EFFECT OF DOWNHILL RUNNING ON BIOMECHANICAL RISK FACTORS ASSOCIATED WITH ILIOTIBIAL BAND SYNDROME

Leon Robertz[1], Kevin Bill[1], Uwe G. Kersting[1], Igor Komnik[1,2], Markus Kurz[4], Patrick Mai[1,3], Wolfgang Potthast[1] and Steffen Willwacher[1,3]

[1] Institute of Biomechanics and Orthopaedics, German Sport University
[2] Institute of Movement and Sport Gerontology, German Sport University
[3] Department of Mechanical and Process Engineering, Offenburg University
[4] Sports Tech Research Centre, Mid Sweden University, Östersund, Sweden

The purpose of this study was to identify the influence of downhill running on biomechanical risk factors for iliotibial band syndrome. We conducted a 3D motion analysis of 22 females and males running on an instrumented treadmill at four different inclinations (0%, -5%, -10%, -15%) at a speed of 3.5 m/s. We found significant differences for biomechanical risk factors associated with iliotibial band syndrome. Peak knee flexion angle at initial ground contact ($p < .001$), peak knee adduction angle ($p = .005$), and iliotibial band strain ($p < .001$) systematically increased with increasing slope. Downhill running increases biomechanical risk factors for iliotibial band syndrome. Our results highlight the need to consider the individual running environment in assessing overuse injury risk in runners.

KEYWORDS: injury, overuse, slope.

INTRODUCTION: Despite the beneficial influence of running on well-being, overuse injuries are widespread. Overall, incidence rates vary between 10 to 93%, with iliotibial band (ITB) syndrome being one of the most common overuse injuries (Francis et al., 2019). ITB syndrome is associated with an inflammation near the lateral femoral epicondyle (Fairclough et al., 2006) and pain on the lateral side of the knee (Hutchinson et al., 2022). Recently, Willwacher and colleagues (2022) reviewed biomechanical risk factors (BRFs) for specific overuse injuries, including ITB syndrome. They found inconsistent evidence for peak frontal and transverse plane knee joint kinematics and reduced knee flexion at initial ground contact (IC) as risk factors for ITB syndrome. Further, they found very limited evidence for peak femur external rotation, ITB strain, and strain rate. ITB pain develops more commonly with downhill running (Noble 1980, Staff and Nilsson, 1980), which might be due to a more extended knee at IC when running downhill (Sundström et al., 2021). However, the effect on other BRFs associated with the risk of developing ITB syndrome remains mostly unknown. Therefore, the purpose of the study was to investigate the effect of downhill running on BRFs for ITB syndrome. We hypothesized that downhill running negatively affects BRFs for ITB syndrome.

METHODS: We recruited 22 injury-free recreational runners (9 females, 13 males; mean ± SD: 67.8 ± 4.0 kg, 176.41 ± 6.55 cm, 24 ± 4 years). Lower body kinematics were captured with a marker-based 3D motion capturing system (17 cameras, 200 Hz, Qualisys AB, Gothenburg, Sweden), and ground reaction forces (GRFs) were recorded using a force-instrumented treadmill (2000 Hz, Gaitway 3D, HP Cosmos, Traunstein, Germany). After a warm-up to familiarize themselves with downhill running on a treadmill, participants performed runs at 3.5 m/s in four randomized inclinations (0%, -5%, -10%, -15%). Runners were allowed to run in their own running shoes. The recordings of 30-second trials were started after the treadmill belt had reached the target speed.

Raw kinematic and kinetic data were filtered with a recursive 4th order low-pass Butterworth filter with a 20 Hz cut-off frequency (Mai & Willwacher, 2019). BRFs identified by Willwacher et al. (2022) including ITB strain and strain rate, peak femur external rotation angle, peak knee internal rotation and adduction angle, and knee flexion angle at initial ground contact (IC) were calculated during the stance phase of the right lower extremities.

ITB strain and strain rate were calculated using a modified OpenSim model with three degrees of freedom knee and hip joints and one degree of freedom ankle, subtalar and

metatarsophalangeal joints (gait2392, Delp et al., 2007). The ITB was added following the tensor fasciae latae's path and modeled as a muscle with only a passive contractile component (Foch, 2013). To prevent structures from passing through the femur and the femur epicondyle, cylindrical and spherical wrappings were added to the femur (Miller et al., 2007). ITB strain was calculated by dividing the length change of the ITB by the resting length of the ITB during the static calibration trial. Five steps were averaged for each subject in each condition for ITB strain and strain rates due to computational restraints. For the other kinematic risk factors, a minimum of 20 steps were averaged for each subject in each condition. IC (>20 N) and toe-off (<20N) were determined based on the unfiltered vertical GRF.
Separate repeated-measures ANOVAs were applied for each of the BRFs. Effect sizes were calculated using partial eta squared (η_p^2). Post hoc tests were performed using Bonferroni correction. All data were tested for normality and sphericity. The level of significance was set to α = .05. Calculations were performed using a custom-made Matlab script (R2021a, The Mathworks, Natick, USA) and OpenSim v4.3. Statistical analyses were performed using JASP (JASP 0.16, University of Amsterdam, Amsterdam, The Netherlands).

RESULTS: Knee flexion angles at IC differed significantly between conditions ($p < .001$, $\eta_p^2 = .70$) and decreased systematically with increasing inclinations (Table 1, Figure 1A). Post hoc analysis revealed significant differences between level running and all other conditions ($p_{posthoc} < .001$), as well as between -5% and -15% inclination ($p_{posthoc} < .001$). Peak knee adduction angles differed significantly between conditions ($p = .005$, $\eta_p^2 = .25$). The steepest inclination resulted in the highest peak knee adduction angle (4.3 ± 2.9°), which significantly differed from -5% (3.6 ± 2.6°, $p_{posthoc} = .007$) and level running (3.4 ± 2.5°, $p_{posthoc} < .001$). Peak knee internal rotation angles ($p = .146$) and peak femur external rotation angles (p = .063) showed no significant difference between conditions (Table 1, Figure 1C and 1D, respectively). ITB strain varied significantly ($p < .001$, $\eta_p^2 = .40$) between conditions. Compared to level running (7.3 ± 0.3%), the two steepest slopes (-10%: 7.5 ± 0.4%, $p_{posthoc} = .001$; -15%: 7.6 ± 0.3%, $p_{posthoc} < .001$) resulted in significantly higher peak ITB strain. Moreover, running on a -15% inclination resulted in significantly higher ITB strain than running at -5% (7.4 ± 0.3%, $p_{posthoc} = .001$). No significant effects on ITB strain rates were observed between conditions ($p = .085$).

Table 1: Means ± SD of the BRFs associated with ITB syndrome for downhill and level running (n = 22). Bold values indicate significant differences to the respective negative inclination.

Parameter/Slope	0%	5%	10%	15%	p	η_p^2
Knee flexion at IC [°]	14.9 ± 3.4 **5, 10, 15	11.7 ± 4.0 **0, 15	10.6 ± 4.1 **0	9.8 ± 3.5 **05	< .001	.70
Peak knee adduction [°]	3.4 ± 2.6 **15	3.6 ± 2.6 *15	4.0 ± 2.8	4.4 ± 3.0 *5, **0	.005	.25
Peak knee internal rotation [°]	12.2 ± 4.0	12.2 ± 3.6	12.5 ± 3.4	13.0 ± 3.5	.146	.09
Peak femur external rotation [°]	9.5 ± 4.4	10.2 ± 4.1	9.9 ± 3.9	10.7 ± 4.3	.063	.13
Peak ITB strain [%]	7.3 ± 0.3 *10, **15	7.4 ± 0.3 *15	7.5 ± 0.4 *0	7.6 ± 0.3 *5, **0	< .001	.40
Peak ITB strain rate [%/s]	13.4 ± 2.4	13.7 ± 2.4	14.2 ± 2.8	14.2 ± 2.9	.085	.02

***** $p_{posthoc} < .05$; ****** $p_{posthoc} < .001$

DISCUSSION: The purpose of the study was to investigate the influence of downhill running on BRFs for ITB syndrome. Previous research indicated that symptoms for ITB syndrome aggravate while running downhill (Noble 1980, Staff and Nilsson, 1980). Our findings demonstrate that downhill running systematically affects knee flexion angle at IC (Figure 1A) and the peak knee adduction angle (Figure 1B). Results for knee flexion angle are compliant with previous literature (Sundström et al., 2021). Additionally, we were able to show that downhill running elevates peak ITB strain (Figure 1E), which is in accordance with previously published values for ITB strain (Hamill et al., 2008). Prospectively, Hamill et al. (2008) showed that ITB strain was higher for runners developing ITB syndrome compared to uninjured runners. We found no significant effects for peak knee internal rotation, peak femur external rotation, and ITB strain rate. Interestingly, sagittal and frontal plane BRFs were affected by downhill running; however, transverse plane knee joint kinematics remained unaffected.

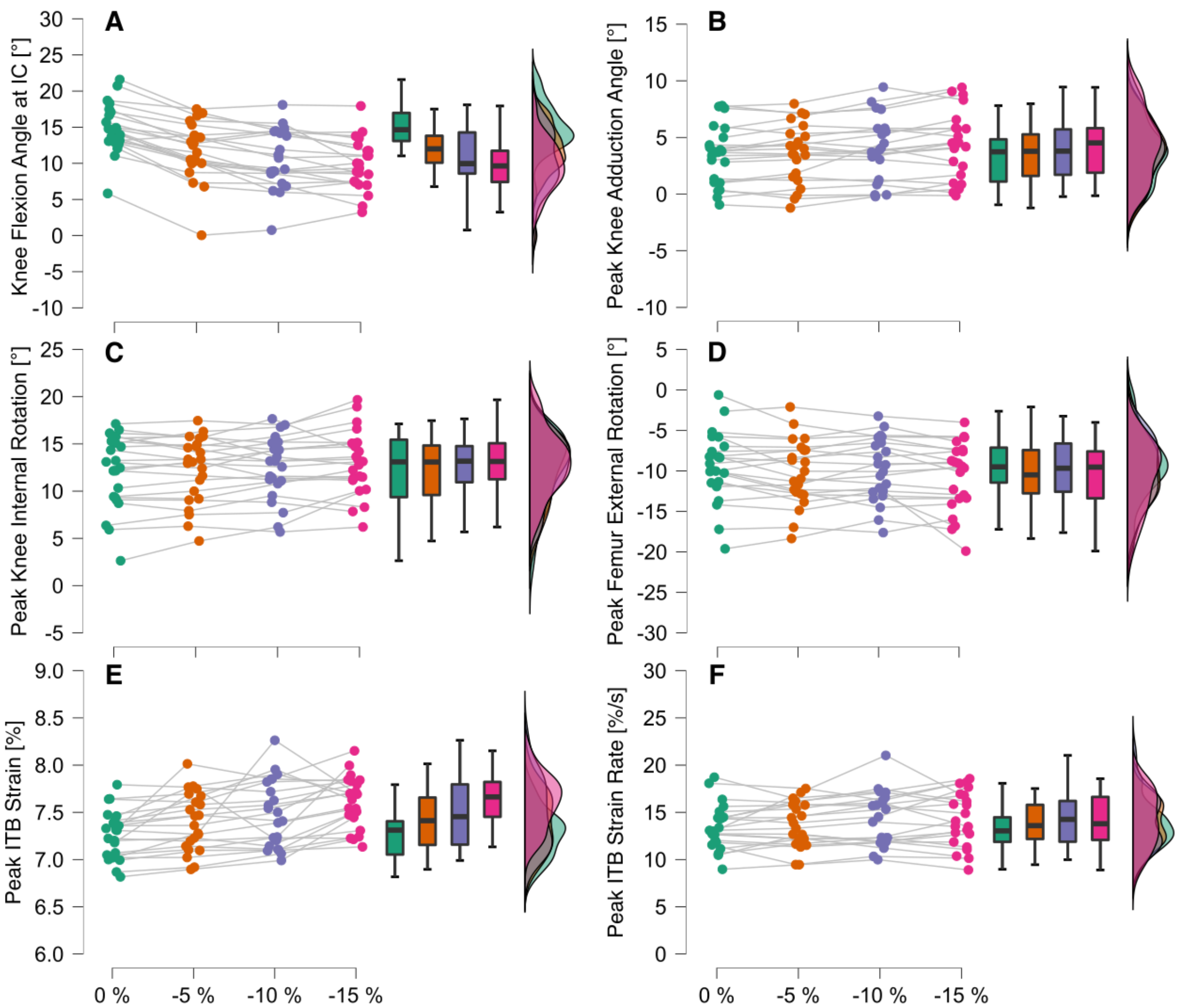

Figure 1: Box plots and distributions of the BRFs associated with ITB syndrome. Thick lines in the box plots represent the medians. Lower and upper boundaries of the boxes indicate 25th and 75th percentiles, respectively. Whiskers show the most extreme values within 1.5 times the interquartile range. Violin graphs respresent the distribution of the data.

The strength of calculating ITB strain characteristics using musculoskeletal simulation lies in the consideration of the entire interaction of joint kinematics and kinetics. However, this study has some limitations. While sagittal plane lower extremity kinematics are comparable between downhill treadmill and overground running (Firminger et al., 2018), comparability in the frontal and transverse plane is unknown. Furthermore, we only investigated running at a steady state of 3.5 m/s. Yet, this might not be applicable to trail running. Therefore, further studies need to investigate the transitions between combinations of speed and inclination on BRFs for ITB syndrome during running. Further, we looked at discrete biomechanical parameters only. Since this gives only insight for one instance in time, applying a functional approach by considering variables in the time domain may provide additional insight, especially because the pain caused by ITB syndrome usually appears within 20 – 30° knee flexion (Fairclough et al., 2006; Hamill et al., 2008). Moreover, the investigated BRFs showed very limited evidence at most (Willwacher et al., 2022). This underlines that still little is known about the complex behavior of the ITB and BRFs for ITB syndrome, which opens the opportunity for further studies. Finally, our modeling approach contains several constraints. We modeled it as one discrete structure following the tensor fasciae latae's path. This simplistic approach neglects the complexity of the ITB with its multiple muscle insertions (Fairclough et al., 2006; Hutchinson et al., 2022).

CONCLUSION: Downhill running at 3.5 m/s amplifies BRFs associated with ITB syndrome, showing a systematic increase for knee flexion angle at IC, peak knee adduction angle, and peak ITB strain. Runners acutely suffering from ITB syndrome should therefore avoid downhill running. Additionally, adequate adaptation and recovery periods need to be considered when transitioning to trail running, and hip and knee stabilization should be ensured.

REFERENCES

Delp, S.L., Anderson, F.C., Arnold, A.S., Loan, P., Habib, A., John, C.T., Guendelman, E., Thelen, D.G. OpenSim: Open-source software to create and analyze dynamic simulations of movement. *IEEE Transactions on Biomedical Engineering*, 54(11), pp 1940-1950. (2007) http://doi.org/10.1109/TBME.2007.901024

Fairclough, J., Hayashi, K., Toumi, H., Lyons, K., Bydder, G., Phillips, N., Best, T. M., & Benjamin, M. (2006). The functional anatomy of the iliotibial band during flexion and extension of the knee: Implications for understanding iliotibial band syndrome. *Journal of Anatomy*, *208*(3), 309–316. https://doi.org/10.1111/j.1469-7580.2006.00531.x

Firminger, C. R., Vernillo, G., Savoldelli, A., Stefanyshyn, D. J., Millet, G. Y., & Edwards, W. B. (2018). Joint kinematics and ground reaction forces in overground versus treadmill graded running. *Gait & Posture*, 63, 109–113. https://doi.org/10.1016/j.gaitpost.2018.04.042

Foch, E. H. (2013). *Association between Iliotibial Band Syndrome Status and Running Biomechanics in Women* [Doctoral Dissertation, University of Tennessee].

Francis, P., Whatman, C., Sheerin, K., Hume, P., & Johnson, M. I. (2019). The proportion of lower limb running injuries by gender, anatomical location and specific pathology: a systematic review. *Journal of sports science & medicine*, 18(1), 21.

Hamill, J., Miller, R., Noehren, B., & Davis, I. (2008). A prospective study of iliotibial band strain in runners. *Clinical Biomechanics*, *23*(8), 1018–1025. https://doi.org/10.1016/j.clinbiomech.2008.04.017

Hutchinson, L. A., Lichtwark, G. A., Willy, R. W., & Kelly, L. A. (2022). The Iliotibial Band: A Complex Structure with Versatile Functions. *Sports Medicine*. https://doi.org/10.1007/s40279-021-01634-3

Mai, P., & Willwacher, S. (2019). Effects of low-pass filter combinations on lower extremity joint moments in distance running. *Journal of Biomechanics*, *95*, 109311. https://doi.org/10.1016/j.jbiomech.2019.08.005

Miller, R. H., Lowry, J. L., Meardon, S. A., & Gillette, J. C. (2007). Lower extremity mechanics of iliotibial band syndrome during an exhaustive run. *Gait & Posture*, *26*(3), 407–413. https://doi.org/10.1016/j.gaitpost.2006.10.007

Noble, C. A. (1980). Iliotibial band friction syndrome in runners. *The American Journal of Sports Medicine*, *8*(4), 232–234. https://doi.org/10.1177/036354658000800403

Staff, P. H., & Nilsson, S. (1980). Tendoperiostitis in the lateral femoral condyle in long-distance runners. *British Journal of Sports Medicine*, 14(1), 38.

Sundström, D., Kurz, M., & Björklund, G. (2021). Runners Adapt Different Lower-Limb Movement Patterns With Respect to Different Speeds and Downhill Slopes. *Frontiers in Sports and Active Living*, *3*, 682401. https://doi.org/10.3389/fspor.2021.682401

Willwacher, S., Kurz, M., Robbin, J., Thelen, M., Hamill, J., Kelly, L., & Mai, P. (2022). Running-Related Biomechanical Risk Factors for Overuse Injuries in Distance Runners: A Systematic Review Considering Injury Specificity and the Potentials for Future Research. *Sports Medicine*. https://doi.org/10.1007/s40279-022-01666-3