INDUSTRY BULLETIN JANUARY 2025

Christopher MacLean, Ph.D.

HABITUAL MOVEMENT PATHWAY

Building on our previous Industry Bulletins, we will finish this line of content with The Habitual Motion Path (HMP) model. The HMP model suggests that each of our joints has it's own range of motion that it moves through along the path of least resistance. The HMP for foot and ankle joints differs amongst individuals but is consistent within an individual. The joint HMP depends on an individual's bone geometry and tissue biomechanics. This model leads to questions surrounding how footwear affects the HMP for lower extremity joints and how these pathways are influenced by increased forces that present with varying activities. The current Industry Bulletin will review how the HMP model has evolved over the past 25 years.

Background

In 2001, Benno Nigg published an article in *the Clinical Journal of Sports Medicine* titled, "*The Role of Impact Forces and Foot Pronation: A New Paradigm*". At this time, Nigg acknowledged that generally there was a lack of evidence supporting or establishing a causative link between foot pronation and impact forces with injuries. Also, Nigg suggested there was a lack of evidence suggesting any systematic results achieved with footwear interventions such as inserts and foot orthoses. This was an observation made from research conducted through the 1980s and 1990s.

Interestingly, between 2002 and 2009 there were several papers published by the University of Calgary and our group at the University of Massachusetts Amherst reporting systematic results with custom foot orthotic intervention. Specifically, several studies revealed a reduction in the intrinsic ankle inversion moment, impact forces, and vertical loading rates. The ankle inversion moment is a kinetic variable reflecting the frontal plane, and rotational forces of eversion or pronation. Impact forces and vertical loading rates have been associated with injury recurrence for decades. What is true, however, is that there has not been a causative relationship established between these variables and injury. This is likely because it is difficult to do this prospectively.

Nevertheless, Nigg proposed in 2001 an interesting model referred to as the Preferred Movement Path or PMP model. The premise of the PMP model is that during movement the locomotor system chooses a movement strategy to keep the skeletal movement in a constant pathway following a minimal resistance movement path. Under this premise, the appropriate muscles would be activated with any intervention (shoes, surfaces, orthoses) that produces a different movement pathway away from the PMP. Therefore, the optimal intervention would minimize additional muscle activity which should influence fatigue, comfort, injury prevention, and work/performance.

As it relates to footwear and footwear interventions, the framework proposed by Nigg was as follows:

1. Forces on the foot act as an input signal;
2. The shoe acts as the first filter for this input signal, an insert or orthosis acts as the second filter;
3. The musculoskeletal (MSK) system response to these forces by adapting the muscle activity;
4. If an intervention supports the preferred movement path (PMP), muscle activity and tissue strain will be reduced. If the footwear intervention counteracts the PMP, muscle activity and tissue strain will be increased; and
5. Thus, shoes, inserts and orthoses can affect muscle activity and, therefore fatigue, comfort, tissue strain and work/performance.

Nigg introduced this idea in 2001 and very little work was published shortly thereafter to support this hypothesis, until 2017. This paper was titled The Preferred Movement Path Paradigm: Influence of Running Shoes on Joint Movement. Notably, at the time this paper was published Matthieu Trudeau was working at the University of Calgary. Trudeau eventually went on to Brooks Running, where a group of collaborators further evolved this idea.

Brooks Running's Contribution

The groundwork originally proposed by Nigg led to further study that has mainly been performed through group collaboration between Brooks Running (Seattle, WA), the University of Massachusetts Amherst, and the University of Sport Cologne (Cologne, Germany). These researchers were interested in building on the PMP model and better understanding the variability of movement across individuals. They coined a new term, Habitual Motion Pattern (HMP). These researchers were interested in better understanding the increased variability across individuals in their biomechanical responses to movement interventions (footwear, surfaces) and how that relates to chronic running injury and the effect of footwear on the HMP.

continued on next page →

The premise for this was based on the work of Wilson et al. (1996) who studied cadaver knee kinematics and suggested that "*individuals may have a minimal resistance movement path: A movement path that is optimized to reduce loading on the passive joint structures.*"

One of the collaborators, Trudeau, investigated 6 cadaveric knees that were moved through flexion-extension cycles and observed that there was marked variability between specimens however each specimen exhibited minimal variability between the coupling of knee kinematics. This result suggested that it is possible that an individual's joints may have an HMP that is dictated by an individual's bone geometry and the mechanical properties of the individual's active and passive joint structures (ligaments, joint capsule, tendons). *(Figure 1)*

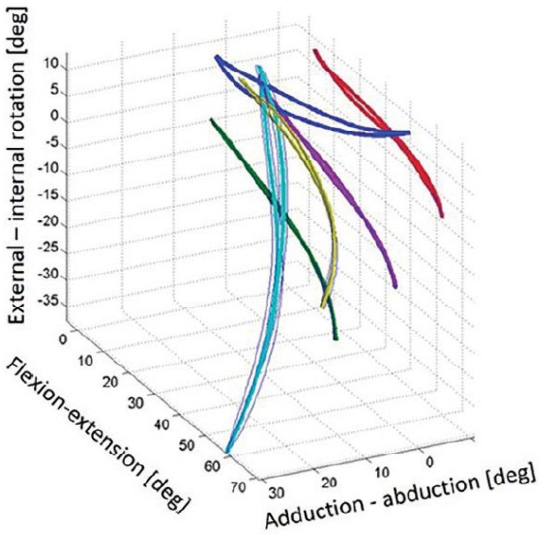

Figure 1: Variable kinematics between knee kinematics in cadaver specimens.

Supporting this idea, that a runner will perform running in an individual-specific pathway of least resistance, can also be observed qualitatively. In 2012, a study was conducted by Brigham Young University (BYU) using video to capture the variability of foot contact/strikes in the top 10 K distance qualifying for the London Olympics. These videos revealed that each individual runner landed with a different foot position. *(Figure 2)*

Figure 2: Brigham Young University investigating variable landing kinematics.

Some landed on the rearfoot, while others landed on the forefoot and each with differing degrees of foot eversion, inversion, and abduction. These runners exhibited slight differences likely representing each individual's HMP while running. Although running is of interest, the same principles likely apply to individuals when walking, jumping, and performing cutting tasks.

This led to the idea that the HMP exhibited by an individual performing a given task could potentially lead to injury. For example, when an individual performs an athletic task, increased forces associated with that task and differing footwear, orthoses, or surface environments could push the individual beyond the HMP for a given joint. The associated deviation of joint kinematics with increased loads and/or varying footwear or surfaces has been termed a deviated HMP. This would likely result in:

1. Increased stress and strain on the tissues surrounding (ligaments, joint capsules) and acting (muscles, tendons) on the joint, and potentially lead to chronic overuse injuries;
2. Increased muscular activity; and
3. Increased metabolic cost.

From this perspective, the role of any footwear intervention would be to optimize metabolic cost, optimize muscular activity, and decrease joint loading during exercise.

The research team developed an initial method to determine a joint's HMP. This technique was performed at the Brooks Running laboratory using motion capture technology. During 10 repetitions of half knee squats, knee flexion, and internal rotation, angles were measured. This simple movement task would define the baseline, habitual movement pattern for each individual. Following this, each individual performed a treadmill run at their preferred running speed. Again, knee flexion and internal rotation angles were recorded and quantified. These researchers focused on the knee because of the high frequency of overuse running injuries.

To establish whether a runner was performing the running task with high or low deviation from their HMP, several kinematic variables were compared between the half squat and running dynamics. The idea was that the half squat demonstrated the habitual movement pattern or path of least resistance for the knee joint. Under greater forces with running, did the individual exhibit a similar range of motion and, if not, did running force them into a highly deviated pattern outside of the habitual movement pattern? If this was the case, the runner would be deemed a **high deviator**. If not, if the individual demonstrated kinematics that were similar to the half squat maneuver, they were deemed a **low deviator**.

Once this was determined, footwear could be prescribed based on the dynamics. The general rule of thumb was that **high deviators would receive more of a stability shoe** and then be retested to see if they progressed from a high deviator to a low deviator. Alternatively, a **low deviator would be retested in a neutral shoe** and remeasured to establish that they maintained low deviation in their habitual movement pattern. The underlying concept here is that footwear would help to guide the runner toward their established habitual movement pattern.

continued on next page →

Like all initial attempts at identifying a methodology, it was recognized that the method had limitations. In March of 2024, Sumner et al. published the most recent paper that suggested that having only one maneuver measured *(i.e. The half squat)* to establish a baseline habitual movement pattern had limitations. So, these researchers built on the original methodology by adding:

1. a lunge;
2. stair descent; and
3. walking along with the half squat to include more fundamental movement patterns. *(Figure 3)*

Without getting into the complexity of the analysis, this technique provided a more robust method to identify low and high deviators. These techniques were the premise for the Brooks Run Signature program/ offering which attempts, in the retail setting, to better match running technique with footwear selection.

Figure 3: Fundamental movement patterns to determine an individual's habitual movement path.

The Relationship Between HMP and Injury Mechanism

The area that remained unclear was the connection between deviating from one's habitual movement pattern and injury mechanism. A potential mechanism was revealed by Willwacher et al. (2020) in a study where they hypothesized that knee joint cartilage loading would be decreased in people who exhibited a low deviation when compared to those who exhibited a high deviation from their HMP. Secondly, these researchers hypothesized that specific footwear would minimize the high deviators and therefore lead to decreased loading with appropriate footwear prescription.

MRI was used in this study to quantify knee joint cartilage loading. *(Figure 4)* Footwear interventions included neutral running shoes (Brooks Glycerin and Lauch), as well as medially and laterally

posted shoes of this design. To ensure a more ecological study design, runners were asked to perform a 75-minute run. Their results indicated that high deviators from habitual movement patterns exhibited increased knee joint cartilage loading after a 75-minute run. Specifically, increased loading was measured at the medial tibial plateau, the medial femoral condyle, and the infrapatellar surface. Secondly, in the high deviator group, loading in these specific areas of the knee was reduced when the individuals were dispensed footwear that minimized the deviation from the HMP. This suggests that if people can perform a running task, or any athletic maneuver, in a manner that is similar to their HMP baseline, loading and potentially increased injury risk can be mitigated.

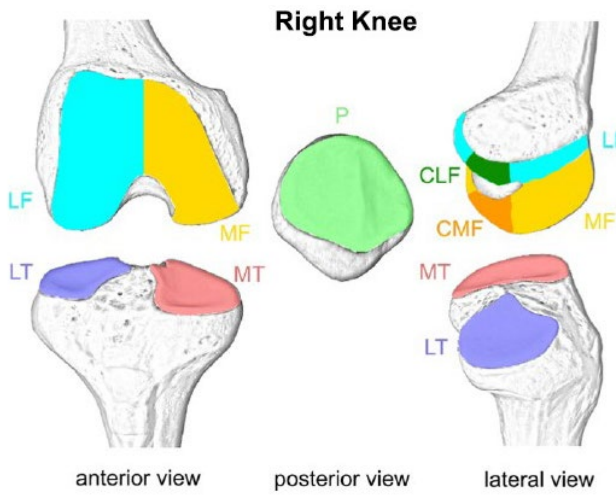

Figure 4: From Willwacher et al., 2020.

In summary, the idea of PMP/ HMP models has evolved tremendously over the past 25 years. It is an interesting alternative to pre-existing models of podiatric biomechanics. That being said, it remains unclear how this relates to foot and ankle function and injury mechanisms. Hopefully, future research will focus on the foot and ankle to help establish how foot-ankle-knee couplings/coordination can cause injury.

In the next *Industry Bulletin*, we will present how the various models of podiatric medicine help to inform how custom foot orthoses help manage or prevent lower extremity injury.

Thank you for reading this edition of the Industry Bulletin.

If you are interested in any of the publications cited please contact:

Chris MacLean Ph.D.
cmaclean@parisorthotics.com

To subscribe to our email list, please register at: education@parisorthotics.com

Visit our resource page on **PARISORTHOTICS.COM** to download our most recent Industry Bulletins or sign up to receive one.

Move With Excellence
Paris Orthotics Ltd. 2025