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WHAT'S MORE IMPORTANT, THE FOOT OR THE HIP? - A BIOMECHANIST'S PERSPECTIVE

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PART II: THE HIP YEARS

In the previous Industry Bulletin, we presented a historical perspective of how clinicians/scientists first tried to describe lower extremity coupling/coordination and the potential role that de-coupling might play in injury mechanism. In Part II, we will move forward and discuss how hip dynamics came into focus after the 1990s. This led to new ideas that suggested that the pelvic/hip complex plays a predominant role in knee biomechanics.

In the late 1990s, researchers began to investigate whether the foot was the primary driver of tibial internal rotation. Movement scientists were interested in better understanding the role that the hip plays, from proximal-to-distal. Interestingly, this very question arose when researchers wondered why some people respond positively to foot orthotic therapy while others do not. In 2000, a paper was published by Bellchamber & van den Bogert that explored energy/power transfer to better understand the influence of the foot and the femur, on tibial rotation.

These scientists investigated this question for individuals while walking and running. Their findings revealed that there was variability:

1) Across individuals in whether the foot or femur was primarily influencing the knee;
2) Between walking and running tasks; and
3) Across the stance phase of walking and running.

In part, this study contributed to inspiring a plethora of future research that aimed to explore and better understand the roll that the femur plays on affecting lower extremity function from a proximal-to-distal perspective. Essentially, this paper suggested that the foot may be a more predominant driver in some individuals and during some movement tasks. Conversely, it was suggested that the hip likely plays an important role for other individuals during some activities.

Increased interest in this area was ignited by movement scientists trying to better understand the underlying mechanisms for: 1) non-contact ACL injuries; 2) patellofemoral pain syndrome (PFPS); and 3) other traumatic and overuse injuries in sport. Again, as mentioned in Part I, it has been ACL injury and the high frequency PFPS injuries that have fueled this research interest. There is still a lot of work to do to better understand how this applies to the common foot and ankle pathologies that you see every day in your clinical practice.

In its simplest form, the idea of proximal-to-distal coupling can be described as the coordinated movement sequence of the pelvis and hip, and how femoral movement influences the tibia and foot. In the case of knee valgus (Powers, 2003; Powers, 2010) the proposed model suggests a coupling of contralateral pelvic drop, increased hip adduction and internal rotation as the primary driver of knee valgus/abduction, internal rotation of the tibia and foot pronation.(FIGURE 1)

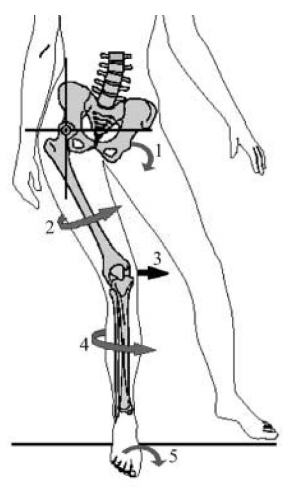

Figure 1: from Powers (2003)

This was contrary to an earlier model that suggested that foot pronation was coordinated with tibial internal rotation and thus influence the knee from the ground up.

In some individuals, the hip/femur might be that the primary driver whereas in other individuals, the foot might play the predominant role. This presents a challenge in terms of injury prevention and management. Therefore, it is imperative to assess athletes from both perspectives so that intervention solutions (exercises, therapy, footwear, orthoses) can be recommended to ensure comprehensive athlete/patient care.

A plethora of research focusing primarily on non-contact ACL injuries and patellofemoral pain syndrome focused on proximal to distal coupling and convincing results were published providing us with a better understanding of the influence of the hip on ACL injury and patellofemoral pain. This was followed up by further studies on iliotibial band syndrome. As a result, some professions have shifted their entire focus to strengthening of the hip abductors and external rotators and have somewhat abandoned the important role played by the foot.

From a biomechanical perspective, what becomes obvious is that it is not all about the foot, or all about the hip. The key point is that both play roll and that this is highly variable across individuals. The most comprehensive way to manage these individuals is with footwear interventions as well as exercises and gait retraining to help to address more proximal issues.

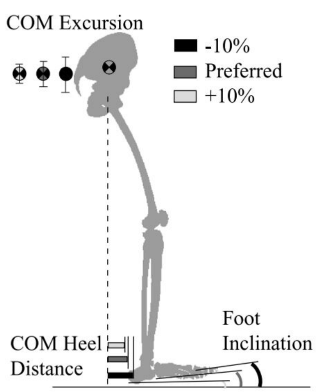

Figure 2: from Heiderscheit et al. (2011)

For the clinician, one way to conceptualize this is that when we move (walk, run, cut and jump) our lower extremity is sandwiched between the center of mass (COM) and the ground (Figure 2). The COM is the location in your body around which your mass is centralized (it is at approximately the level of your belly button). To the athlete/client, we have described this as the Kinetic Sandwich.

The lower extremity is essentially sandwiched between the ground and the COM. We describe that there are forces and energy traveling from the ground up influencing proximal movement, and forces and energy traveling from the COM downward via the pelvic/hip complex influencing movement, distally.

The vertical displacement of the COM clearly influences vertical ground reaction forces. The frontal and sagittal plane positions also influence pelvic and hip dynamics. Most recently, gait retraining has been recommended to decrease vertical displacement. Put simply, if the running cadence is decreased, the athlete typically takes longer steps and there is greater vertical displacement of the COM. With this, forces increase that could potentially be deleterious. By increasing, cadence (~170-180 steps per minute), step length deceases, vertical displacement of the COM decreases, and deleterious forces could potentially be mitigated.

During running for example, the center of mass reaches its highest position during flight phase and as the individual lands the COM displaces downward until approximately midstance (Figure 3). At mid stance, the ground reaction forces are the greatest on the body. In flight phase, when the COM is at its highest position, there are no ground reaction forces on the body. Similarly, with walking, the COM is at its lowest position during the breaking peak.

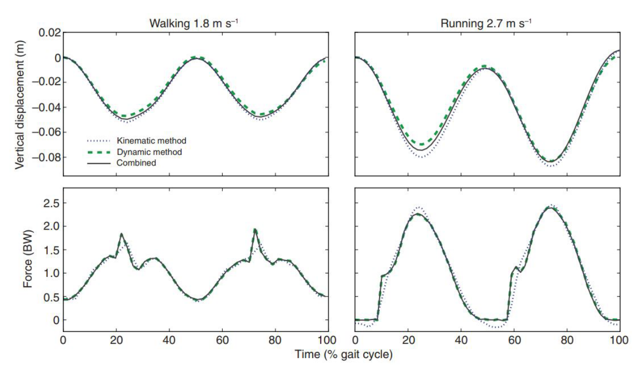

Figure 3: Vertical Displacement of the COM and grounds reaction forces.

So along with the vertical displacement of the COM, the other key issues are:

1) The position of the body/joints; and
2) How they respond to ground reaction forces acting on the system.

It is certainly over simplistic to think that only the hip, or that only the foot, can be responsible for what happens at the knee. Therefore, the answer to our original question What's More Important, The Foot or The Hip?, the answer is that both are important. As footcare specialists we need to consider the entire kinetic chain.

Custom foot orthoses (CFOs) and running shoe design have been long thought to contribute to the prevention and management of lower extremity injuries. Footwear interventions are an important tool in the practitioner toolbox. In the final section of this Industry Bulletin, we will discuss what we have learned above and the influence that custom foot orthotic therapy has on lower extremity dynamics. There have been many studies completed looking at the dynamic influence of foot orthotic therapy. Research has primarily focused on running because of the high-frequency of distance running injuries. Through the early 2000s, there was a flurry of research performed looking at this very question.

Foot pronation angles have traditionally been the focus of these studies. The studies that have typically focused on joint and segmental angular changes (i.e. rearfoot eversion and tibial internal rotation angles). The orthotic designs have been highly variable and the results have shown small changes with and without orthoses in the magnitude of 1-2°of change. However, we began seeing more systematic results when it became customary to use true custom foot orthoses as the intervention and the focus shifted toward kinetic analyses. Kinetic analyses focus on internal and external forces including ground reaction forces and resultant joint moments.

The ankle inversion moment is one variable where we have observed systematic reductions and this has been reported on a number of occasions. This is a kinetic measure that measures the internal rotational forces produced to resist rearfoot eversion or the frontal plane aspect of pronation. These rotational forces are likely produced bythe active and passive tissues the across the foot and ankle to resist eversion or pronation. The structures likely include the medial ligaments of the ankle, the tibialis posterior and other structures that are typically called ankle inverters. The velocity of rearfoot eversion speaks to the rate of change of the rearfoot angle. Numerous studies have shown that custom foot orthoses reduce these two variables, however, it is not clear how these variables relate to injury mechanism.

It is possible that we as researchers need to focus on rotatory forces rather than changes in rearfoot, frontal plane angles. This may be a better measure for pronation. Keep in mind, however, that this does not include the transverse plane component which is also important. In the laboratory, we have observed that the ankle inversion moment is often influenced by the amount of foot abduction. Abduction of the foot is one of the triplanar motions contributing to foot pronation and thus transverse plane dynamics should not be overlooked.

Vertical loading rate and impact peak magnitudes have also been shown to be causative for, or associated with, a number of lower extremity overuse injuries. For example, tibial stress fractures have been shown to be caused by increased vertical loading rate and impact peak magnitudes. In the foot orthotic literature, we also see systematic reductions in vertical loading rates and impact peak with custom foot orthotic interventions. In a recent study by Davis et al. (2016), the authors reported that runners with diagnosed running-related injuries exhibited significantly greater magnitudes for vertical loading rate and impact peak magnitudes. Those athletes were diagnosed with several different injuries including stress fractures/reactions, muscle strains, plantar fasciitis, Achilles tendinopathy and anterior compartment syndrome. Intuitively, foot orthotic therapy is likely a viable clinical tool that can help some individuals with these injuries.

In conclusion, it may be more appropriate to consider footwear interventions as force mitigating rather than interventions that influence alignment or position. As a footcare specialist, it would be beneficial to consider not only the role the foot plays an injury mechanism but also how proximal contributors can be leading to injuries at the knee but also at the foot and ankle. There are additional tools such as movement reeducation (gait re-training) and there are benefits to occasionally increasing stride width and/or decreasing step length to decrease deleterious forces to lower extremity.

Thank you for reading this edition of the Industry Bulletin.

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