The Influence of Running on Patellar Water Content and Bone Marrow Edema in Females with and without Patellofemoral Pain

K-Y. Ho[1], H. H. Hu[2], K. S. Nayak[2], P. M. Colletti[3], and C. M. Powers[1]

[1]Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, California, United States, [2]Department of Electrical Engineering, University of Southern California, Los Angeles, California, United States, [3]Department of Radiology, University of Southern California, Los Angeles, California, United States

Introduction – It has been suggested that patellofemoral pain (PFP) is the result of increased pressure on highly innervated subchondral bone[1]. Current literature also suggests that individuals with PFP exhibit greater patellofemoral joint stress during functional activities[2]. Repetitive overloading of the patellofemoral joint is thought to result in articular cartilage breakdown, increased subchondral bone thickness and stiffness, and bone marrow edema (BME)[3]. Bone marrow edema is the accumulation of extracellular fluid within bone marrow and has been suggested as the source of pain in degenerated joints[4]. Additionally, it has been suggested that BME is related to repetitive high-stress activities (e.g., running)[5]. The purpose of this study was to quantify the influence of running on bone marrow water content changes in individuals with and without PFP. To accomplish this goal, we used an iterative decomposition of water and fat with echo asymmetry and least squares estimation (IDEAL) MR protocol[6,7].

Methods – Two female subjects with PFP (34.5±6.4 years, 1.68±0.0 m, 60.3±4.6 kg) and 2 pain-free female controls (28.0±4.2 years, 1.64±0.0 m, 55.5±5.0 kg) participated in this study. Study procedures included 1) a pre-running MR scan, 2) a 40-min running session, and 3) a post-running MR scan immediately following running. Each subject performed treadmill running with a perceived exertion level of 13 (moderate) based on the Borg Scale. A 10-cm visual analog scale (VAS) was used to assess pain levels before and after running. MRI assessments were performed on a GE 3Tesla scanner with an 8-element knee coil. A spoiled-gradient-echo IDEAL pulse sequence was utilized: TR= 20.2 ms, TE= {1.68 2.67 3.65 4.63 5.62 6.61} ms, slice thickness= 2 mm, FOV= 160*160 mm, matrix= 256*256, BW= 125 kHz. The reconstructed fat-fraction images were used for analysis. Water fraction was defined as 100-fat fraction (%). Local BME was defined as the diffuse dark signals adjacent to the articular cartilage (Fig. 1b). To compare the water signal before and after exercise, the local BME sites and the subchodral bone marrow region (defined as the bright region under articular cartilage) was manually contoured and measured (Fig. 1). Equation 1 was used to compute the water content of the images measured. Equation 2 was used to estimate the water volume of local BME.

$$Eq.1.\quad Water\ Content\ (\%) = \frac{\sum_1^n (Water\ Fraction\ (n) \times Area\ Measured\ (n))}{\sum_1^n Area\ Measured\ (n)}$$

$$Eq.2\quad Water\ Volume\ (mm^3) = \sum_1^n [Water\ Fraction\ (n) \times Voxel\ volume \times Number\ of\ Voxels]$$

, where n=number of images

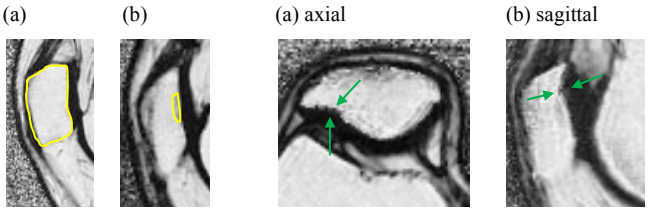

Fig.1. Measurement of water signal: (a) bone marrow region; (b) local BME.

Fig. 2. Both PFP subjects showed local BME on the lateral facet of patella in fat-fraction images. Arrows highlight the local BME.

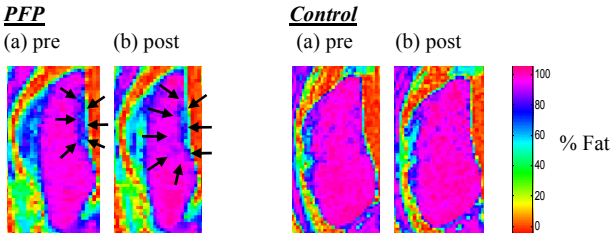

Fig. 3. Diffuse and growing region of local BME was found in PFP subjects after running. Arrows highlight the local BME sites.

Results – Prior to running, the subjects with PFP demonstrated greater patellar water content compared to the pain-free controls (Fig. 4a). Additionally, both subjects with PFP demonstrated local BME on the lateral facet of patella (Fig. 2). After running, PFP subjects reported an average increase in pain of 4.7±4.4. No pain was reported in the control subjects post-running. The increased pain in the PFP subjects was accompanied by elevated water content and increased volume of local BME (Fig.3, Fig. 4b-c). Additionally, the PFP subjects demonstrated increased water content of the subchondral bone marrow region of patella post-running while the controls showed no changes in water content (Fig. 4a).

Discussion – The current study demonstrates that the IDEAL sequence can be used to quantify water signal in the patella. Our data reveal that in persons with PFP, water content and volume of local BME increases in response to 40-min of moderate effort running. The higher water content post-running may result in elevated intraosseous pressure thereby creating pain. As only 2 PFP and 2 control subjects were studied in this preliminary investigation, future efforts will focus on increasing the sample size to better understand the influence of loading on bone marrow water signal in persons with PFP.

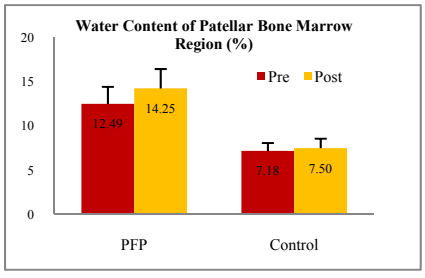

Fig. 4a. Average water content of patellar bone marrow region in PFP and control subjects.

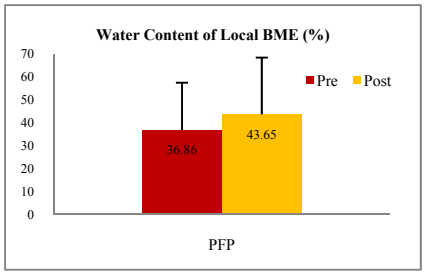

Fig. 4b. Average water content of local BME in PFP subjects.

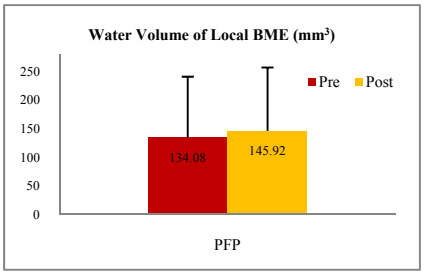

Fig. 4c. Average water volume of local BME in PFP subjects.

Acknowledgement – The authors thank Huanzhou Yu and Ann Shimakawa from GE Healthcare Applied Science Laboratory for support.

Reference – [1] Gerbino P, et al. *Clin J Pain* 22:154-159, 2006. [2] Heino Brechter J and Powers C. *Med Sci Sports Exerc* 34: 1582-1593, 2002. [3] Karsdal M, et al. *Osteoarthritis Cartilage* 16: 638-646, 2008. [4] Sowers M, et al. *Osteoarthritis Cartilage* 11:387-383, 2003. [5] Hofmann S, et al. *Orthop Clin North Am* 35: 321-333, 2004. [6] Kijowski R, et al. *J Magn Reson Imaging* 29:436-442, 2009. [7] Reeder SB, et al. *J Magn Reson Imaging*. 25:644-652, 2007.