

Motion as Medicine:

Do Patients with Osteoarthritis Need Stability or Mobility?

BY ROY H. LIDTKE, DPM, FACFAOM

BILLIONS OF DOLLARS SPENT ANNUALLY. OVER 650,000 TOTAL KNEE SURGERIES DONE ANNUALLY. NUMBERS LIKE THIS FORCE US TO PAY ATTENTION TO A RISING PROBLEM IN HEALTHCARE.

Osteoarthritis (OA) is the most common form of lower extremity arthritis with close to 30 million people in the U.S. suffering from this debilitating disease.¹ One third of all adults over 65 have osteoarthritis with the medial knee the most affected joint.²⁻⁴ The economic and societal impact of lower extremity arthritis is a staggering \$171 billion per year in direct medical care and job related costs of \$13.2 billion per year.⁵⁻⁸

Knee OA is no longer seen as a disease of the old. In 1990 the average age of physician diagnosed osteoarthritis was 69 years old. Twenty years later the average age of diagnosed OA fell to 56. Currently 40% of knee replacements are done on patients under the age of 65. Research is showing that osteoarthritis probably begins in the second and third decades of life and continues to progress until it becomes symptomatic and we seek medical treatment.

Much of the research for the past 20 years has been focused on the biochemical and metabolic processes of cartilage damage and repair. Despite these great efforts, treatment of knee OA remains largely palliative focusing on oral analgesics and often ending in destruction of the joint with an arthroplasty. Researchers have only recently returned to investigating the biomechanical pathology that underlies much of the disease progression.

For years the general consensus was that pain in arthritis was a direct result of the movement of the joint, therefore the best treatment was to try and immobilize the joint as best we can. What the researchers have recently discovered is beginning to change the way we think about joint loading, the influence of the foot on lower extremity mechanics, and even our notions of what is best for our patient, mobility or stability.

Knee Mechanics and the Foot

There are only two sources of aberrant loads on the knee. One is the external ground reaction force (GRF) from gravity acting on our body mass and the other from our internal muscles. As we walk, the external ground reaction force vector applied to the lower extremity is counteracted by the internal muscle moments around each joint segment. Since these forces are applied at a distance from the rotational center of the joints they are considered moments of force. Individuals with a varus alignment of the knee joint have a greater incidence of arthritis related pain and have a larger external adduction moment

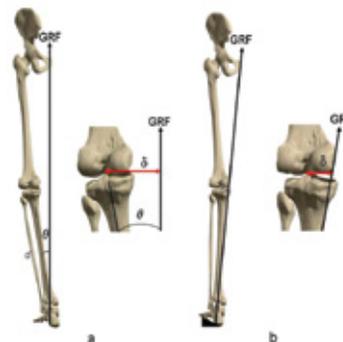


Figure 1a. Ground reaction force (GRF) vector pointing to body center of mass. The force is at a distance from the rotational center of the knee joint thereby producing an external adduction moment of force.

Figure 1b. A valgus wedge under the foot can produce a decreased knee adduction moment by altering the GRF vector thereby reducing the moment arm

MOTION AS MEDICINE: DO PATIENTS WITH OSTEOARTHRITIS NEED STABILITY OR MOBILITY?

applied to the knee than those with a more rectus knee.⁹⁻¹² (Figure 1) Dynamically there are two periods where the external knee adduction moment peaks, one is at the loading phase of the gait cycle and the other during the propulsive phase.¹³ Of all the biomechanical factors that influence gait, the external knee adduction moment has been shown to be most closely associated with pain^{14,15} and progression¹⁶ of medial knee OA.¹⁴⁻¹⁹

The ground reaction force vector originates at the foot ground interface during the contact phase of gait. So if one wanted to manipulate the position of the ground reaction force vector, the foot ground interface or plantar aspect of the foot would be a great place to start. The magnitude of the ground reaction force vector is largely dependent on gravity and body mass, both are notoriously difficult to influence. However the direction or position of the ground reaction force vector with respect to the joint rotational center can be easily manipulated.

One method used by clinicians for many years is the introduction of a valgus wedge under the foot.²⁰ The theory is that the valgus wedge slightly alters the orientation of the ground reaction vector thereby placing it closer to the rotational center of the knee joint axis. (Figure 2) Several studies have confirmed a decrease in the peak knee adduction moment using either valgus wedges or valgus posting in a foot orthosis.²¹⁻²³ Studies by Daviset. al. showed there is a dose dependent response to the wedge, suggesting that determining the appropriate degree of valgus post for the foot orthosis may be the appropriate approach to reducing loads across the medial knee in OA.²⁴⁻²⁶ It is important to keep in mind there have been several studies that show valgus posting or wedges have little beneficial effect on the progression of knee OA.²⁷⁻²⁹ Clearly we need to continue the research to better understand the role the foot in the mechanics of medial knee OA.

Over the past 15 years the work of this author, and others at Rush University Medical Center in Chicago, have evaluated the effects of various interventions on the biochemistry, anatomy and biomechanics of medial knee OA. Through controlled trials of thousands of individuals we have seen significant, long term beneficial effects of manipulating the foot ground interface and observed others whom the modifications seem to provide no significant beneficial effects. For those that did complete the multiple years of an intervention, there was a statistically significant reduction in the loads at the medial knee and reduction in pain.³⁰

Focus soon turned to the question of what allowed the valgus wedge to work amazingly well in some subjects with medial knee OA while others seem to get little benefit. The answer may lie in an individual's biomechanics.

While conducting this study it was observed that some patients had considerable frontal plane mobility in their rearfoot that allowed the valgus post to more efficiently alter the leg and knee orientation while others seem to have a more dominant transverse plane translation between rearfoot motion and leg position. When the researchers went back in the post hoc analysis of the moment data there was a significant long term reduction in the peak knee adduction moment in the high frontal plane mobility sub-group compared to the transverse plane dominant sub-group.³¹ While there was not a significant difference in pain reduction between these groups during the same period there was a trend for less pain in the sub-group corresponding to the reduction in knee adduction moments.

A possible explanation for the lack of significance is the reduced power due to the smaller sample size in that these are sub-groups of a treatment group that represents only half of the enrolled subjects. Recently others have reported similar findings that foot mobility directly affects the magnitude of knee unloading provided by orthotic wedges.^{32,33}

Given these findings and findings from previous work that show a varus posted device increases the peak knee adduction moment, there may be translational value to this knowledge.³⁴

If one can clinically observe greater frontal plane motion of the rearfoot and leg in a subject with medial knee OA there may be greater likelihood of reducing the medial knee loads by using a valgus foot-ground intervention. However if there is more transverse plane motion observed in the leg with foot pronation-supination, then other options may be better.

The researchers have focused on not only the peak adduction moment that represents the largest moment at any one point in time within the stance phase, but also the amount of time spent with large moments applied to the biological tissue. The area under the curve of the knee adduction moment represents the angular momentum acting on the knee and has been shown to be more specific to severity of medial knee OA.³⁵

While conducting this study it was observed that some patients had considerable frontal plane mobility in their rearfoot that allowed the valgus post to more efficiently alter the leg and knee orientation while others seem to have a more dominant transverse plane translation between rearfoot motion and leg position.

While researchers continue to work through the multiple possibilities between interventions and patient mechanics, trying to scientifically understand the role the foot has the progression of the disease, it remains evident that the foot-ground interface plays a role in medial knee OA.

Plantar Foot Pressure

The most direct measurement of the foot ground interface is plantar pressure measurements. This is done either with electronic in-shoe sensors or with an electronic sensor mat the barefoot subject walks over. There have been several studies that show a relationship between pain, arthritis and changes in foot pressure.³⁶⁻⁴⁰ Most have focused on peak regional pressures or the pressure-time integral but few have looked at the loading pattern during gait.

One way to assess the loading pattern over the entire gait cycle is the Center of Pressure (COP) trace. This is a calculated measurement based on foot-ground contact area and magnitude of pressure for each pressure sample taken during the gait cycle. An example would be the center of pressure for a donut sitting on the pressure mat would be at the center of the hole since the calculated center of the pressure is within the ring where there is no contact.

It would be logical to conclude that if a deviation in foot position altered the ground reaction force vector then there would be a corresponding alteration in the plantar foot pressure pattern. This is fairly evident when there is a more varus position to the static foot and leg, there is more pressure left under the plantar lateral foot.⁴¹ Our research concluded that indeed subjects with medial knee OA had a more lateral COP trace in gait than the matched controls.⁴² Moreover, there was a statistically significant increase in pain related to the lateral COP trace. This study showed that those with medial knee OA have a deviated foot ground interface that can be measured with a clinical gait test. It would also seem logical that a treatment that altered the COP trace in a medial direction would benefit those who suffer from medial knee OA. This however needs more studies before we can have a definitive answer.

Shoe Stability vs. Mobility

Fifteen years ago when this author proposed evaluating plantar pressure in knee OA, it was decided that barefoot kinetics and kinematics would be needed to compare to the pressure data. When data started coming in that barefoot walking produced the greatest reduction in loads the concept seemed counterintuitive to a biomechanist. Most assumed it would be higher since when one walks across the force plates barefoot, greater shock was felt at initial contact compared to the shod condition. Even when the researchers accounted for body weight, height, speed, step and stride length the data showed that barefoot walking reduced the loads the greatest.⁴³ This began the work into an area that even today is controversial. That is, what is it about shoes versus barefoot that produces these differences?

One of the first possible explanations came from the fact that most

pathology seen in physicians' offices are related to over pronation of the foot. Shoe companies had responded over the years to make shoes more stable to restrict pronation. This is often accomplished using dual density midsoles, added reinforcement to the midsole, rigid heel counters and extra foxing or layering the upper with extra material to provide medial stability. The end result was a fairly stiff shoe that essentially became a more efficient lever arm to transfer the ground reaction force into the lower extremity. Additionally heels were elevated higher than the forefoot and outsoles were flared out for more stability. This essentially increased the lever arm between the ground reaction force vector and the center of rotation of each of the lower extremity joint segments. (Figure 3)

If shoe construction was to blame for increased loads on the lower extremity then shoe construction should be able to reduce the loads. This author evaluated the magnitude and location of the external ground reaction force vector at each part of the stance phase of the gait cycle to assess how they could be altered. For example at initial heel contact, the ground reaction force vector is at the posterior lateral to the heel pointing towards the center of mass of the body. It is therefore applying an external pronation moment to the ankle and subtalar joint, extension, internal rotation and adduction moment at the knee, and flexion adduction, internal rotation moment at the hip. All of these external moments have to be counteracted by the internal muscle moments.

So if one wanted to reduce these moments, one could decrease the lever arm from the posterior lateral heel to the rotational center of each segment by decreasing the size and thickness of shoe material at the heel. Of course there is only so much that can be reduced external to the body before contact is made at the surface of the heel. Another possible manipulation is the property of the material in that it can be made soft and compressible thereby making it an inefficient lever arm. The final way to manipulate the GRF is to have the shoe essentially "break away" that is have the contact surface move as it makes contact with the ground. By doing so, the moment arm becomes less efficient at transferring the load to the next segment and the orientation of the vector can even be slightly altered.

The end result of these experiments was a shoe designed at Rush University with a modified outsole and midsole. The design was tested with the results very similar to barefoot walking moments.⁴⁴ The shoe continues to be evaluated at major universities in the US and UK in the treatment of medial knee osteoarthritis.

Researchers continued to show that stability shoes produced higher moments while flexible shoes and even minimal shoes like flip flops produced less loads across lower extremity joints.⁴⁵ This opened up the flood gates to marketing "barefoot" shoes from manufacturers who were trying to understand the implications of this work.

The final possible rationale for why shoes produce measurable differences is neuromuscular adaptation. That is, one can more easily feel the ground and sense the pressure/forces being applied

MOTION AS MEDICINE: DO PATIENTS WITH OSTEOARTHRITIS NEED STABILITY OR MOBILITY?

to the various tissues that have afferent nerve fibers, sending signals along the neurological pathways. Proprioceptive feedback mechanisms can quickly alter a muscles contraction to counteract the external GRF.

It may be that shoes somehow alter these neuromuscular feedback mechanisms thereby dampening the response of the internal moments produced by the muscles to the external stimulus of the ground reaction force. This is very difficult to prove with current techniques and technology. However there was a finding that supported the neuromuscular adaptation theory.

In all of the knee OA intervention studies at Rush there was an interesting observation no matter what the mechanical intervention. In most cases there was an immediate reduction in the external knee adduction moment with the introduction of the mechanical intervention. The studies showed a sustained reduction in knee adduction moments or shift in the center of pressure over time even when walking without the intervention. The important point here is that when the mechanical device was removed, the body continued to function as if the intervention was still there. The only possible explanation is neuromuscular adaptation.

One of the more interesting findings was the effects mobility shoes have on subchondral bone. It has been known for years that the subchondral bone gets stiffer and denser in osteoarthritis. Proximal tibial bone mineral density (BMD) serves as a marker for structural consequences of altered joint loading. Thorp et al showed that local bone mass increases with increased joint loads and it

decreases with decreased loads. (Thorp et al, Bone 2006)

Researchers at Rush evaluated changes in the proximal tibial BMD associated with the use of the mobility shoe over 48 weeks in patients with knee OA. They performed DXA scans of the knees at baseline, 24 and 48 weeks and compared them to the knee adduction moments. What they discovered was that the mobility shoe significantly reduced the proximal tibial bone mineral density after 48 weeks. This is important enough to state it again. The research shows that wearing mobility shoes produces a physiological change within the bone. Ponder this for a moment. We are beginning to demonstrate shoes produce physiological changes within our body.

It is entirely likely that similar to the valgus wedge research, individual biomechanics will dictate who will benefit from mobility and those who need a more supported stable foot structure. Hopefully research will continue to provide us with more clues, but we all must keep in mind that research only provides us with pieces of truth, it is up to us to assimilate the information.

[Note: Dr. Roy Lidke will be conducting a workshop on “Biomechanics of the Foot and Knee-Treating Knee Osteoarthritis (OA) as Pedorthists” at PFA’s 54th Annual Symposium & Exhibition in Boston, October 31 – November, 2013].

See this article’s complete references online.

CLASSIFIED RATES

Words	Member	Non-Member
50 or fewer words	\$30	\$50
51-75 words	\$50	\$70
76-150 words	\$70	\$130

The following rates are calculated by counting complete words. (A telephone number is counted as a complete word.)

To place a classified ad, email margaret@pedorthics.org, send a fax to (703) 995-4456, or mail to Pedorthic Footcare Association, ATTN: Current Pedorthics, 8400 Westpart Drive, 2nd Floor, McLean, VA 22101.

