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Independent Research & further reading

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Contents

Foot Function, Structure, and Anatomy

Foot Structure

"The widest part of our foot should be our toes."

Research indicates that foot shape and toe width vary between individuals and genders. However, the ball of the foot–where the heads of the first to fifth metatarsal bones are located–is identified as the widest part of the foot in both children and adults. Measurements of "foot width" or "ball width" in research refer to this area, and it is the primary reference for shoe design and fitting.

References 1-5.

Forefoot

"The forefoot, when we are walking, can take on many times our body weight."

During the "push-off" phase of walking, the load on the forefoot can exceed body weight by about 20%, meaning the forefoot may bear up to 1.2 times body weight at peak loading, but not several times body weight. The resultant force on the first metatarsal head (a key part of the forefoot) is estimated at about 119% of body weight, while the second metatarsal head experiences about 45% of body weight. In normal barefoot walking, the forefoot carries a total load about three times that of the heel, but this refers to the distribution of load between foot regions, not a multiplication of total body weight.

References 6-8.

Splaying of Feet and Walking

> *"When we have a foot that can splay, you have strength, you have stability, and that is what is required for forward ambulation."*

Walking without shoes allows for increased forefoot spreading (splaying) under load. Habitual barefoot walkers tend to have anatomically wider feet, and their gait shows more forefoot splay compared to those who regularly wear shoes. This splaying is associated with reduced step length, increased cadence, and lower peak plantar pressures, suggesting a more natural distribution of forces across the foot. Common footwear restricts natural foot splaying, altering foot position and mechanics. This can affect gait kinematics and kinetics both acutely and over time.

The placement of the foot during walking is crucial for maintaining balance and stability. Foot placement is actively coordinated with the body's centre of mass (CoM) to stabilise gait, but this does not specifically require splaying. Instead, it involves precise positioning of the foot relative to the body, which can be achieved with or without significant splaying, depending on footwear and individual anatomy. Intrinsic and extrinsic foot muscles coordinate in a task-specific manner during walking. While some muscle activity supports foot spreading, the main biomechanical contributions during forward walking are separable and do not depend solely on splaying.

References 9-12.

Sensory Receptors in Feet

> *"The problem with cushion is that the more stuff that's between your foot and the ground, the less you feel. So there's a loss of sensory acuity. There's a loss of sensory perception. Remember, the foot is, imagine the foot's a sensory organ, and it is because there's thousands of receptors that are, you know, screaming for information to help keep us upright in a biped."*

The foot contains a dense network of sensory receptors that provide essential information for balance, movement, and interaction with the environment. The skin of the foot, especially the sole, is packed with mechanoreceptors that detect touch, pressure, and vibration. These receptors send signals to the brain to help control balance and adjust movement during walking and standing.

The foot’s sensory feedback is vital for postural control. Loss of foot sensation, as seen in neuropathy, leads to poorer balance and a higher risk of falls.

References 13-16.

Risk of Falling

> *"Toe weakness is one of the biggest predictors of falls as we age."*

Multiple studies show that older adults who fall tend to have significantly weaker toe flexor strength compared to non-fallers. This weakness is independently associated with a higher risk of falls, even after accounting for other physiological risk factors and age. Conditions such as hallux valgus (bunion) and lesser toe deformities are also strongly linked to increased fall risk. These deformities are often related to, or worsened by, toe muscle weakness. Additionally, Weakness in the hallux and lesser toes is associated with poorer balance, reduced mobility, and lower performance on physical function tests, all of which contribute to a higher likelihood of falling.

References 17-20.

Toe Spring

> *"When you put your foot in a position with toe spring, you will weaken the intrinsic muscles of the foot."*

Toe spring, a term used in the shoe industry, refers to the upward curve at the toe of a shoe. It's designed to assist with the toe-off phase of walking or running, helping the forefoot roll smoothly onto the toes. While often touted as a positive feature, toe spring can also have negative effects on foot biomechanics and potentially increase the risk of injury.

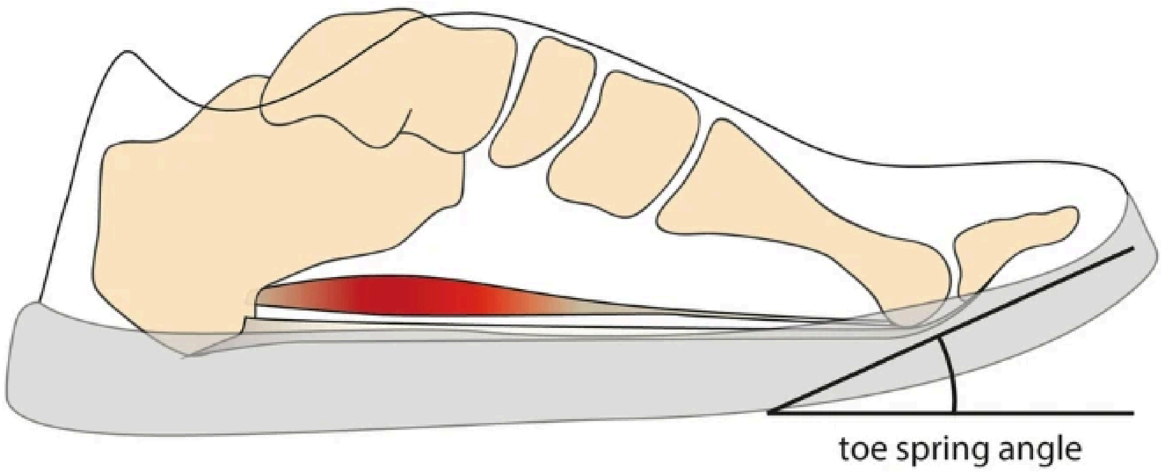

Figure adapted from Sichting et al. 2020.

Intrinsic foot muscles are crucial for supporting the foot’s arch, stabilising the foot, and maintaining balance, especially during dynamic activities and weight-bearing tasks. Weakness or disuse of these muscles can lead to dysfunction, poor toe alignment, and increased risk of instability and falls, particularly in older adults.

References 21-25.

The Calcaneus

> *"So our calcaneus, this heel bone was beautifully designed to absorb shock."*

The calcaneus is the largest tarsal bone and is well-adapted to sustain high tensile, bending, and compressive forces, which are common during activities like walking and running. In typical foot anatomy, the calcaneus works with the tibia and talus to transfer and dissipate forces from the ground up through the leg, helping to reduce the impact on other bones and joints.

The specialized plantar heel pad, which covers the calcaneus, is specifically designed to absorb ground reaction forces during gait. If this pad is compromised, the calcaneus is exposed to abnormal and potentially damaging forces, highlighting the importance of the soft tissue in shock absorption. The calcaneus shows increased bone density and growth at articulation points in response to higher stress and loading, indicating its ability to adapt structurally to absorb and manage shock over time.

References 26, 27.

High Heels

> *"Your foot in that position [in high heels] is not the position it is supposed to be in."*

High heels force the ankle into a plantar flexed position, which is not the natural position for standing or walking. This alters the rollover function of the foot and increases stress on the forefoot and metatarsal heads. There is a significant increase in pressure on the forefoot and a decrease on the heel, especially as heel height increases. This can lead to discomfort and potential deformities over time. Additionally, high heels can reduce the longitudinal arch (leading to a flatter foot) and alter the transverse arch, especially with higher heels. This can contribute to abnormal foot mechanics and reduced balance.

References 28-34.

Feet Influence Structures Above It

> *"if my foot is supposed to sit flat, I have tissues in the back of my leg that are in a good length, tension relationship. I have even pressures across my foot. Yeah. The second I go and change those things where I go into a heel, you put additional pressure on the front of the foot, you shorten the muscles in the back of the leg. So you start changing the, the function and the structure of not only the foot, but everything that sits above it. Steve: You calf your Yes, your back. Do you see a lot of back injuries that are relating to things like heels?"*

A study showed wearing high heels shortens the gastrocnemius muscle fascicles by up to 5% and another study showed increases in Achilles tendon stiffness.

Multiple studies report a significant association between high heel use and low back pain, particularly with frequent or long-term use. For example, 56% of young female students who wore high heels reported low back pain, with higher heel heights increasing both the incidence and intensity of pain. A meta-analysis found that women who wear high heels, especially in occupations requiring prolonged standing or walking, have a higher risk of developing low back pain. However, some population-based studies found a relatively low prevalence of disabling low back pain among habitual high heel wearers, suggesting individual variability in susceptibility.

References 35-41.

How the Hip Impacts the Foot

> *"The strength of the hip, for example, controls the foot, it controls how the foot unlocks. So you have to take that into account when you're looking at patients with foot pain."*

Reduced hip abductor strength relative to adductors is associated with increased foot pronation (flattening of the arch). This relationship suggests that weak hip abductors may allow the foot to roll inwards more during standing and walking. Additionally, greater hip abductor strength is linked to a more neutral foot position during walking, especially in males, which may help distribute knee loading more evenly. The degree of foot pronation during walking is influenced by complex interactions between hip stiffness, hip strength, and foot alignment. Certain combinations of hip and foot factors predict greater or lower pronation.

Individuals with chronic ankle sprains often have weaker hip abductors on the affected side, suggesting that hip weakness may contribute to or result from foot and ankle injuries. Hip abductor strength is moderately correlated with better balance and ankle mobility, which are important for injury prevention and athletic performance. Strengthening the hip abductors and external rotators leads to changes in lower limb mechanics, such as reduced rearfoot eversion (less pronation) and altered joint loading, potentially lowering injury risk.

References 42-49.

Splaying of the toes

> *"I think about, you know, one of the biggest things when I'm working with my patients from a strength perspective is can the foot do what someone's hands can do? So, for example, can the toes splay? Can you lift your big toe? Can you lift your lesser toes?*

During walking and running, the intrinsic muscles of the toes are active from mid-stance to lift-off, helping to lift and sometimes splay the toes as the foot pushes off the ground. This action supports balance and propulsion, especially during running and sprinting, where toe muscles are active throughout the weight-bearing phase. Dynamic footprints show that as the heel lifts, the distal ends of the toes come into contact with the ground, causing splaying. This splaying is associated with the toes leaving the ground and is a normal part of the gait cycle.

References 50, 51.

Running

> *"t's the heavy overstride you wanna avoid. Okay. Okay. But if I can't feel anything you don't know, that's the, the more stuff on the shoe you can override hot and heavy. And because you have all this cushion there, you're be like, well, yeah."*

The relationship between shoe cushioning and running mechanics is complex. While it's often assumed that more cushioning reduces injury risk, research shows that highly cushioned shoes can actually change how runners move, sometimes increasing impact forces. These shoes can lead to increased leg stiffness and higher impact loading, especially at faster speeds.

Although the research does not directly link cushioning to overstriding, the changes in leg stiffness and impact loading suggest that running mechanics are altered and may influence stride patterns. Notably, lower leg stiffness doesn't cause overstriding; instead, elite runners with lower leg stiffness tend to overstride more, possibly to maximise speed at the expense of efficiency.

References 52-55.

Footwear and Effects on Health

Children Wearing the Wrong Shoe Size

> *"When you look at the statistics of, especially with, um, children with girls, around 70% are wearing shoes that are too narrow."*

A 2019 survey revealed that 65% of parents were unable to accurately determine their children's shoe sizes when compared to precise foot measurements.

Reference 56.

Balance, Fall Risk, Aging

Rate of Falls Among the Elderly

> *"25 to 40% of people over 70 will fall at least once a year."*

References 57-59.

Mortality Rates Following a Hip Fracture

> *"25% of people who suffer a hip fracture will be dead within a year."*

Recent studies report one-year mortality rates after hip fractures ranging from about 16% to 35%, with most large studies and reviews finding rates between 16% and 24% for the general elderly population. Older data and some specific cohorts (e.g., very elderly, those with more comorbidities) report rates closer to or above 25%.

References 60-64.

Falls Due to Weak Feet

"Falls are one of the biggest consequences of weak feet."

Foot pain, hallux valgus (a deformity of the big toe), and lesser toe deformities are consistently linked to a higher risk of falls in older adults. In a study by Sánchez-Sanjuan et al. (2022), older adults with hallux valgus or tailor's bunion had about twice the probability of falling compared to those without these foot issues. This increased risk is further compounded by weakness in both intrinsic and extrinsic foot muscles, particularly the toe flexors and plantarflexors, which are essential for maintaining balance and mobility. Additionally, limited ankle flexibility, reduced toe movement, and diminished tactile sensitivity in the feet all contribute to impaired stability and a greater likelihood of falling.

References 65-69.

Development, Kids, and Evolution

Impact of Footwear on Development of Feet

"I always say that if we started with our children and put them in the right footwear, I'd be out of a job because that's when it starts. That's when the foot starts developing and that's when we start to build strength and, you know, structure to the foot. And from a very young age, we start interfering with what goes on the foot. And when you think about all of the things that the foot can do, it's why I'm obsessed with it. I mean, there's bones and ligaments and the foot should be designed."

Footwear plays a significant role in the development of children's feet, with regular use of closed-toe and less flexible shoes linked to lower longitudinal arches and a higher incidence of flatfoot. In contrast, children who grow up barefoot or wearing minimal footwear tend to have stronger arches and fewer structural issues. One of the major concerns is poor shoe fit—whether too long, too short, too wide, or too narrow—which is associated with deformities such as hallux valgus (bunions) and changes in toe and heel alignment.

Conventional shoes also restrict the natural range of motion in the foot, particularly in the arch and during torsional movement. More flexible shoes help reduce these limitations and better replicate the benefits of barefoot walking. Unfortunately, many children wear improperly fitted footwear, which can negatively impact foot structure, including arch height and toe alignment. To support healthy development, shoes for young children should be flexible and offered in a variety of widths to accommodate different foot shapes. Overly stiff or cushioned shoes can interfere with natural muscle and bone development. Evidence also suggests that closed-toe shoes are more likely to be associated with flatfoot, while sandals, slippers, or going barefoot may support healthier arch formation.

References 70-76.

General Health, Movement & Longevity

Health Benefits of Walking

> *"If you were to walk an additional 500 steps in a day, your baseline's 2,500, you can reduce your risk of cardiovascular mortality by 7%."*

Walking an additional 500 steps per day is associated with about a 6–7% reduction in cardiovascular mortality. This benefit is observed across diverse populations and is part of a broader trend where more daily steps lead to greater health benefits.

References 77, 78.

> *"A 1,000-step increase reduces all-cause mortality by 15%."*

A 1,000-step increase per day is associated with a 12–15% reduction in all-cause mortality. This benefit is seen across different ages and health backgrounds, and even modest increases in daily steps can provide significant health advantages.

References 79-82.

> *""If you think about, if you look at the research on average step count that most people globally are taking, it's about 45 to 4,900."*

Large-scale analyses and meta-analyses report that healthy adults typically take between 4,000 and 9,000 steps per day, with many populations—especially older adults—averaging closer to the lower end of this range.

References 79, 83-85.

> *"there's like the dementia study getting to around 9,800. We see that steady decline in the risks of dementia."*

Higher daily step counts are linked to a steady decline in dementia incidence, with benefits observed up to about 9,800 steps per day. The step count associated with 50% of the maximal observed benefit is around 3,800 steps per day. Walking at a higher intensity (faster pace) further reduces dementia risk.

Reference 86.

Walking *versus* standing

> *"I don't know if standing in one place is any better than sitting in one place other than when you're standing you can actually like, you know, move around and, you know, make it more active standing. But it is a matter of taking movement breaks. Like that's, I call them, you know, movement snacks."*

Research shows that dynamic movement and the ability to transition between positions are more strongly linked to functional health, balance, and physical activity than static standing alone.

Interrupting sitting with standing can modestly reduce post-meal (postprandial) glucose and insulin levels, but light-intensity walking leads to much greater reductions in both glucose and insulin compared to standing or sitting alone. Walking breaks can also lower blood pressure and improve cholesterol profiles, while standing shows little to no effect on these markers.

Prolonged standing can cause leg swelling and muscle fatigue, while walking does not. Walking is recommended to prevent the negative effects of long periods of standing. Additionally, walking burns significantly more calories than standing. Standing is not an effective substitute for walking if the goal is to increase energy expenditure.

References 87-94.

Step Count and Depression

> *"5,000 steps a day. Can reduce the risk of having symptoms of depression. If you get to 7,500 steps per day, it can reduce the prevalence of the diagnosis of depression."*

There is a clear, linear relationship: each additional 1,000 steps per day is linked to a further reduction in depressive symptoms. For example, older adults who walked between 3,500 and 6,999 steps daily had significantly fewer depressive symptoms than those walking less, and those reaching 7,000 or more steps had the greatest protection.

References 95, 96.

Running, Training & Performance

Running Shoes and Running Economy

> *""You get the research will tell you two to 4% running economy, people run faster because the shoe has the technology to facilitate gait."*

The Nike Alphafly (and similar models like the Vaporfly) show running economy improvements of 2–4% compared to traditional racing shoes and track spikes.

References 97-101.

Plyometric Training and Barefoot Strengthening

> *"There's research that will show you that plyometrics also increase capacity in running by two to 4%."*

Studies report improvements in running economy ranging from 2% to 7%, with most falling in the 2–4% range after 4–9 weeks of plyometric training. These improvements in running economy are often accompanied by better time trial performance (e.g., 1.6–2.7% faster over 3–5 km). Greater improvements are seen with longer interventions (>7 weeks), higher frequency (>2 sessions/week), and more total sessions (>15).

References 102-107.

> *"There's research that will show you that plyometrics also increase capacity in running by two to 4%. So my conversation I have with my patients is, listen, what if we stacked therapies? Right? What if you did plyometric work... and we worked on your strength?"*

Plyometric training utilises explosive, stretch-shortening cycle movements to increase muscle power, strength, and neuromuscular efficiency, which can translate to improved running speed, running economy, and performance over various distances. Barefoot/foot-strengthening (e.g., jump rope) heavily engages foot muscles and joints and can thus increase foot-arch stiffness and lower-limb reactivity, both linked to better running performance.

References 102-108.

Overstriding

> *"Steve: What's the most common issue with someone's gait that you tend to see?*
>
> *Courtney: The overstride. Overstride."*

Overstriding—landing with the foot too far ahead of the body's centre of mass—is widely recognised as a common running technique error. While it is discussed in both research and coaching, the evidence does not definitively state that it is the single most common running mistake, but it is consistently identified as a key flaw linked to injury risk and suboptimal performance. Greater overstride angles and ankle dorsiflexion are observed in runners with chronic exertional compartment syndrome (CECS), suggesting a link between overstriding and certain running injuries. Overstriding is often accompanied by tibial extension and a rearfoot landing pattern, both of which may elevate injury risk. In professional and coaching contexts, overstriding is regularly cited as a primary mechanical flaw, alongside issues like pelvic instability.

References 109-111.

> *"“So our calcaneus, this heel bone was beautifully designed to absorb shock. … When I overstride and I can feel it, what am I gonna do that's gonna hurt? So you're not gonna do it anymore. You're gonna override and you be like, ah, that hurts."*

Wearable sensors have shown that overstriding correlates with biomechanical changes that may increase injury risk, highlighting the importance of proper shock absorption mechanics in preventing pain and injury.

Reference 112.

Foot Strike in Relation to Centre of Mass

> *"I want my foot to strike as close to my center of mass as possible."*

The research suggests that while the relationship between foot strike and the centre of mass (COM) is crucial for balance and stability, the optimal foot strike position is not necessarily directly under the COM, but rather is dynamically adjusted based on velocity, gait phase, and individual biomechanics. Overemphasis on striking directly under the COM may not be necessary or optimal for all runners, as dynamic adjustments are part of efficient and stable running. However, evidence suggests that a foot strike closer to the body's COM—often achieved with a midfoot or forefoot strike—can reduce impact forces and may help stabilise the COM, but the ideal position depends on individual biomechanics and running goals. The patterns that typically result in the foot landing closer to the COM, are associated with lower vertical loading rates and reduced impact severity compared to rearfoot strikes. This can decrease stress on the knee and may help stabilise the vertical movement of the COM.

References 113-115.

Plantar Fasciitis

> *"Plantar fasciitis often occurs from adding load too quickly to a weak foot."*

Plantar fasciitis frequently results from repetitive stress or overuse, especially in runners, athletes, or those with jobs requiring prolonged standing or walking. Microtears and degeneration, rather than inflammation, are typical findings in the plantar fascia. Individuals with flat feet (pes planus), high arches (pes cavus), or tight calf muscles are at higher risk. Poorly supportive footwear and excessive pronation also contribute. Atrophy or weakness of the intrinsic foot muscles, particularly in the rearfoot, is associated with plantar fasciitis and may destabilise the foot’s arch, increasing strain on the fascia.

References 116-121.

Walking and Psychological Well-Being

> *"Walking regulates the nervous system."*

Multiple systematic reviews and meta-analyses show that walking significantly reduces symptoms of depression and anxiety in adults, with effects comparable to other active interventions.

Both individuals with and without depression benefit, though those with depression may experience greater improvements.

References 122-124.

References

1. Janisse, D.J. (1992). The Art and Science of Fitting Shoes. Foot & Ankle International, 13, 257 - 262.
2. Krauss, I., Grau, S., Mauch, M., Maiwald, C., & Horstmann, T. (2008). Sex-related differences in foot shape. Ergonomics, 51, 1693 - 1709.

3. Stanković, K., Booth, B., Danckaers, F., Burg, F., Vermaelen, P., Duerinck, S., Sijbers, J., & Huysmans, T. (2018). Three-dimensional quantitative analysis of healthy foot shape: a proof of concept study. Journal of Foot and Ankle Research, 11.

4. Puszczałowska-Lizis, E., Lizis, S., Prusak, M., & Omorczyk, J. (2022). Impact of length and width of footwear on foot structure of preschool-aged children. PeerJ, 10.

5. Łabęcka, M., Górniak, K., & Lichota, M. (2021). DYNAMICS OF CHANGES IN SELECTED PARAMETERS OF FOOT ARCHING IN CHILDREN BETWEEN 5 AND 9 YEARS OLD.

6. Stokes, I., Hutton, W., & Stott, J. (1979). Forces acting on the metatarsals during normal walking.. Journal of anatomy, 129 Pt 3, 579-90 .
7. Jacob, H. (2001). Forces acting in the forefoot during normal gait--an estimate.. Clinical biomechanics, 16 9, 783-92 .
8. Grundy, M., Tosh, P., McLeish, R., & Smidt, L. (1975). An investigation of the centres of pressure under the foot while walking.. The Journal of bone and joint surgery. British volume, 57 1, 98-103.

9. Franklin, S., Grey, M., Heneghan, N., Bowen, L., & Li, F. (2015). Barefoot vs common footwear: A systematic review of the kinematic, kinetic and muscle activity differences during walking.. Gait & posture, 42 3, 230-9 .

10. Bruijn, S., & Van Dieën, J. (2018). Control of human gait stability through foot placement. Journal of the Royal Society Interface, 15.

11. Zelik, K., La Scaleia, V., Ivanenko, Y., & Lacquaniti, F. (2015). Coordination of intrinsic and extrinsic foot muscles during walking. European Journal of Applied Physiology, 115, 691-701.

12. Kreter, N., & Fino, P. (2024). Consequences of changing planned foot placement on balance control and forward progress. Journal of the Royal Society Interface, 21.

13. Hennig, E., & Sterzing, T. (2009). Sensitivity Mapping of the Human Foot: Thresholds at 30 Skin Locations. Foot & Ankle International, 30, 986 - 991.

14. Leem, J., Willis, W., & Chung, J. (1993). Cutaneous sensory receptors in the rat foot.. Journal of neurophysiology, 69 5, 1684-99 .

15. Viseux, F. (2020). The sensory role of the sole of the foot: Review and update on clinical perspectives. Neurophysiologie Clinique, 50, 55-68.

16. Deursen, R., & Simoneau, G. (1999). Foot and ankle sensory neuropathy, proprioception, and postural stability.. The Journal of orthopaedic and sports physical therapy, 29 12, 718-26 .

17. Menz, H., Auhl, M., & Spink, M. (2018). Foot problems as a risk factor for falls in community-dwelling older people: A systematic review and meta-analysis.. Maturitas, 118, 7-14 .

18. Menz, H., Morris, M., & Lord, S. (2006). Foot and ankle risk factors for falls in older people: a prospective study.. The journals of gerontology. Series A, Biological sciences and medical sciences, 61 8, 866-70 .

19. White, J., Maier, A., Iacobaccio, L., & Iseli, R. (2024). Foot problems in older adults presenting to a Falls and Balance Clinic.. Gerontology.

20. Mickle, K., Munro, B., Lord, S., Menz, H., & Steele, J. (2009). ISB Clinical Biomechanics Award 2009: toe weakness and deformity increase the risk of falls in older people.. Clinical biomechanics, 24 10, 787-91.

21. Jastifer, J. (2023). Intrinsic muscles of the foot: Anatomy, function, rehabilitation.. Physical therapy in sport : official journal of the Association of Chartered Physiotherapists in Sports Medicine, 61, 27-36.

22. Ferrari, E., Cooper, G., Reeves, N., & Hodson-Tole, E. (2020). Intrinsic foot muscles act to stabilise the foot when greater fluctuations in centre of pressure movement result from increased postural balance challenge.. Gait & posture, 79, 229-233 .

23. Komiya, M., Maeda, N., Tsutsumi, S., Ishihara, H., Mizuta, R., Nishikawa, Y., Arima, S., Kaneda, K., Ushio, K., & Urabe, Y. (2023). Effect of postural differences on the activation of intrinsic foot muscles during ramp-up toe flexion in young men.. Gait & posture, 102, 112-117 .

24. Taylor, J., Higgins, S., Zeller, A., Landmann, M., & Wunderlich, R. (2022). Function of the Intrinsic Foot Muscles During Balance and Turning. The FASEB Journal, 36.

25. Sichting, F., Holowka, N. B., Hansen, O. B., & Lieberman, D. E. (2020). Effect of the upward curvature of toe springs on walking biomechanics in humans. Scientific Reports, 10(1), 14643.

26. Hall, R., & Shereff, M. (1993). Anatomy of the Calcaneus. Clinical Orthopaedics and Related Research, 290, 27–35.

27. Mei, Q., Gu, Y., Kim, J., Xiang, L., Shim, V., & Fernandez, J. (2022). Form and Function in Chinese Bound Foot.

28. Wiedemeijer, M., & Otten, E. (2018). Effects of high heeled shoes on gait. A review.. Gait & posture, 61, 423-430 .

29. Hasiuk, A., Jaszczur-Nowicki, J., Granda, T., Potocka-Mitan, M., Perliński, J., Zhang, G., Kruczkowski, D., & Bukowska, J. (2023). Effect of wearing high heels on the biomechanical parameters of the foot. Journal of Kinesiology and Exercise Sciences.

30. Leroch, M., Łaszcz, J., Malon, M., & Jarząb, S. (2021). Impact of wearing high heels shoes on pelvic floor muscle activity and incontinence. Aesthetic Cosmetology and Medicine.

31. Cronin, N. (2014). The effects of high heeled shoes on female gait: a review.. Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology, 24 2, 258-63.

32. Zeidan, H., Kawagoe, M., Kajiwara, Y., Harada, K., Nishida, Y., Yamada, K., Kawabe, R., Yokota, J., Yamashiro, C., Odake, Y., Takeda, M., Doi, N., Negoro, K., Matsumura, N., Morino, T., Yoshioka, C., Chen, C., & Aoyama, T. (2020). The shape of the transverse arch in high heels while standing. PLoS ONE, 15.

33. Yu, J., Cheung, J., Fan, Y., Zhang, Y., Leung, A., & Zhang, M. (2008). Development of a finite element model of female foot for high-heeled shoe design.. Clinical biomechanics, 23 Suppl 1, S31-8.

34. Michoński, J., Witkowski, M., Glinkowska, B., Sitnik, R., & Glinkowski, W. (2019). Decreased Vertical Trunk Inclination Angle and Pelvic Inclination as the Result of Mid-High-Heeled Footwear on Static Posture Parameters in Asymptomatic Young Adult Women. International Journal of Environmental Research and Public Health, 16.

35. Csapo, R., Maganaris, C. N., Seynnes, O. R., & Narici, M. V. (2010). On muscle, tendon and high heels. Journal of Experimental Biology, 213(15), 2582–2588.

36. Zöllner, A. M., Pok, J. M., McWalter, E. J., Gold, G. E., & Kuhl, E. (2015). On high heels and short muscles: a multiscale model for sarcomere loss in the gastrocnemius muscle. Journal of theoretical biology, 365, 301–310.

37. Altaf, F., Manzoor, U., Prveen, N., Mazhar, M., Ejaz, R., & Abbass, M. (2023). Prevalence of Low Back Pain in Women Wearing High Heels Residing in Khanewal, Pakistan. American Journal of Health, Medicine and Nursing Practice.

38. Lee, C., Jeong, E., & Freivalds, A. (2001). Biomechanical effects of wearing high-heeled shoes. International Journal of Industrial Ergonomics, 28, 321-326.

39. Firmanurulita, F., Kristiyanto, A., & Prasetya, H. (2023). Meta-Analysis of the Effect of Prolonged Use of High Heels on Low Back Pain in Female Sales Employees. Journal of Epidemiology and Public Health.

40. Dai, M., Li, X., Zhou, X., Hu, Y., Luo, Q., & Zhou, S. (2015). High-heeled-related alterations in the static sagittal profile of the spino-pelvic structure in young women. European Spine Journal, 24, 1274-1281.

41. Nadeem, I., Kashif, M., Mushtaq, S., Hussain, R., Naseem, N., Darain, H., & Khan, D. (2018). High Heels and Low Back Pain in Young Female Students. , 87-91.

42. Hollman, J., Kolbeck, K., Hitchcock, J., Koverman, J., & Krause, D. (2006). Correlations between Hip Strength and Static Foot and Knee Posture. Journal of Sport Rehabilitation, 15, 12-23.

43. Holmes, S., Montgomery, M., Lynn, S., & Pamukoff, D. (2022). Sex-Specific associations between hip muscle strength and foot progression angle.. Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology, 68, 102723.

44. Friel, K., McLean, N., Myers, C., & Caceres, M. (2006). Ipsilateral hip abductor weakness after inversion ankle sprain.. Journal of athletic training, 41 1, 74-8 .

45. Cruz, A., Fonseca, S., Araújo, V., Ocarino, J., Mendonça, L., Resende, R., & Souza, T. (2024). Non-linear interactions among hip and foot biomechanical factors predict foot pronation during walking in women.. Brazilian journal of physical therapy, 28 6, 101136 .

46. Domínguez-Navarro, F., Benítez-Martínez, J., Ricart-Luna, B., Cotolí-Suárez, P., Blasco-Igual, J., & Casaña-Granell, J. (2022). Impact of hip abductor and adductor strength on dynamic balance and ankle biomechanics in young elite female basketball players. Scientific Reports, 12.

47. Alahmri, F., Alsaadi, S., Ahsan, M., & Almousa, S. (2022). The effect of isokinetic hip muscle strength on normal medial longitudinal arch feet and pes planus. Journal of Medicine and Life, 15, 1164 - 1169.

48. Snyder, K., Earl, J., O'Connor, K., & Ebersole, K. (2009). Resistance training is accompanied by increases in hip strength and changes in lower extremity biomechanics during running.. Clinical biomechanics, 24 1, 26-34.

49. Steinberg, N., Dar, G., Dunlop, M., & Gaida, J. E. (2017). The relationship of hip muscle performance to leg, ankle and foot injuries: a systematic review. The Physician and Sportsmedicine, 45(1), 49–63.

50. Mann, R., & Hagy, J. (1979). The function of the toes in walking, jogging and running.. Clinical orthopaedics and related research, 142, 24-9 .

51. Obe, W., Simmonite, N., Reel, S., & Reidy, S. (2017). An investigation into the cause of the inner dark areas and outer lighter areas (ghosting) seen in dynamically-created two-dimensional bare footprints.. Science & justice : journal of the Forensic Science Society, 57 4, 276-282 .

52. Meardon, S. A., Willson ,John D., Kernozek ,Thomas W., Duerst ,Alicia H., & and Derrick, T. R. (2018). Shoe cushioning affects lower extremity joint contact forces during running. Footwear Science, 10(2), 109–117.

53. Kulmala, J.-P., Kosonen, J., Nurminen, J., & Avela, J. (2018). Running in highly cushioned shoes increases leg stiffness and amplifies impact loading. Scientific Reports, 8(1), 17496.

54. Malisoux, L., Delattre, N., Urhausen, A., & Theisen, D. (2019). Shoe Cushioning Influences the Running Injury Risk According to Body Mass: A Randomized Controlled Trial Involving 848 Recreational Runners. The American Journal of Sports Medicine, 48, 473 - 480.

55. Kulmala, J., Kosonen, J., Nurminen, J., & Avela, J. (2018). Running in highly cushioned shoes increases leg stiffness and amplifies impact loading. Scientific Reports, 8.

56. Survey Finds That 65% of All Kids Are Wearing the Wrong Shoe Size *(blitzresults.com)*

57. Tinetti, M., & Speechley, M. (1989). Prevention of falls among the elderly.. The New England journal of medicine, 320 16, 1055-9.

58. Ambrose, A., Paul, G., & Hausdorff, J. (2013). Risk factors for falls among older adults: a review of the literature.. Maturitas, 75 1, 51-61.

59. Bolding, D., & Corman, E. (2019). Falls in the Geriatric Patient.. Clinics in geriatric medicine, 35 1, 115-126 .

60. Morri, M., Ambrosi, E., Chiari, P., Magli, A., Gazineo, D., Alessandro, F., & Forni, C. (2019). One-year mortality after hip fracture surgery and prognostic factors: a prospective cohort study. Scientific Reports, 9.

61. Downey, C., Kelly, M., & Quinlan, J. (2019). Changing trends in the mortality rate at 1-year post hip fracture - a systematic review. World Journal of Orthopedics, 10, 166 - 175.

62. Mundi, S., Pindiprolu, B., Simunovic, N., & Bhandari, M. (2014). Similar mortality rates in hip fracture patients over the past 31 years. Acta Orthopaedica, 85, 54 - 59.

63. Cumming, R., Nevitt, M., & Cummings, S. (1997). Epidemiology of hip fractures.. Epidemiologic reviews, 19 2, 244-57 .

64. Özel, M., Altintaş, M., & Tatlıparmak, A. (2023). Predictors of one-year mortality following hip fracture surgery in elderly. PeerJ, 11.

65. Menz, H., Auhl, M., & Spink, M. (2018). Foot problems as a risk factor for falls in community-dwelling older people: A systematic review and meta-analysis.. Maturitas, 118, 7-14.

66. Menz, H., Morris, M., & Lord, S. (2006). Foot and ankle risk factors for falls in older people: a prospective study.. The journals of gerontology. Series A, Biological sciences and medical sciences, 61 8, 866-70 .

67. Pol, F., Forghany, S., Hosseini, S., Taheri, A., & Menz, H. (2021). Structural and functional foot and ankle characteristics associated with falls in older people.. Gait & posture, 88, 78-83 .

68. Mickle, K., Munro, B., Lord, S., Menz, H., & Steele, J. (2009). ISB Clinical Biomechanics Award 2009: toe weakness and deformity increase the risk of falls in older people.. Clinical biomechanics, 24 10, 787-91 .

69. White, J., Maier, A., Iacobaccio, L., & Iseli, R. (2024). Foot problems in older adults presenting to a Falls and Balance Clinic.. Gerontology.

70. Sánchez-Sanjuan, A., Romero-Morales, C., Alfaro-Santafé, J., Almenar-Arasanz, A., Gómez-Bernal, A., & Pareja-Galeano, H. (2022). Foot Anatomical Structural Variations Increase the Risk of Falls in Older Adults. Applied Sciences.

71. Hollander, K., De Villiers, J., Sehner, S., Wegscheider, K., Braumann, K., Venter, R., & Zech, A. (2017). Growing-up (habitually) barefoot influences the development of foot and arch morphology in children and adolescents. Scientific Reports, 7.

72. Puszczałowska-Lizis, E., Lukasiewicz, A., Lizis, S., & Omorczyk, J. (2021). The impact of functional excess of footwear on the foot shape of 7-year-old girls and boys. PeerJ, 9.

73. Puszczałowska-Lizis, E., Lizis, S., Prusak, M., & Omorczyk, J. (2022). Impact of length and width of footwear on foot structure of preschool-aged children. PeerJ, 10.

74. Wolf, S., Simon, J., Patikas, D., Schuster, W., Armbrust, P., & Döderlein, L. (2008). Foot motion in children shoes: a comparison of barefoot walking with shod walking in conventional and flexible shoes.. Gait & posture, 27 1, 51-9 .

75. Wang, Y., Jiang, H., Yu, L., Gao, Z., Liu, W., Mei, Q., & Gu, Y. (2023). Understanding the Role of Children's Footwear on Children's Feet and Gait Development: A Systematic Scoping Review. Healthcare, 11.

76. Rao, U., & Joseph, B. (1992). The influence of footwear on the prevalence of flat foot. A survey of 2300 children.. The Journal of bone and joint surgery. British volume, 74 4, 525-7 .

77. Banach, M., Lewek, J., Surma, S., Penson, P., Sahebkar, A., Martin, S., Bajraktari, G., Henein, M., Reiner, Ž., Bielecka-Dabrowa, A., & Bytyçi, I. (2023). The association between daily step count and all-cause and cardiovascular mortality: a meta-analysis.. European journal of preventive cardiology.

78. Bytyçi, I., Surma, S., Lewek, J., & Banach, M. (2022). Abstract 15520: The Relationships Between Daily Step Counts With All-Cause and Cardiovascular Mortality: A Meta-Analysis. Circulation.

79. Banach, M., Lewek, J., Surma, S., Penson, P., Sahebkar, A., Martin, S., Bajraktari, G., Henein, M., Reiner, Ž., Bielecka-Dabrowa, A., & Bytyçi, I. (2023). The association between daily step count and all-cause and cardiovascular mortality: a meta-analysis.. European journal of preventive cardiology.

80. Hall, K., Hyde, E., Bassett, D., Carlson, S., Carnethon, M., Ekelund, U., Evenson, K., Galuska, D., Kraus, W., Lee, I., Matthews, C., Omura, J., Paluch, A., Thomas, W., & Fulton, J. (2020). Systematic review of the prospective association of daily step counts with risk of mortality, cardiovascular disease, and dysglycemia. The International Journal of Behavioral Nutrition and Physical Activity, 17.

81. Jayedi, A., Gohari, A., & Shab-Bidar, S. (2021). Daily Step Count and All-Cause Mortality: A Dose–Response Meta-analysis of Prospective Cohort Studies. Sports Medicine, 52, 89-99.

82. Rodríguez-Gutiérrez, E., Torres-Costoso, A., Del Pozo-Cruz, B., De Arenas-Arroyo, S., Pascual-Morena, C., Bizzozero-Peroni, B., & Martínez-Vizcaíno, V. (2024). Daily steps and all-cause mortality: An umbrella review and meta-analysis.. Preventive medicine, 108047 .

83. Paluch, A., Bajpai, S., Bassett, D., Carnethon, M., Ekelund, U., Evenson, K., Galuska, D., Jefferis, B., Kraus, W., Lee, I., Matthews, C., Omura, J., Patel, A., Pieper, C., Rees-Punia, E., Dallmeier, D., Klenk, J., Whincup, P., Dooley, E., Gabriel, K., Palta, P., Pompeii, L., Chernofsky, A., Larson, M., Vasan, R., Spartano, N., Ballin, M., Nordström, P., Nordström, A., Anderssen, S., Hansen, B., Cochrane, J., Dwyer, T., Wang, J., Ferrucci, L., Liu, F., Schrack, J., Urbanek, J., Saint-Maurice, P., Yamamoto, N., Yoshitake, Y., Newton, R., Yang, S., Shiroma, E., & Fulton, J. (2022). Daily steps and all-cause mortality: a meta-analysis of 15 international cohorts. The Lancet. Public health, 7, e219 - e228.

84. Tudor-Locke, C., Craig, C., Brown, W., Clemes, S., De Cocker, K., Giles-Corti, B., Hatano, Y., Inoue, S., Matsudo, S., Mutrie, N., Oppert, J., Rowe, D., Schmidt, M., Schofield, G., Spence, J., Teixeira, P., Tully, M., & Blair, S. (2011). How many steps/day are enough? for adults. The International Journal of Behavioral Nutrition and Physical Activity, 8, 79 - 79.

85. Bohannon, R. (2007). Number of Pedometer-Assessed Steps Taken Per Day by Adults: A Descriptive Meta-Analysis. Physical Therapy, 87, 1642 - 1650.

86. Del Pozo Cruz, B., Ahmadi, M., Naismith, S., & Stamatakis, E. (2022). Association of Daily Step Count and Intensity With Incident Dementia in 78 430 Adults Living in the UK. JAMA Neurology, 79, 1059 - 1063.

87. Buffey, A., Herring, M., Langley, C., Donnelly, A., & Carson, B. (2022). The Acute Effects of Interrupting Prolonged Sitting Time in Adults with Standing and Light-Intensity Walking on Biomarkers of Cardiometabolic Health in Adults: A Systematic Review and Meta-analysis. Sports Medicine (Auckland, N.z.), 52, 1765 - 1787.

88. Henson, J., Davies, M., Bodicoat, D., Edwardson, C., Gill, J., Stensel, D., Tolfrey, K., Dunstan, D., Khunti, K., & Yates, T. (2015). Breaking Up Prolonged Sitting With Standing or Walking Attenuates the Postprandial Metabolic Response in Postmenopausal Women: A Randomized Acute Study. Diabetes Care, 39, 130 - 138.

89. Duvivier, B., Schaper, N., Koster, A., Van Kan, L., Peters, H., Adam, J., Giesbrecht, T., Kornips, E., Hulsbosch, M., Willems, P., Hesselink, M., Schrauwen, P., & Savelberg, H. (2017). Benefits of Substituting Sitting with Standing and Walking in Free-Living Conditions for Cardiometabolic Risk Markers, Cognition and Mood in Overweight Adults. Frontiers in Physiology, 8.

90. Yates, T., Edwardson, C., Celis-Morales, C., Biddle, S., Bodicoat, D., Davies, M., Esliger, D., Henson, J., Kazi, A., Khunti, K., Sattar, N., Sinclair, A., Rowlands, A., Velayudhan, L., Zaccardi, F., & Gill, J. (2018). Metabolic Effects of Breaking Prolonged Sitting With Standing or Light Walking in Older South Asians and White Europeans: A Randomized Acute Study. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 75, 139 - 146.

91. Wall, R., Garcia, G., Läubli, T., Seibt, R., Rieger, M., Martin, B., & Steinhilber, B. (2020). Physiological changes during prolonged standing and walking considering age, gender and standing work experience. Ergonomics, 63, 579 - 592.

92. Bailey, D., & Locke, C. (2015). Breaking up prolonged sitting with light-intensity walking improves postprandial glycemia, but breaking up sitting with standing does not.. Journal of science and medicine in sport, 18 3, 294-8 .

93. Miller, R., Edwards, W., & Deluzio, K. (2015). Energy expended and knee joint load accumulated when walking, running, or standing for the same amount of time.. Gait & posture, 41 1, 326-8 .

94. Pulsford, R., Blackwell, J., Hillsdon, M., & Kos, K. (2017). Intermittent walking, but not standing, improves postprandial insulin and glucose relative to sustained sitting: A randomised cross-over study in inactive middle-aged men.. Journal of science and medicine in sport, 20 3, 278-283 .

95. Ramsey, C., Lynch, K., Gehrman, P., Vairavan, S., Narayan, V., Li, Q., & Oslin, D. (2021). Daily steps and depressive symptoms: A longitudinal evaluation of patients with Major Depressive Disorder in the Precision Medicine in Mental Health Care study.. Journal of affective disorders.

96. Hsueh, M., Stubbs, B., Lai, Y., Sun, C., Chen, L., & Ku, P. (2020). A dose response relationship between accelerometer assessed daily steps and depressive symptoms in older adults: a two-year cohort study.. Age and ageing.

97. Hunter, I., McLeod, A., Valentine, D., Low, T., Ward, J., & Hager, R. (2019). Running economy, mechanics, and marathon racing shoes. Journal of Sports Sciences, 37, 2367 - 2373.

98. Hébert-Losier, K., Finlayson, S., Driller, M., Dubois, B., Esculier, J., & Beaven, C. (2020). Metabolic and performance responses of male runners wearing 3 types of footwear: Nike Vaporfly 4%, Saucony Endorphin racing flats, and their own shoes. Journal of Sport and Health Science, 11, 275 - 284.

99. Joubert, D., & Jones, G. (2022). A comparison of running economy across seven highly cushioned racing shoes with carbon-fibre plates. Footwear Science, 14, 71 - 83.

100. Barnes, K., & Kilding, A. (2018). A Randomized Crossover Study Investigating the Running Economy of Highly-Trained Male and Female Distance Runners in Marathon Racing Shoes versus Track Spikes. Sports Medicine, 49, 331-342.

101. Hébert-Losier, K., Finlayson, S., Lamb, P., Driller, M., Hanzlíková, I., Dubois, B., Esculier, J., & Beaven, C. (2022). Kinematics of recreational male runners in “super”, minimalist and habitual shoes. Journal of Sports Sciences, 40, 1426 - 1435.

102. Saunders, P., Telford, R., Pyne, D., Peltola, E., Cunningham, R., Gore, C., & Hawley, J. (2006). SHORT-TERM PLYOMETRIC TRAINING IMPROVES RUNNING ECONOMY IN HIGHLY TRAINED MIDDLE AND LONG DISTANCE RUNNERS. Journal of Strength and Conditioning Research, 20, 947–954.

103. Spurrs, R., Murphy, A., & Watsford, M. (2003). The effect of plyometric training on distance running performance. European Journal of Applied Physiology, 89, 1-7.

104. Filipas, L., Bonato, M., Maggio, A., Gallo, G., & Codella, R. (2022). Effects of plyometric training on different 8-week training intensity distributions in well-trained endurance runners. Scandinavian Journal of Medicine & Science in Sports, 33, 200 - 212.

105. Lännerström, J., Nilsson, L., Cardinale, D., Björklund, G., & Larsen, F. (2021). Effects of Plyometric Training on Soft and Hard Surfaces for Improving Running Economy. Journal of Human Kinetics, 79, 187 - 196.

106. Eihara, Y., Takao, K., Sugiyama, T., Maeo, S., Kanehisa, H., & Isaka, T. (2024). The effects of plyometric versus resistance training on running economy and 5-km running time in middle-aged recreational runners. European Journal of Sport Science, 24, 1820 - 1829.

107. Patoz, A., Lussiana, T., Breine, B., Mourot, L., Gindre, C., & Hébert-Losier, K. (2023). Concurrent endurance training with either plyometric or dynamic body-weight training both improve running economy with minimal or no changes in running biomechanics.. Sports biomechanics, 1-18 .

108. García-Pinillos, F., Lago-Fuentes, C., Latorre-Román, P., Pantoja-Vallejo, A., & Ramirez-Campillo, R. (2020). Jump-Rope Training: Improved 3-km Time-Trial Performance in Endurance Runners via Enhanced Lower-Limb Reactivity and Foot-Arch Stiffness.. International journal of sports physiology and performance, 1-7 .

109. Sugimoto, D., Brilliant, A., d'Hemecourt, D., d'Hemecourt, C., Morse, J., & D'hemecourt, P. (2018). Running mechanics of females with bilateral compartment syndrome. Journal of Physical Therapy Science, 30, 1056 - 1062.

110. Ferdiansyah, R., Yunus, M., Abdullah, A., & Raharjo, S. (2023). Analisis Gerak Pendaratan Kaki Terkait Risiko Berlari Overstriding Pada Pelari Remaja Malang 2 Training Club. Sport Science and Health.

111. Wallace, I., Kraft, T., Venkataraman, V., Davis, H., Holowka, N., Harris, A., Lieberman, D., & Gurven, M. (2022). Cultural variation in running techniques among non-industrial societies. Evolutionary human sciences, 4.

112. Baker, L., Yawar, A., Lieberman, D., & Walsh, C. (2024). Predicting overstriding with wearable IMUs during treadmill and overground running. Scientific Reports, 14.

113. Almeida, M., Davis, I., & Lópes, A. (2015). Biomechanical Differences of Foot-Strike Patterns During Running: A Systematic Review With Meta-analysis.. The Journal of orthopaedic and sports physical therapy, 45 10, 738-5 .

114. Anderson, L., Bonanno, D., Hart, H., & Barton, C. (2019). What are the Benefits and Risks Associated with Changing Foot Strike Pattern During Running? A Systematic Review and Meta-analysis of Injury, Running Economy, and Biomechanics. Sports Medicine, 50, 885-917.

115. Liew, B., Rügamer, D., & Birn-Jeffery, A. (2023). Neuromechanical stabilisation of the centre of mass during running.. Gait & posture, 108, 189-194 .

116. Muth, C. (2017). Plantar Fasciitis.. JAMA, 318 4, 400.

117. Desnantyo, A. (2024). Controversies of the Plantar Fasciitis. Orthopaedic Journal of Sports Medicine, 12..

118. Thing, J., Maruthappu, M., & Rogers, J. (2012). Diagnosis and management of plantar fasciitis in primary care.. The British journal of general practice : the journal of the Royal College of General Practitioners, 62 601, 443-4 .

119. Middleton, J., & Kolodin, E. (1992). Plantar fasciitis-heel pain in athletes.. Journal of athletic training, 27 1, 70-5 .

120. Ryskalin, L., Morucci, G., Soldani, P., & Gesi, M. (2023). Do the fasciae of the soleus have a role in plantar fasciitis?. Clinical Anatomy, 37, 413 - 424.

121. Cheung, R., Sze, L., Mok, N., & Ng, G. (2016). Intrinsic foot muscle volume in experienced runners with and without chronic plantar fasciitis.. Journal of science and medicine in sport, 19 9, 713-5 .

122. Kelly, P., Williamson, C., Niven, A., Hunter, R., Mutrie, N., & Richards, J. (2018). Walking on sunshine: scoping review of the evidence for walking and mental health. British Journal of Sports Medicine, 52, 800 - 806.

123. Xu, Z., Zheng, X., Ding, H., Zhang, D., Cheung, P., Yang, Z., Tam, K., Zhou, W., Chan, D., Wang, W., & Wong, S. (2024). The Effect of Walking on Depressive and Anxiety Symptoms: Systematic Review and Meta-Analysis. JMIR Public Health and Surveillance, 10.

124. Wu, B., Xiong, G., Zhang, P., & , X. (2024). Effects of tai chi, ba duan jin, and walking on the mental health status of urban older people living alone: the mediating role of social

participation and the moderating role of the exercise environment. Frontiers in Public Health, 12.