



ÓBUDAI EGYETEM
ÓBUDA UNIVERSITY

DOCTORAL (PhD) THESIS BOOKLET

XINYAN JIANG

Biomechanical alteration in
response to long-distance
running, running
experiences, running
speed and the gender of
runners

Supervisor: Prof. Dr. Bíró István

**DOCTORAL SCHOOL ON SAFETY
AND SECURITY SCIENCES**

2025/12/01

Table of Contents

1. Summary in Hungarian Language	3
2. Antecedents of the Research	4
3. Objectives	6
4. Research Methods and Challenges	7
5. New Scientific Results	9
6. Possibility to utilize the Results	12
7. References.....	13
8. Publications	15
8.1 Scientific Publications related to the Thesis Points.....	15
8.2 Additional Scientific Publications.....	16

1. Summary in Hungarian Language

A futás népszerűsége és a magas sérülési arány miatt ez a tanulmány a hosszútávfutás biomechanikai változásait, valamint a futási tapasztalat, a sebesség és a nem szerepét vizsgálta. Biomechanikai modellezés és OpenSim-alapú szimuláció segítségével elemeztük a kezdő és tapasztalt futók izomerőit és térdízületi reakcióerőit. Az eredmények azt mutatták, hogy a kezdő futók nagyobb térdízületi terhelést és izomerőket produkáltak a támaszfázis jelentős részében. Mivel a megnövekedett ízületi terhelés összefüggésbe hozható a futással kapcsolatos sérülések (RRI-k) magasabb kockázatával, ezek az eredmények arra utalnak, hogy a kezdő futók sérülésveszélye nagyobb lehet. Ugyanakkor további kutatások szükségesek annak tisztázására, hogy ezek a mechanikai eltérések milyen mértékben befolyásolják a teljesítményt és a sérüléskockázatot. Jelenleg nem állnak rendelkezésre pontos küszöbértékek az izomerők vagy az ízületi reakcióerők tekintetében, amelyek megbízhatóan előre jeleznék az RRI-ket. Hosszú távú vizsgálatokra van szükség annak feltárására, hogy ezek a változók alkalmasak-e a sérülésmegelőzési stratégiák fejlesztésére, különösen kezdő futók esetében.

A tanulmány másik célja az volt, hogy egy 5 km-es futás során hagyományos diszkrét változók és főkomponens-analízis (PCA) segítségével összehasonlítsa a különböző tapasztalatú futók futásmechanikáját. A PCA lehetővé tette, hogy a kutatás finomabb biomechanikai mintázatokat is azonosítson, amelyek a sérülésmechanizmusokkal állhatnak összefüggésben. A kezdő futók nagyobb változékonyságot mutattak az ízületi szögek és nyomatékok terén, ami nagyobb ízületi terhelést és ezáltal nagyobb sérüléskockázatot is jelenthet. Eredményeink alátámasztják, hogy az edzettségi szint jelentős hatással van a mozgásmintázatokra, és hangsúlyozzák a fejlett biomechanikai módszerek, például a PCA alkalmazásának fontosságát a futás finom mechanikai különbségeinek feltárásában.

Ezenkívül vizsgáltuk a futási sebesség növekedésének (10–16 km/h) hatását a földre ható reakcióerőkre (GRF) férfi és női futók esetében. Az eredmények szerint mindkét nemnél a vertikális és elülső-hátsó GRF-ek növekedtek a sebesség emelkedésével, különösen a támaszfázis korai és késői szakaszaiban. Érdekes megfigyelés, hogy a női futók minden sebességnél nagyobb hajtó- és vertikális erőt fejtettek ki a támaszfázis végén, mint a férfiak. Ez arra utalhat, hogy a női futók nagyobb mechanikai erőfeszítést tesznek ugyanazon

futási sebesség eléréséért, valószínűleg izomerő- vagy futásmechanikai különbségek miatt. Az ilyen nemspecifikus biomechanikai jellemzők megértése kulcsfontosságú a teljesítmény optimalizálása és a sérülések megelőzése szempontjából. A jövőbeni kutatásoknak érdemes tovább vizsgálniuk, hogy a nemek közti GRF-különbségek milyen mértékben járulnak hozzá az RRI-k kialakulásához, és hogyan lehet ezek alapján személyre szabott megelőzési stratégiákat kidolgozni mind férfi, mind női futók számára.

2. Antecedents of the Research

Running is recognized as one of the most prevalent forms of physical activity worldwide, with a significant increase in participation over the past few decades. Due to its accessibility, minimal cost, and ease of implementation, running is frequently adopted by individuals seeking to improve health outcomes, such as weight management and enhanced physical fitness [1,2].

Studies have demonstrated that running not only enhances physical function but also effectively promotes mental well-being of runners [3]. Despite the positive health impacts of running, the sharp increase in participation has led to a corresponding rise in running-related injuries (RRIs) [4,5]. During long-distance running, runners are subjected to vertical ground reaction force (GRF) equivalent to two to three times their body weight (BW) [6]. As a result, they repeatedly experience the impact of vertical GRF. Reports on RRIs indicate that the incidence rate of such injuries ranges from 30% to 79% [5,7]. A majority of these RRIs (50%-75%) are attributed to overuse of the knee joint and areas below it, with the knee and ankle being the most commonly affected regions [8].

The factors influencing RRIs are multifaceted, encompassing both intrinsic and extrinsic factors. Intrinsic factors include biomechanical and morphological differences among runners, as well as age, gender, medical history, and body mass index (BMI). Extrinsic factors involve training experience, physical fitness, type of running shoes, and other athletic equipment [9-13]. Despite significant efforts by clinicians and researchers to reduce the incidence of RRIs, alongside continuous advancements and innovations in running gear such as shoes, the injury rate has not declined over the past 40 years [4,8,14]. Research indicates that novice runners with no prior running experience are at higher risk of sustaining RRIs [9,15]. Therefore, it is particularly

important for novice runners to focus on injury prevention during running, as this can enhance their long-term participation and contribute to the promotion of public health.

Sex-specific anatomical variations are widely recognized to affect lower extremity kinematics during running, particularly in parameters such as hip adduction, hip internal rotation, and knee abduction [16,17]. Female runners typically exhibit a greater range of motion in both the frontal and transverse planes when compared to male runners. These differences are largely attributed to the distinctive morphology of female runners, including a higher hip-width to femoral length ratio, which may play a role in the differential risk of RRIs. Abnormal movement mechanics, often cited as a contributing factor to injury, also differs between sexes. Female runners, in contrast to males, show increased hip internal rotation and adduction, along with greater peak knee abduction, all of which may contribute to a heightened susceptibility to injury. Biomechanical differences in the lower limbs between male and female runners can impact running economy, affecting energy efficiency and performance [18]. A comprehensive understanding of the kinetic and kinematic differences between male and female runners may provide insights into sex-specific injury rates and patterns. Considering these biomechanical variations can enhance the effectiveness of injury prevention strategies.

As running speed increases, the magnitude of forces acting on the body also rises. Studies have documented changes in GRFs, joint moments, muscle activity, leg stiffness, and body segment motions at varying running speeds [19]. Understanding the biomechanical behavior of the lower limbs across different speeds is critical for advancing knowledge of human performance and identifying factors contributing to injury. Higher running speeds amplify the forces transmitted through the lower extremities. At slower speeds, stride length and contact time decrease while step frequency increases, potentially allowing more time for force dissipation upon ground impact [20]. In controlled overground conditions, higher speeds result in shorter contact times and greater peak forces [21]. Consequently, reducing running speed may serve as an effective strategy to lower biomechanical load. The positive correlation between ground reaction force and running speed is well established in the literature [22,23]. Based on the above findings, this dissertation further aims to explore strategies to reduce running injury rates and prevent lower limb injuries during long-distance running, thereby providing meaningful guidance for the practice of running and the prevention of RRIs.

3. Objectives

The first research objective: This study aims to develop musculoskeletal modeling and simulation techniques to compare muscle forces and knee reaction force between novice and experienced runners. Novice runners are defined as individuals who run between 2 – 10 km per week and do not participate in any formal running competitions or training programs. In contrast, experienced runners consistently run at least 30 km per week and have a minimum of three years of running experience. Although increased running experience is associated with a reduced risk of RRIs, the underlying biomechanical mechanisms remain unclear. Since recent advancements in musculoskeletal modeling and power computing, researchers have been allowed to develop motion simulations to value muscle forces, and then joint forces. Muscles reduce the bending stress on bones and dampen the peak dynamic loads from unprotected impulsive loads that can cause harm to musculoskeletal tissues. The knee muscle groups were the important contributors during running, due to the large amount of work those muscles generate. Information on this is especially pertinent to the fields of injury prevention and running performance. The objective of this research is to investigate the biomechanical differences between runners with varying levels of experience to enhance understanding of the factors that may contribute to reduced injury risk among runners.

The second research objective: To quantitatively explore the underlying mechanisms contributing to the development of RRIs during long-distance running, this study focuses on examining biomechanical changes in the lower extremities. Specifically, we aim to investigate alterations in joint angles and moments over the course of a 5 km run in two distinct groups of runners: experienced and novice. Through a detailed analysis of these biomechanical variations, we seek to identify key risk factors that may increase the likelihood of injury. By focusing on the differences in joint loading patterns and kinematic behaviors between the two groups, this study will offer critical insights into the biomechanical triggers that lead to RRIs. Moreover, the findings will contribute to the development of evidence-based guidelines for safer, more effective long-distance practices. These guidelines will not only assist in reducing injury risks but also support long-term performance enhancement and the overall health of runners. Ultimately, the practical recommendations derived from this research will be applicable to both novice and seasoned runners, promoting injury prevention and facilitating healthier, sustained participation in running activities.

The third research objective: During running training sessions, speed is frequently adjusted as a key indicator of the task's physical intensity. While many studies have investigated the biomechanical effects of varying running speeds, the majority have focused on only one gender, leaving the gender-specific biomechanical responses to speed largely unexplored. The current study seeks to fill this gap by examining the differences in gait patterns between male and female runners across seven discrete running speeds: 10, 11, 12, 13, 14, 15, and 16 km/h. Specifically, the study will explore the relationship between GRFs and running speed in both genders. Understanding GRF variations across different speeds is crucial for identifying biomechanical factors that may contribute to RRIs. Despite the importance of this relationship, current research provides insufficient evidence regarding the confounding effects of running speed and gender on GRFs. Key questions remain unanswered, including whether males and females adapt differently to changes in running speed, how speed influences GRFs during overground running, and whether GRF parameters can reliably predict changes in running speed. Addressing these questions could lead to more effective injury prevention strategies and a deeper understanding of the biomechanical adaptations to varying speeds in runners.

4. Research Methods and Challenges

Methods: 30 healthy male runners (15 experienced, 15 novice) were recruited. Novice runners ran 2 - 10 km/week with no competition history but had regular activity (Tegner ≥ 5); experienced runners ran ≥ 30 km/week for over 3 years. All participants used heel-strike patterns, preferred their right leg, had treadmill experience, and no lower limb injuries in the prior 6 months. Another group of 48 recreational runners (30 male, 18 female) also participated. All ran ≥ 20 km/week, used rearfoot strike, and met similar injury and experience criteria. Ethical approval was granted by Ningbo University (RAGH20210627), and all participants signed informed consent. Experiments were conducted in the Biomechanics Lab of the Research Academy of Grand Health.

Participants completed a personal form and underwent anthropometric measurements. Standardized gear was provided, followed by a 10-minute treadmill warm-up at 8 km/h. Reflective markers were placed per OpenSim 2392 model requirements (23 DOF, 92 MTUs), and a static trial was recorded in anatomical position.

In Section 1, biomechanical data (kinematics, kinetics, EMG) were collected before and after a 5 km treadmill run at self-selected speed (9–12 km/h). Each participant completed three valid trials per condition. EMG sensors monitored six lower limb muscles (per SENIAM guidelines). Successful trials required natural gait, full right foot contact on the force plate, steady speed (2.77–3.33 m/s), and intact markers. Post-run data were collected within 2 minutes of run completion. In Section 2, runners performed tests at seven speeds (10–16 km/h) on a 20 m runway, completing three valid trials per speed ($\pm 2\%$). Timing gates confirmed velocity. Adequate rest was ensured to prevent fatigue, and participants were monitored throughout.

Motion capture data were processed using Vicon Nexus 1.8.5 to label markers and extract stance phases. C3D files were then imported into OpenSim 4.2 and Visual 3D 6.0 for musculoskeletal simulation and kinematic/kinetic analysis. EMG data were filtered (10 – 500 Hz band-pass, full-wave rectified), normalized, and compared with OpenSim-predicted muscle activations to validate simulation accuracy. Muscle forces and joint loads were estimated using OpenSim 4.3 with an enhanced 2392 model (23 DOF, 92 MTUs). Anthropometric scaling was based on static trials and body mass. Computed Muscle Control (CMC) was used to generate muscle-driven simulations, and joint forces (anterior-posterior, medial-lateral, and compressive) were analyzed. Visual 3D calculated joint angles and moments (via inverse dynamics). All biomechanical data were time-normalized to 101 points per stance phase using MATLAB.

Kinematic and kinetic variables included joint angles, ROMs, joint moments, GRFs, and knee reaction forces (normalized to body weight or mass). Muscle parameters included peak forces and force curves of major lower-limb muscles. Key GRF variables (e.g., VALR, impulses, peak forces) were selected based on prior studies. PCA was applied to reduce dimensionality and identify biomechanical patterns.

In Section 1, independent t-tests and two-way repeated-measures ANOVA were used to compare groups and conditions. SPM1d tested waveform differences; Pearson correlations examined links between peak muscle and knee forces. In Section 2, Shapiro–Wilk tests assessed normality; Pearson correlations and stepwise regressions analyzed the relationship between GRFs and running speed. SPM and repeated-measures ANOVA were used to test speed and gender effects on GRF waveforms. All stats were conducted using SPSS 25.0.

Challenges: This study faced several challenges during both experimental execution and data processing, particularly concerning the sensitivity of running tests to uncontrolled variables. Running, as a highly dynamic and repetitive activity, requires a stable testing environment and consistent subject performance. Despite standardized warm-up and familiarization procedures, factors such as psychological tension, fatigue, and subtle gait adjustments could still influence critical outcomes like force plate contact, muscle activation, and joint kinematics. Moreover, ensuring that the right foot fully contacted the force plate at the correct speed range demanded precise laboratory setup and equipment synchronization. Any deviation—such as a missed foot strike or dislodged marker—necessitated a trial repeat, reducing efficiency and potentially affecting data consistency.

On the analytical side, musculoskeletal modeling and the integration of large-scale kinematic, kinetic, and EMG datasets presented significant complexity. OpenSim simulations are highly sensitive to model scaling, marker placement accuracy, and motion tracking quality. Even minor errors in these processes can lead to systematic deviations in estimated muscle forces or joint reaction forces. To validate model outputs, simulated muscle activations were compared against EMG measurements, a step that hinges on accurate electrode placement and meticulous signal filtering and normalization. With such a high-dimensional, interdependent data structure, any inaccuracies in preprocessing, noise removal, or normalization can obscure true biomechanical differences and potentially lead to misleading interpretations.

5. New Scientific Results

1st Thesis point: Based on my experiments, the lower limb muscle forces and knee joint loading of runners were estimated by musculoskeletal modeling based on OpenSim (Figure 1). The results showed that novice runners had significantly bigger knee loading and muscle forces than the experienced group in most of the stance phases. Given that excessive and repetitive knee joint loading is strongly associated with the development of RRIs, particularly patellofemoral pain and tibial stress injuries, the increased muscle force may contribute to elevated compressive and shear forces at the knee joint. Therefore, we propose that the observed biomechanical pattern in novice runners—characterized by increased muscle force and resultant knee joint loading—may underlie their potentially higher susceptibility to RRIs. This highlights a possible

mechanistic pathway connecting neuromuscular control deficits with increased joint stress in early running adaptations.

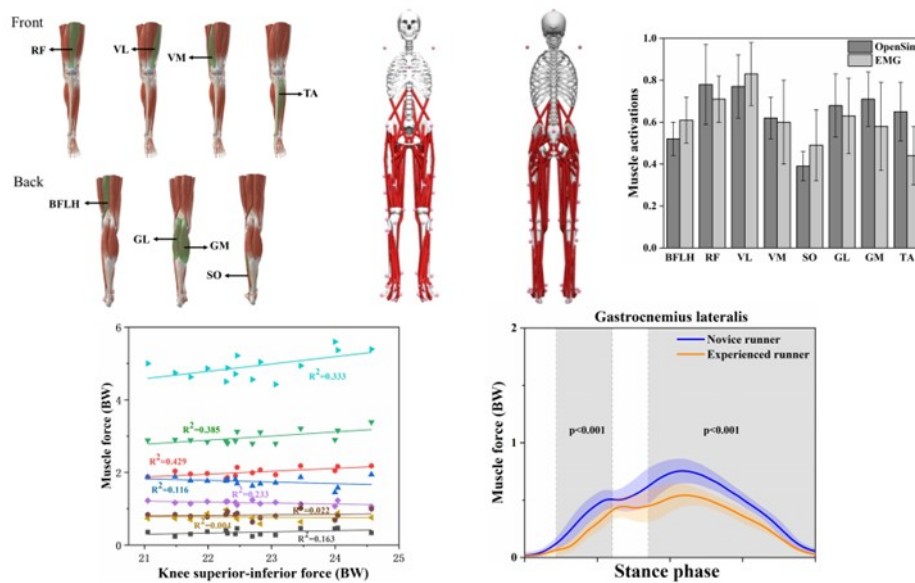


Figure 1 Muscle force differences between the novice and experienced runners

[Related publications: Kang, Z., Jiang, X. (2024). The effect of running experience on muscle forces and knee joint reaction forces during running. International Journal of Biomedical Engineering and Technology.]

2nd Thesis point: Based on my experiments (biomechanical data were collected from 15 novice and 15 experienced runners), which I used both PCA with single-component reconstruction and a two-way repeated-measures ANOVA was conducted to explore the effects of runner and a 5 km run (Figure 2). I found that novice runners exhibited greater changes in joint angles and joint moments than experienced runners regardless of the prolonged running session, and those patterns may relate to lower limb injuries. I also found that the reduced ankle plantarflexion moment may be due to the decrease in energy absorption caused by sustained running, and the decreased knee extension moment during the middle stance and later stance may indicate that runners have weak extensor muscles after a 5 km run. The results of this study suggest that the PCA approach can provide unique insight into running biomechanics and injury mechanisms. The findings

from the study could potentially guide training program developments and injury prevention protocols for runners with different running experiences.

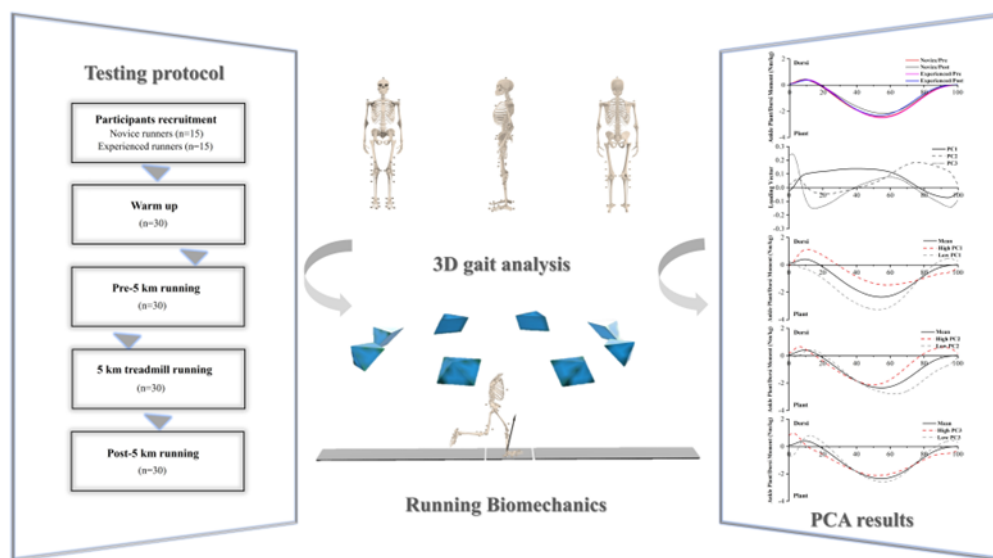


Figure 2 The overview of running biomechanical study on runners

[Related publications: Jiang, X., Xu, D., Fang, Y., Bíró, I., Baker, J. S., Gu, Y. (2023). PCA of Running Biomechanics after 5 km between Novice and Experienced Runners. *Bioengineering*, 10(7), 876.]

3rd Thesis point: Based on my experiments, I investigated the gait pattern differences between males and females while running at different speeds and verified the relationship between GRFs and running speed among both males and females (Figure 3). GRF data were collected from thirty male runners and eighteen female runners while running at seven discrete speeds: 10, 11, 12, 13, 14, 15 and 16 km/h. The ANOVA results showed that running speed had a significant effect ($p < 0.05$) on GRFs, propulsive and vertical forces increased with increasing speed. An independent t-test also showed significant differences ($p < 0.05$) in vertical and anterior-posterior GRFs at all running speeds, specifically, female runners demonstrated higher propulsive and vertical forces than males during the late stance phase of running. Pearson correlation and stepwise multiple linear regression showed significant correlations between running speed and the GRF variables. These findings suggest that female runners require more effort to keep the same speed as male

runners. This study may provide valuable insights into the underlying biomechanical factors of the movement patterns at GRFs during running.

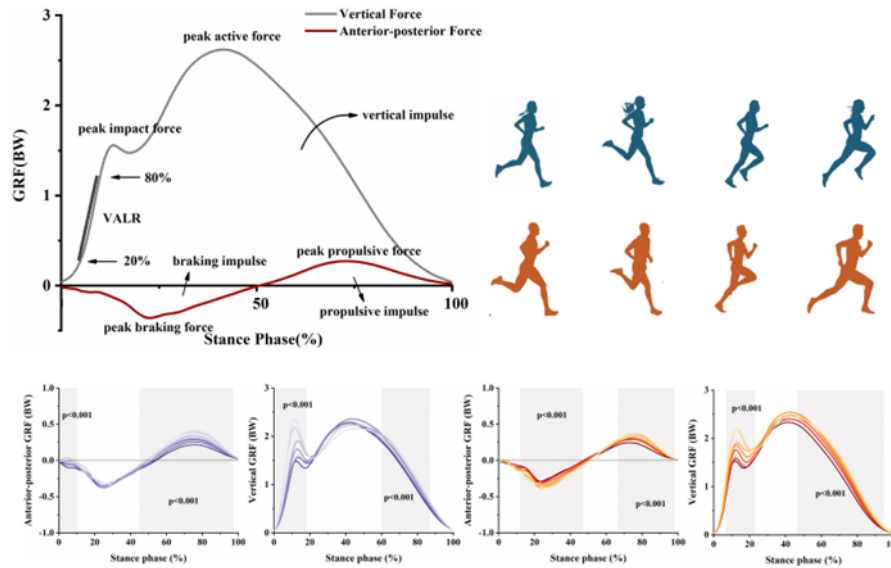


Figure 3 GRF changes between female and male runners across 7 running speeds

[Related publications: 1. Jiang, X., Bíró, I., Sárosi, J., Fang, Y., Gu, Y. (2024). Comparison of ground reaction forces as running speed increases between male and female runners. *Frontiers in Bioengineering and Biotechnology*, 12, 1378284.]

6. Possibility to utilize the Results

The findings of this study offer valuable insights that can be practically applied in multiple domains. For coaches and runners, the observed biomechanical differences between novice and experienced individuals provide a scientific basis for tailoring training programs. By identifying specific phases of running where joint loading and muscle forces are elevated, targeted interventions can be designed to improve movement efficiency and reduce the risk of running-related injuries (RRIs). Furthermore, the validated musculoskeletal modeling framework offers a potential tool for individualized biomechanical assessment, enabling early detection of injury-prone patterns. From an industry perspective, the results can inform footwear designers in developing running shoes that better accommodate the biomechanical needs of different runner profiles. For

example, cushioning systems or structural reinforcements could be optimized based on peak forces and joint mechanics observed during long-distance running. Ultimately, these applications contribute to enhancing performance, promoting safe training practices, and supporting injury prevention strategies in both recreational and competitive running.

7. References

1. Mandolesi, L.; Pol1. Mandolesi, L.; Polverino, A.; Montuori, S.; Foti, F.; Ferraioli, G.; Sorrentino, P.; Sorrentino, G. Effects of physical exercise on cognitive functioning and wellbeing: biological and psychological benefits. *Frontiers in psychology* 2018, 9, 509.
2. Lee, D.-c.; Brellenthin, A.G.; Thompson, P.D.; Sui, X.; Lee, I.-M.; Lavie, C.J. Running as a key lifestyle medicine for longevity. *Progress in cardiovascular diseases* 2017, 60, 45-55.
3. Oswald, F.; Campbell, J.; Williamson, C.; Richards, J.; Kelly, P. A scoping review of the relationship between running and mental health. *International journal of environmental research and public health* 2020, 17, 8059.
4. Messier, S.P.; Martin, D.F.; Mihalko, S.L.; Ip, E.; DeVita, P.; Cannon, D.W.; Love, M.; Beringer, D.; Saldana, S.; Fellin, R.E. A 2-year prospective cohort study of overuse running injuries: the runners and injury longitudinal study (TRAILS). *The American journal of sports medicine* 2018, 46, 2211-2221.
5. Van Gent, R.; Siem, D.; van Middelkoop, M.; Van Os, A.; Bierma-Zeinstra, S.; Koes, B. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *British journal of sports medicine* 2007, 41, 469-480.
6. Lieberman, D.E.; Venkadesan, M.; Werbel, W.A.; Daoud, A.I.; D'andrea, S.; Davis, I.S.; Mang'Eni, R.O.; Pitsiladis, Y. Foot strike patterns and collision forces in habitually barefoot versus shod runners. *Nature* 2010, 463, 531-535.
7. Lun, V.; Meeuwisse, W.; Stergiou, P.; Stefanyshyn, D. Relation between running injury and static lower limb alignment in recreational runners. *British journal of sports medicine* 2004, 38, 576-580.

8. Buist, I.; Bredeweg, S.W.; Bessem, B.; Van Mechelen, W.; Lemmink, K.A.; Diercks, R.L. Incidence and risk factors of running-related injuries during preparation for a 4-mile recreational running event. *British journal of sports medicine* 2010, 44, 598-604.
9. Buist, I.; Bredeweg, S.W.; Lemmink, K.A.; Van Mechelen, W.; Diercks, R.L. Predictors of running-related injuries in novice runners enrolled in a systematic training program: a prospective cohort study. *The American journal of sports medicine* 2010, 38, 273-280.
10. Jiang, X.; Chen, H.; Sun, D.; Baker, J.S.; Gu, Y. Running speed does not influence the asymmetry of kinematic variables of the lower limb joints in novice runners. *Acta of Bioengineering and Biomechanics* 2021, 23.
11. Blair, S.N.; Kohl, H.W.; Goodyear, N.N. Rates and risks for running and exercise injuries: studies in three populations. *Research Quarterly for Exercise and Sport* 1987, 58, 221-228.
12. Xiang, L.; Mei, Q.; Wang, A.; Shim, V.; Fernandez, J.; Gu, Y. Evaluating function in the hallux valgus foot following a 12-week minimalist footwear intervention: A pilot computational analysis. *Journal of Biomechanics* 2022, 132, 110941.
13. Gu, Y.; Lu, Y.; Mei, Q.; Li, J.; Ren, J. Effects of different unstable sole construction on kinematics and muscle activity of lower limb. *Human movement science* 2014, 36, 46-57.
14. Hannigan, J.; Pollard, C.D. Differences in running biomechanics between a maximal, traditional, and minimal running shoe. *Journal of science and medicine in sport* 2020, 23, 15-19.
15. Buist, I.; Bredeweg, S.W.; Van Mechelen, W.; Lemmink, K.A.; Pepping, G.-J.; Diercks, R.L. No effect of a graded training program on the number of running-related injuries in novice runners: a randomized controlled trial. *The American journal of sports medicine* 2008, 36, 33-39.
16. Ferber, R.; Davis, I.M.; Williams Iii, D.S. Gender differences in lower extremity mechanics during running. *Clinical biomechanics* 2003, 18, 350-357.

17. Chumanov, E.S.; Wall-Scheffler, C.; Heiderscheit, B.C. Gender differences in walking and running on level and inclined surfaces. *Clinical biomechanics* 2008, 23, 1260-1268.
18. Xie, P.-P.; István, B.; Liang, M. Sex-specific differences in biomechanics among runners: A systematic review with meta-analysis. *Frontiers in Physiology* 2022, 13, 994076.
19. Hamner, S.R.; Delp, S.L. Muscle contributions to fore-aft and vertical body mass center accelerations over a range of running speeds. *Journal of biomechanics* 2013, 46, 780-787.
20. Stoquart, G.; Detrembleur, C.; Lejeune, T. Effect of speed on kinematic, kinetic, electromyographic and energetic reference values during treadmill walking. *Neurophysiologie Clinique/Clinical Neurophysiology* 2008, 38, 105-116.
21. Nilsson, J.; Thorstensson, A. Ground reaction forces at different speeds of human walking and running. *Acta Physiologica Scandinavica* 1989, 136, 217-227.
22. Hollis, C.R.; Koldenhoven, R.M.; Resch, J.E.; Hertel, J. Running biomechanics as measured by wearable sensors: effects of speed and surface. *Sports biomechanics* 2021.
23. Jiang, X.; Bíró, I.; Sárosi, J.; Fang, Y.; Gu, Y. Comparison of ground reaction forces as running speed increases between male and female runners. *Frontiers in Bioengineering and Biotechnology* 2024, 12, 1378284.

8. Publications

8.1 Scientific Publications related to the Thesis Points

1. **Jiang, X.**, Xu, D., Fang, Y., Bíró, I., Baker, J. S., & Gu, Y. (2023). PCA of Running Biomechanics after 5 km between Novice and Experienced Runners. *Bioengineering*, 10(7), 876. **IF: 3.8, Q3**
2. **Jiang, X.**, Bíró, I., Sárosi, J., Fang, Y., Gu, Y. (2024). Comparison of ground reaction forces as running speed increases between male and female runners. *Frontiers in Bioengineering and Biotechnology*, 12, 1378284. **IF: 4.3, Q1**
3. Kang, Z., **Jiang, X.** (2024). The effect of running experience on muscle forces and knee joint reaction

forces during running. *International Journal of Biomedical Engineering and Technology*. **IF: 0.7, Q4**

8.2 Additional Scientific Publications

1. **Jiang, X.**, Sárosi, J., Bíró, I. (2024). Characteristics of lower limb running-related injuries in trail runners: a systematic review. *Physical Activity and Health*, 8(1). **CS (Scopus CiteScore): 4.4, Q1**
2. Zhang, L., Zhang, Q., Liu, Q., **Jiang, X.**, Simon, J., Hortobágyi, T., & Gu, Y. (2025). Dual Transverse Arch Foot Orthosis Improves Gait Biomechanics in Females with Flexible Flatfoot. *Bioengineering*, 12(4), 418. **IF: 3.8, Q3**
3. Xu, D., Zhou, H., Quan, W., **Jiang, X.**, Liang, M., Li, S., ... & Gu, Y. (2024). A new method proposed for realizing human gait pattern recognition: Inspirations for the application of sports and clinical gait analysis. *Gait & Posture*, 107, 293-305. **IF:2.2, Q1**
4. Xu, D., Zhou, H., **Jiang, X.**, Li, S., Zhang, Q., Baker, J. S., & Gu, Y. (2022). New insights for the design of bionic robots: adaptive motion adjustment strategies during feline landings. *Frontiers in Veterinary Science*, 9, 836043. **IF:2.6, Q1**