**<u>Appendix 1: Third-party Studies</u>**

The purpose of Appendix 1 is to provide a reference list of studies to document the relationship between fatigue, trips/falls and overuse injuries and the biomechanics of the kinetic chain. Each section has a list of separate verified studies with an associated citation concluding each bullet point. A bibliography is included at the end of appendix 1, with each study referenced.

**Alignment**

1. *"The results of the present study revealed sacral angle, pelvic inclination, lumbar lordosis, and thoracic kyphosis were increased with an increase in bilateral foot pronation. In fact, each one of them is a compensatory phenomenon."* (Ghasemi, 2016)
2. *"The authors suggest that excessive pronation is the causative factor directing asynchronous rotation between the shank and femur. This forces the patella out of its normal tracking groove, which, in turn, generates erosion between the inferior margin of the patella and femoral epicondyles." (Rothbart, 1988)*

**Fatigue**

1. *"Postural stability and postural control were studied before and after a fatigue protocol of soleus muscles." "Results of the whole group showed that fatigue modified postural control."* (Caron, 2003)
2. *"Fatigued recreational athletes demonstrate altered motor control strategies, which may increase anterior tibial shear force, strain on the anterior cruciate ligament, and risk of injury for both female and male subjects."* (Chappel, 2005)
3. *"Subjects performed 10, 10-second single-leg balance trials on a force platform prior to performing each of three conditions (local, whole body, and control), in a randomized order, on separate days." "The major findings of the present investigation demonstrated that measures of postural control, namely M/L, A/P sway and total sway, were adversely affected following fatiguing exercise, with differential effects between men and women."* (Springer, 2009)
4. *"Healthy subjects (N = 14) performed a continuous reaching task by pointing between two targets placed at shoulder height, at 100 and 30% arm's length, anterior to the subject's midline until fatigue (assessed using the Borg CR-10 scale)." "Our results suggest that the effects of fatigue on repetitive movement kinematics can be observed across three temporal dimensions of the task: (1) within individual movements, (2) from one movement to the next, and (3) as fatigue develops."* (Fuller, 2011)
5. *"Repetitive motion-induced fatigue not only alters local motion characteristics but also provokes global reorganization of movement. These changes were accompanied by a lateral shift of the body's center of mass towards the non-reaching arm. These findings suggest a compensatory strategy to decrease the load on the fatigued shoulder musculature."* (Fuller, 2008)
6. *The ankle joint complex, defined as the talocrucral and subtalar joints , contributes between 40% to 70% of forward propulsion during walking, but only accounts for 7–26% of the metabolic cost . With a loss of ankle function, hip flexors and extensors are more heavily utilized during gait, increasing the physiologic expenditure . This shift from relying on the ankle to relying on the hip to deliver forward propulsion during gait may explain the relatively higher energetic costs of walking that older adults experience in comparison to their younger counterparts.* (Rao, 2012)
7. *"Females with PTTD* (Flat Feet, translated by Protalus) *performed significantly fewer single-leg heel raises and repeated sagittal and frontal plane non-weight-bearing leg lifts, and also had lower hip extensor and abductor torques than age-matched controls. There were no differences between sides for hip strength and endurance measures for either group, but differences between*

*sides in ankle strength measures were noted in both groups."* (Kulig, 2011)

**Trips and Falls**

1. *"Probability of tripping (PT) was calculated by modeling and then integrating the MTC (Minimum Toe Clearance) sample distribution. Results from a young male subject continuously walking for 1 hour show the MTC distribution is not normally distributed with mean=1.03 cm, S.D.=0.25 cm, skew=1.01 and kurtosis=3.47. For this distribution, PT for an unseen 0.2 cm high obstacle is calculated to be 1 in every 10,363 strides. Without skew- and kurtosis-modeling PT reduced to 1 in every 1901 strides, which highlights the importance of skew and kurtosis-modeling for PT estimation. Predicted PT is seen to increase with increasing obstacle heights (e.g. PT for an unseen 0.5 cm obstacle is 1 in 95 strides and PT for an unseen 1.0 cm obstacle is 1 in 2 strides)."* (Best, 2008)
2. *"The ankle has a larger sensitivity at critical toe clearance (CTC) than either the hip or the knee, and therefore a potentially greater effect on toe clearance. Because it is either dorsiflexing or held in a neutral position at this time, the ankle's action is beneficial to toe clearance; in fact, even slight dorsiflexion of the ankle will contribute significantly to increased clearance of the toe."* For clarity, Protalus has translated the Critical Toe Clearance Sensitivity Metric as, one degree of dorsiflexion can elevate the toe by .3 cm at the CTC, a response that can significantly reduce the probability of tripping. (Moosabhoy, 2006)
3. *"In our study, significant differences in muscle strength and of ROM in dorsiflexion were observed between the two groups. The normal foot group showed higher values than the flat foot group in terms of both ROM in dorsiflexion and muscle strength. This is important because sufficient dorsiflexion at the initial contact during walking is necessary for balanced weight loading in the following loading response and middle stance phases. Flat feet will show unbalanced weight loading compared to normal feet due to the decreased muscle strength and ROM in dorsiflexion. If this mechanism is continued for a long time, the plantar fascia can become thickened due to the increased weight loading. Moreover, people with flat feet use excessive knee and hip joint flexion to compensate for the insufficient dorsiflexion during walking. This implies that energy efficiency will also be negatively affected."* (Park, 2018)

**Overuse Injuries**

1. *"Knee osteoarthritis (OA) is a painful condition that discourages people from walking and increases the risk of falling. OA is frequently associated with pain caused by micro-fractures due to bone-to-bone collision with reduced articular cartilage. Knee adduction moment is the kinetic marker most reliably related to the progression of OA, especially at the medial compartment. A comprehensive review suggested that approximately 10–15% of the senior population show clinical evidence of OA, but it is possible that gait modification interventions using insoles slow the progression of OA if knee adduction moment can be reduced."* (Nagano, 2018)
2. *"Aberrant foot structure has been linked to foot osteoarthritis (OA), as well as OA and pain at the knee and hip." "In individuals with musculoskeletal conditions of the foot and ankle, the chief objectives of treatment are to afford pain relief, restore mechanics (alignment, motion and/or load distribution) and return the patient to their desired level of activity participation."* (Rao, 2012)
3. *"Planus foot morphology* (Flat feet, translated by Protalus) *is associated with frequent knee pain and medial TF cartilage damage in older adults."* (Gross, 2011)
4. *"Primary knee OA varus alignment increases risk of medial OA progression, that valgus alignment increases risk of lateral OA progression, that burden of malalignment predicts decline in physical function, and that these effects can be detected after as little as 18 months of*

*observation."* (Sharma, 2001)

5. *"The HFO-R (Rigid Hindfoot Orthosis) provides significant subtalar joint motion restriction while walking. The HFO-R may be considered an optimal orthosis for patients with subtalar OA pain arising from subtalar motion."* (Huang, 2006)
6. *"Compared with healthy control subjects, all patients with RA demonstrated excessive subtalar joint eversion motion through the stance phase of gait (p < 0.0001) coupled with excessive internal leg rotation (p < 0.0001). Custom-manufactured orthoses significantly reduced eversion through stance (p = 0.009) and re-established equilibrium of motion relative to neutral joint position."* (Woodburn, 2003)
7. *"Subjects with posterior tibial tendon dysfunction (PTTD) regardless of group demonstrated significantly greater hindfoot eversion compared to controls. Subjects with PTTD who were weak demonstrated greater hindfoot eversion compared to subjects with PTTD who were strong."* (Neville, 2010)
8. *"Planus foot posture and pronated foot function are associated with foot symptoms. Interventions that modify abnormal foot posture and function may therefore have a role in the prevention and treatment of foot pain." (Menz, 2013)*
9. *"The results suggest that standing in more lumbar lordosis may be a risk factor for low back pain development during prolonged periods of standing. Identifying risk factors for low back pain development can inform preventative and early intervention strategies."* (Sorensen, 2018)
10. *"Based on the results, the group with flat foot may gradually generate potential of the foot dysfunction and plantar fasciitis. Therefore, the interventions are necessary to improve the foot dysfunction and plantar fasciitis in people with flat foot." (Park, 2018)*
11. *"Based on the foregoing assumptions and inputs, for every 100 employees MSDs cost employers about $103,000 annually." "As noted previously, these are low-end estimates of the full costs of MSDs in the U.S. workforce, as only a limited range of types of MSDs is available in the multiple datasets used to produce these estimates." (Summer, 2015)*

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