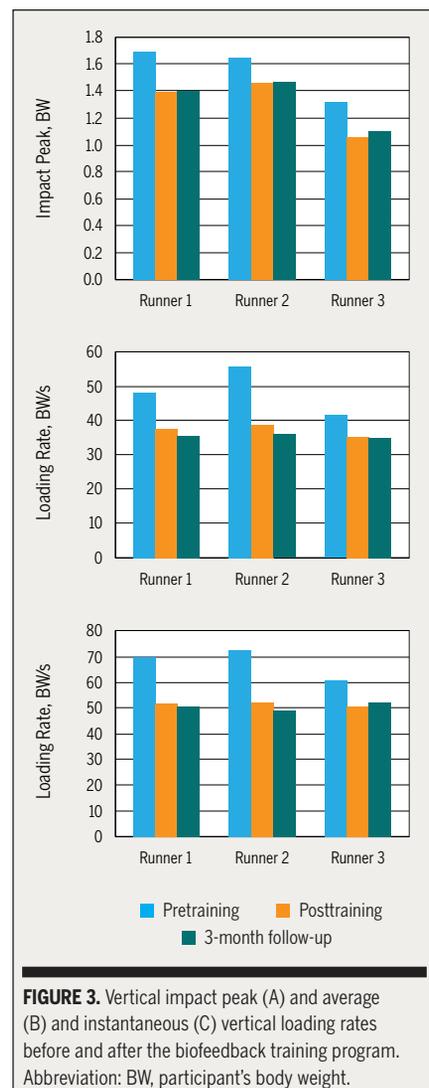
of their footfalls (TABLE 2). Participants demonstrated reductions between 10.9% and 35.1% in VIP, IVLR, and AVLR after the training program (FIGURE 2). These reductions were maintained 3 months after training (FIGURE 3). Additionally, the pain scores on the PFP Scale were improved by 10.4 to 19.5 points. The Kujala Scale score was increased by 7 to 13 points across runners (TABLE 2). Running performance was improved in 1 of the participants (runner 2), who reported a 5-minute decrease in her 10-km run time (TABLE 2).

DISCUSSION

THIS SMALL CASE SERIES PRESENTS preliminary findings to support a novel intervention for runners with PFP. All 3 female participants were able to alter their landing patterns following 8 sessions of gait retraining using audio biofeedback. Changes were maintained at a 3-month follow-up. These changes were associated with reductions in pain and improvements in function.

This case series supports the success-

ful outcomes of other retraining studies of similar intensity. Crowell and Davis⁸ reported that runners were able to reduce the impact peak after 8 sessions of visual feedback training and to maintain this reduction 1 month after training. In a previous study, the runners were not instructed on how to alter their gait and might have used different strategies to reduce their impact loading; conversely, this study standardized the intervention with instructions and audio feedback on a specific modification in landing pattern. In another training program described by Noehren et al,²⁶ 10 runners with PFP underwent a gait reeducation program for 8 sessions to reduce hip internal rotation and adduction, using real-time visual feedback. The participants in that study demonstrated improvement in hip biomechanics, as well as an 86% reduction in pain during activity and an 11-point improvement on the Lower Extremity Functional Index 1 month posttraining. Although the current case series focused on mechanics different from those addressed by Noehren et al,²⁶ improvements in pain and function in its 3 participants



were similar to those reported in the latter study.

Recent publications recommend barefoot running rather than running with shoes, because barefoot running promotes a midfoot strike or a forefoot strike landing pattern and results in reduced impact peak and loading rates.^{14,21} The current program indirectly altered the running kinetics by avoiding rearfoot strike landing pattern. Vertical impact loading (quantified as VIP, AVLR, and IVLR) was reduced in all 3 runners after the program. The amount of reduction in VIP in this case series was similar to the change reported in the study by Altman and Davis,¹ who compared the difference in kinetics between runners with rearfoot

[CASE REPORT]

strike and midfoot strike patterns. The runners in our case series demonstrated greater reductions in AVLr (15.1%-35.1%) and IVLr (13.7%-32.3%) than those reported by Altman and Davis¹ (12%-16%).

In this case series, the change in Kujala Scale scores in 2 of the runners exceeded the MCID for this outcome measure, indicating that the observed changes were clinically relevant. The improvement presented in the other runner (runner 1) was marginally relevant. Although there is no reference MCID value for the PFP Scale, an improvement in scores on the PFP Scale by 37% to 70% may be regarded as clinically meaningful. While all 3 participants demonstrated reductions in PFP after training, only 1 runner reported improvement in her 10-km run time. Interestingly, this runner presented with the greatest initial level of PFP and the slowest 10-km time. Therefore, her success might be due to the fact that she had the greatest opportunity for improvement among the 3 participants.

Previous approaches to manage PFP have focused on, among other interventions, quadriceps training,²⁵ patella taping,²⁴ hip strengthening,^{11,29} and foot postural alignment correction.⁴ However, none of these interventions directly address underlying running mechanics that may be contributing to this injury. This preliminary investigation suggests that retraining landing pattern addresses one of these underlying issues.

We hypothesize that the change in external mechanics had a beneficial effect on the loading of the patellofemoral joint. While joint kinetics were not measured in this study, other studies have demonstrated a reduced knee extension moment with a more midfoot or forefoot strike pattern.³⁷ It is likely that lower rates of external loading associated with change in strike pattern reduce the loading rates at the patellofemoral joint level, which may account for the improvement in pain and function experienced by the 3 runners in this case series.

CONCLUSION

THE RESULTS OF THIS CASE SERIES suggest that gait retraining to reduce loading in runners with PFP has promise and may provide a basis for conducting a larger scale study. ●

ACKNOWLEDGEMENTS: *The authors thank Mr Shing-chung Chan and Mr Sean Kwan from the Department of Rehabilitation Sciences, Hong Kong Polytechnic University, for their technical support.*

REFERENCES

1. Altman A, Davis I. Impact loading can be reduced with a midfoot strike pattern. *Med Sci Sports Exerc.* 2010;42:676-677.
2. Bishop M, Fiolkowski P, Conrad B, Brunt D, Horodyski M. Athletic footwear, leg stiffness, and running kinematics. *J Athl Train.* 2006;41:387-392.
3. Bobbert MF, Schamhardt HC, Nigg BM. Calculation of vertical ground reaction force estimates during running from positional data. *J Biomech.* 1991;24:1095-1105.
4. Cheung RT, Ng GY, Chen BF. Association of footwear with patellofemoral pain syndrome in runners. *Sports Med.* 2006;36:199-205.
5. Collado H, Fredericson M. Patellofemoral pain syndrome. *Clin Sports Med.* 2010;29:379-398. <http://dx.doi.org/10.1016/j.csm.2010.03.012>
6. Collins N, Crossley K, Beller E, Darnell R, McPoil T, Vicenzino B. Foot orthoses and physiotherapy in the treatment of patellofemoral pain syndrome: randomised clinical trial. *BMJ.* 2008;337:a1735.
7. Crossley KM, Bennell KL, Cowan SM, Green S. Analysis of outcome measures for persons with patellofemoral pain: which are reliable and valid? *Arch Phys Med Rehabil.* 2004;85:815-822.
8. Crowell HP, Davis IS. Gait retraining to reduce lower extremity loading in runners. *Clin Biomech (Bristol, Avon).* 2011;26:78-83. <http://dx.doi.org/10.1016/j.clinbiomech.2010.09.003>
9. Davis I, Bowser B, Hamill J. Vertical impact loading in runners with a history of patellofemoral pain syndrome [abstract]. *Med Sci Sports Exerc.* 2010;42:682.
10. Davis IS, Powers CM. Patellofemoral pain syndrome: proximal, distal, and local factors, an international retreat, April 30-May 2, 2009, Fells Point, Baltimore, MD. *J Orthop Sports Phys Ther.* 2010;40:A1-16. <http://dx.doi.org/10.2519/jospt.2010.0302>
11. Fukuda TY, Rossetto FM, Magalhaes E, Bryk FF, Lucareli PR, de Almeida Aparecida Carvalho N. Short-term effects of hip abductors and lateral rotators strengthening in females with patellofemoral pain syndrome: a randomized controlled clinical trial. *J Orthop Sports Phys Ther.* 2010;40:736-742. <http://dx.doi.org/10.2519/jospt.2010.3246>
12. Hasegawa H, Yamauchi T, Kraemer WJ. Foot strike patterns of runners at the 15-km point during an elite-level half marathon. *J Strength Cond Res.* 2007;21:888-893. <http://dx.doi.org/10.1519/R-22096.1>
13. Hunt MA, Hinman RS, Metcalf BR, et al. Quadriceps strength is not related to gait impact loading in knee osteoarthritis. *Knee.* 2010;17:296-302. <http://dx.doi.org/10.1016/j.knee.2010.02.010>
14. Jungers WL. Biomechanics: barefoot running strikes back. *Nature.* 2010;463:433-434. <http://dx.doi.org/10.1038/463433a>
15. Kram R, Griffin TM, Donelan JM, Chang YH. Force treadmill for measuring vertical and horizontal ground reaction forces. *J Appl Physiol.* 1998;85:764-769.
16. Kujala UM, Jaakkola LH, Koskinen SK, Taimela S, Hurme M, Nelimarkka O. Scoring of patellofemoral disorders. *Arthroscopy.* 1993;9:159-163.
17. Kulin RM, Jiang F, Vecchio KS. Effects of age and loading rate on equine cortical bone failure. *J Mech Behav Biomed Mater.* 2011;4:57-75. <http://dx.doi.org/10.1016/j.jmbbm.2010.09.006>
18. Laprade J, Culham E. Radiographic measures in subjects who are asymptomatic and subjects with patellofemoral pain syndrome. *Clin Orthop Relat Res.* 2003;172-182. <http://dx.doi.org/10.1097/01.blo.0000079269.91782.f5>
19. Laprade JA, Culham EG. A self-administered pain severity scale for patellofemoral pain syndrome. *Clin Rehabil.* 2002;16:780-788.
20. Levinger P, Gillear W. The heel strike transient during walking in subjects with patellofemoral pain syndrome. *Phys Ther Sport.* 2005;6:83-88.
21. Lieberman DE, Venkadesan M, Werbel WA, et al. Foot strike patterns and collision forces in habitually barefoot versus shod runners. *Nature.* 2010;463:531-535. <http://dx.doi.org/10.1038/nature08723>
22. Lun V, Meeuwisse WH, Stergiou P, Stefanyszyn D. Relation between running injury and static lower limb alignment in recreational runners. *Br J Sports Med.* 2004;38:576-580. <http://dx.doi.org/10.1136/bjism.2003.005488>
23. Mundermann A, Dyrby CO, Andriacchi TP. Secondary gait changes in patients with medial compartment knee osteoarthritis: increased load at the ankle, knee, and hip during walking. *Arthritis Rheum.* 2005;52:2835-2844. <http://dx.doi.org/10.1002/art.21262>
24. Ng GY, Wong PY. Patellar taping affects vastus medialis obliquus activation in subjects with patellofemoral pain before and after quadriceps muscle fatigue. *Clin Rehabil.* 2009;23:705-713. <http://dx.doi.org/10.1177/0269215509334835>
25. Ng GY, Zhang AQ, Li CK. Biofeedback exercise improved the EMG activity ratio of the medial and lateral vasti muscles in subjects with patellofemoral pain syndrome. *J Electromyogr Kinesiol.* 2008;18:128-133. <http://dx.doi.org/10.1016/j.jelekin.2006.08.010>

26. Noehren B, Scholz J, Davis I. The effect of real-time gait retraining on hip kinematics, pain and function in subjects with patellofemoral pain syndrome. *Br J Sports Med.* 2011;45:691-696. <http://dx.doi.org/10.1136/bjism.2009.069112>
27. Pohl MB, Hamill J, Davis IS. Biomechanical and anatomic factors associated with a history of plantar fasciitis in female runners. *Clin J Sport Med.* 2009;19:372-376. <http://dx.doi.org/10.1097/JSM.0b013e3181b8c270>
28. Pohl MB, Mullineaux DR, Milner CE, Hamill J, Davis IS. Biomechanical predictors of retrospective tibial stress fractures in runners. *J Biomech.* 2008;41:1160-1165. <http://dx.doi.org/10.1016/j.jbiomech.2008.02.001>
29. Powers CM. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. *J Orthop Sports Phys Ther.* 2010;40:42-51. <http://dx.doi.org/10.2519/jospt.2010.3337>

30. Schaffler MB, Radin EL, Burr DB. Mechanical and morphological effects of strain rate on fatigue of compact bone. *Bone.* 1989;10:207-214.
31. Shannon C. Communication in the presence of noise. *Proceedings of the IEEE.* 1999;86:447-457.
32. Smith TO, Davies L, O'Driscoll ML, Donell ST. An evaluation of the clinical tests and outcome measures used to assess patellar instability. *Knee.* 2008;15:255-262. <http://dx.doi.org/10.1016/j.knee.2008.02.001>
33. Souza RB, Powers CM. Predictors of hip internal rotation during running: an evaluation of hip strength and femoral structure in women with and without patellofemoral pain. *Am J Sports Med.* 2009;37:579-587. <http://dx.doi.org/10.1177/0363546508326711>
34. Taunton JE, Ryan MB, Clement 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.
35. Utting MR, Davies G, Newman JH. Is anterior knee pain a predisposing factor to patellofemoral osteoarthritis? *Knee.* 2005;12:362-365. <http://dx.doi.org/10.1016/j.knee.2004.12.006>
36. van Mechelen W. Running injuries. A review of the epidemiological literature. *Sports Med.* 1992;14:320-335.
37. Williams K. The dynamics of running. In: Zatsiorsky V, ed. *Biomechanics in Sport.* Oxford, UK: Blackwell Science Ltd; 2000.



MORE INFORMATION
WWW.JOSPT.ORG

EARN CEUs With JOSPT's Read for Credit Program

JOSPT's **Read for Credit (RFC)** program invites *Journal* readers to study and analyze selected JOSPT articles and successfully complete online quizzes about them for continuing education credit. To participate in the program:

1. Go to www.jospt.org and click on **"Read for Credit"** in the left-hand navigation column that runs throughout the site or on the link in the **"Read for Credit"** box in the right-hand column of the home page.
2. Choose an article to study and when ready, click **"Take Exam"** for that article.
3. Login and pay for the quiz by credit card.
4. Take the quiz.
5. Evaluate the RFC experience and receive a personalized certificate of continuing education credits.

The RFC program offers you 2 opportunities to pass the quiz. You may review all of your answers—including the questions you missed. You receive **0.2 CEUs**, or 2 contact hours, for each quiz passed. The *Journal* website maintains a history of the quizzes you have taken and the credits and certificates you have been awarded in the **"My CEUs"** section of your **"My JOSPT"** account.