International Journal of Holistic Health, Sports and Recreation

Int J Holistic Health, Sports and Recreation. Vol. 4, No. 1 (2025) *https://holisticrecreation.com*

E-ISSN: 2979-9740 *DOI:10.5281/zenodo.15763021*

The Effect of Customised Insoles on Performance in Athletes

MSc. Görkem ACAR[1]
[1]Manisa Celal Bayar University, Graduate School of Education, Manisa, TÜRKİYE
Orcid:0000-0002-0970-8625 e-mail: gorkemacar2@gmail.com

Assoc.Prof. Sinan SEYHAN[2]
[2]Manisa Celal Bayar University, Faculty of Sport Sciences, Manisa, TÜRKİYE
Orcid:0000-0002-4979-7992 e-mail: sinanseyhan@gmail.com

Prof. Dr. Kubilay CİMEN[3]
[3]Istanbul Gelisim University, Faculty of Sport Sciences, Istanbul, TÜRKİYE
Orcid:0000-0003-1427-120X e-mail: kcimen@gelisim.edu.tr

Ort. Prot. Hamza SİNEN[4]
[4]Sintech Health Technologies R&D Eng. Ltd. Company, Istanbul, TÜRKİYE
Orcid:0009-0009-3411-6945 e-mail: hamzasinen34@gmail.com

Eng. Sedanur EKENTOK[5]
[5]Sintech Health Technologies R&D Eng. Ltd. Company, Istanbul, TÜRKİYE
Orcid:0009-0000-9671-665X e-mail: ekentoksedanur@gmail.com

Res. Asst. Muhammed Ali GÖKCE[6]
[6]Istanbul Gelisim University, Faculty of Sport Sciences, Istanbul, TÜRKİYE
Orcid:0009-0009-2188-4611 e-mail: magokce@gelisim.edu.tr

Submission received	*Revised*	*Accepted*	*Published*
17.04.2025	*11.05.2025*	*28.05.2025*	*30.06.2025*

Abstract

This review study examined the effects of custom insoles on physical performance parameters in athletes. Insoles are customized according to the individual's foot morphology and biomechanical requirements to optimise plantar pressure distribution, improve lower extremity alignment, and reduce the load on the musculoskeletal system. The literature indicates that they have positive effects, particularly on sprinting, jumping, balance, and agility performance, and that they support energy efficiency and proprioceptive feedback mechanisms. Additionally, it has been reported that custom insoles have a protective effect against plantar stress and fatigue during prolonged activity, thereby enhancing performance sustainability. However, it is emphasised that they may not produce the same results in every individual and that insole design must be tailored to individual needs. Based on current findings, customised insoles are considered an effective orthotic intervention tool for improving sports performance and reducing the risk of injury. Future studies are recommended to examine the effects in more detail across different sports disciplines, surface conditions, and long-term use.

Keywords: Custom insoles, Athletic performance, Foot biomechanics, Plantar pressure

Corresponding author: MSc. Görkem AÇAR PhD(s)**, E-mail:** gorkemacar2@gmail.com

INTRODUCTION

Custom insoles are orthotics that provide orthotic support tailored to an individual's foot morphology, gait pattern, and biomechanical needs. These insoles are typically produced using 3D foot scans, anthropometric measurements, plantar pressure analyses, and digital modelling techniques to provide a custom fit and support (Meng et al., 2020) (Figure 1.). The most important advantage of custom insoles is that they optimise plantar pressure distribution by perfectly conforming to foot anatomy, thereby improving performance and reducing the risk of injury (Lucas-Cuevas et al., 2017). Additionally, these orthotic systems can provide more effective shock absorption and biomechanical alignment compared to prefabricated insoles, particularly in high-impact activities such as running (Crabtree et al., 2009).

Figure 1. Plantar pressure measurement of the foot

Foot biomechanics in athletes is one of the fundamental building blocks of the lower extremity kinetic chain and plays a central role in improving performance and preventing injuries. As the only anatomical structure in contact with the ground, the foot plays a crucial role in both force transmission and maintaining balance. During dynamic activities, the foot functions as a shock absorber, lever, and stabiliser, reducing the load on the upper extremities while providing proprioceptive feedback. Parameters such as the structure of the foot arch, arch height, and subtalar joint range of motion are biomechanical variables that can directly affect athletic performance (Rodgers, 1995; Hollander et al., 2019). In particular, the height of the medial longitudinal arch is decisive for shock absorption and plantar pressure distribution; a low arch can cause increased knee and hip internal rotation, thereby predisposing to medial knee injuries (Hollander et al., 2019; Windsor et al., 2022). Indeed, studies conducted on football players have revealed significant associations between foot arch morphology and balance, agility, and sprint performance (Bukowska et al., 2021). These findings highlight the importance of considering foot biomechanics in training planning. Additionally, custom orthotic supports, particularly those tailored to the athlete's biomechanical profile (Figure 2.),

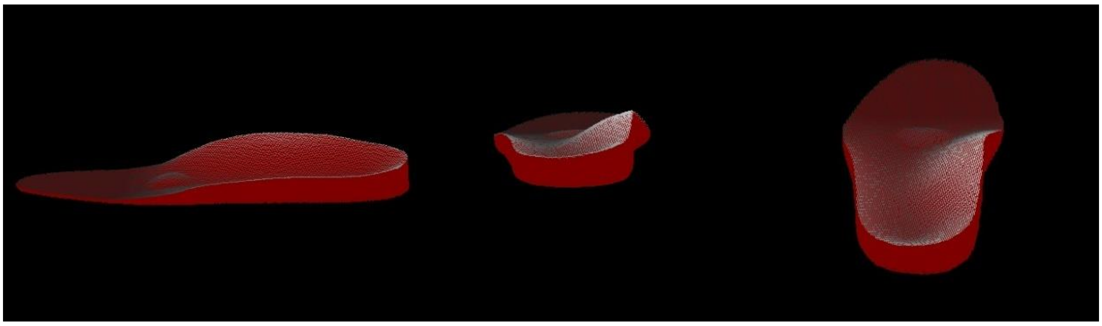

Figure 2. Customised footbed modelling

In the evaluation of physical performance in athletes, fundamental motor skills such as strength, balance, speed, agility, and endurance are not only indicators of physical capacity but also determinants of biomechanical efficiency. These performance parameters also provide an important foundation for assessing the effectiveness of customised footwear applications. Strength, defined as the maximum muscle contraction force of the lower extremity muscles, is the key to success in explosive movements such as sprinting and jumping (Suchomel et al., 2016). Balance, on the other hand, directly influences both postural stability and agility by ensuring optimal control of the body's centre of gravity over the support surface (Hrysomallis, 2011; Sekulic et al., 2013). Speed performance is related to neuromuscular coordination, force production, and foot mechanics, and custom insoles can contribute to acceleration by improving the push-off time and ground reaction force distribution in this mechanical chain (Lockie et al., 2012). Agility requires the coordinated functioning of multiple motor systems, such as changing direction and adapting to sudden movements; therefore, it is closely linked to strength, balance, and speed (Negra et al., 2017). Endurance is the ability of muscles to resist fatigue, and it has been reported that custom insoles can support this capacity by reducing plantar stress (Beattie et al., 2014). Indeed, experimental studies have shown that custom insoles reduce maximum pressure in the heel and forefoot, increase the midfoot contact area, balance load distribution, and thereby support sustainable performance (Gerych et al., 2013).

The limited number of studies in the literature that comprehensively examine the effect of custom insoles on performance parameters in athletes necessitates an in-depth evaluation in this area. The aim of this review is to examine the effects of custom insoles on basic motor performance criteria such as strength, balance, speed, agility, and endurance, as well as the role of custom insoles in preventing injuries.

The Biomechanical Effects of Insoles

The use of insoles causes significant changes in lower extremity biomechanics, playing an effective role in both the treatment of orthopaedic disorders and the improvement of performance in athletes. Especially in conditions such as pes planus, excessive pronation, or knee osteoarthritis, properly designed insoles can alter kinetic and kinematic parameters in the foot, ankle, knee, and hip joints; thereby balancing joint loads, reducing pain, and improving functional performance. Customised or 3D-printed insoles, particularly those that support the medial longitudinal arch, increase navicular height, limit excessive ankle eversion, and reduce adduction moment at the knee, thereby regulating valgus or varus loading. Hsu and colleagues (2022) compared the effects of three different 3D-printed insoles (automatic scanning, total contact, and 5 mm medial wedge) on lower extremity biomechanics in individuals with functional pes planus. According to the findings, all types of insoles significantly increased navicular height and improved the dorsiflexion angle at the ankle joint. In particular, the model with a medial wedge emerged as the most effective solution both in terms of supporting navicular height and increasing ankle dorsiflexion (Hsu et al., 2022). Similarly, insoles with a medial wedge were found to reduce ankle eversion and the range of motion of the knee in the transverse plane in runners with excessive foot pronation, as well as limiting hip adduction and internal rotation. These biomechanical changes have been reported to contribute to the prevention of knee and hip pathologies observed in runners (Braga et al., 2019). In particular, it has been found that insoles with lateral wedges reduce the external adduction moment at the knee in individuals with knee osteoarthritis, but this may lead to an increase in the ankle eversion moment. Therefore, when lateral wedges are used in combination with arch support, both the load on the knee joint is reduced and the adverse biomechanical effects on the ankle are balanced (Shaw et al., 2018). In light of these findings, the effects of insoles on lower extremity biomechanics can be summarised as follows:

1. **Ankle Level:** Prevents excessive pronation by reducing the angle and moment of eversion.

2. **Knee Joint Level:** May limit medial compartment loading by reducing knee adduction moment.

3. **Hip and Pelvis:** By limiting hip adduction and internal rotation movements, they can reduce pelvic drop.

4. **Functional Effect:** Balance, load distribution, and gait pattern improve; pain and injury risks decrease in the long term.

METHOD

This study was meticulously searched by using the keywords ‘Insole’, “Athletes”, ‘Customised Insoles’ and ‘Performance’ in Turkish and English in Pubmed, Dergipark, Google Scholar and ResearchGate search engines between 2005-2025. The literature search was performed by M.A.G, S.E. H.S., analysed in detail by G.A. and checked by S.S. and K.Ç. The articles whose full texts were found as a result of the searches were included in the study in order to provide a comprehensive and detailed review. As a result of the comprehensive search, 34 studies were found. Of these studies, 19 articles were excluded because they were on children's foot deformity and 4 articles were excluded because they described the construction process. As a result, 11 articles were included in our study.

The Effect of Insoles on Performance

Insoles play an important role not only in the management of orthopaedic problems but also in the support of sportive performance. These orthotic structures, which balance the load on the musculoskeletal system thanks to their corrective effects on foot biomechanics, can affect performance parameters such as power generation, balance, agility and running economy at various levels. In particular, insoles containing carbon fibre or custom-made insoles have been shown to improve jump and sprint performance by increasing energy storage and return capacity (Gregory et al., 2018). In addition, it has been reported that sensor-assisted insoles to increase proprioception positively affect agility performance and support neuromuscular control by stimulating lower extremity mechanoreceptors (Miranda et al., 2016). However, it has been noted that the effects on performance may not only be positive, but also neutral or negative. In a systematic review and meta-analysis conducted by Crago et al. (2019), it was pointed out that the effects of insoles on running economy are inconsistent. In particular, semi-rigid structures that limit the arch of the foot can negatively affect elastic energy recovery, increase metabolic cost, and thus impair running economy (Crago et al., 2019). This suggests that not all types of insoles provide the same level of performance benefit. Lucas-Cuevas et al. (2014) found that customised insoles reduced plantar loading in the hallux, medial and lateral midfoot regions, especially after fatigue, and reduced the load on the heel region by 31-54% more than ready-made insoles. This finding suggests that by reducing repetitive loading, the risk of injury can be reduced and thus long-term performance can be maintained. In addition, customised insoles with different degrees of stiffness were found to improve pressure distribution in the forefoot and increase user comfort (Meng et al., 2020). In terms of running economy, which is an important determinant in endurance sports, polyurethane-containing custom insoles have been reported to contribute to performance and user satisfaction by reducing pain in individuals with chronic running injuries (Hirschmüller et al., 2011). However, in the study of Lucas-Cuevas et al. (2017), it was reported that customised or ready-made insoles did not provide a significant superiority in terms of shock absorption compared to control conditions in the analyses performed before and after intense exercise and that acute performance effects may be limited. In a recent randomised controlled study, it was reported that 3D printed customised insoles have the potential to reduce running-related pain and improve running time performance in the long term. At the same time, user compliance and comfort level were also evaluated positively (Ibrahim et al., 2024). Braga et al. (2019) showed that insoles containing a medial wedge reduced ankle eversion, hip adduction and knee range of motion in the transverse plane in overpronated athletes. Such biomechanical adjustments may contribute to the sustainability of performance by increasing lower limb stability during running. In addition, studies in minimalist insoles or shoe conditions have shown that factors such as the type of attachment and the ground are determinants of performance. For example, Siegel et al. (2025) reported that minimalist insoles can reduce performance in some agility and change of direction tasks, but give similar results to conventional shoes in sprinting in a straight line. Finally, the systematic review by Snyder et al. (2009) revealed that insoles may be effective in preventing stress fractures, particularly in the femur and tibia regions. This finding suggests that insoles may offer an important advantage in terms of maintaining long-term performance.

DISCUSSION AND CONCLUSION

Personalised insoles can provide positive effects in areas such as running economy, balance, agility and sprint performance by improving lower extremity biomechanics. In addition, it has been reported to reduce the risk of injury by reducing the load on the musculoskeletal system and contribute to the sustainability of the athlete's career. However, not all insoles show the same effect in every individual; results may vary depending on factors such as foot structure, sports branch and ground. It has been reported that insoles with anatomical incompatibility may adversely affect performance. Therefore, insoles should be designed according to individual and sport-specific needs and more randomised controlled studies are needed.

RECOMMENDATIONS

In future studies, the effects of custom insoles on different sports, age groups, and genders should be evaluated separately. Performance, injury incidence, and comfort levels related to long-term use should be monitored through prospective studies. Additionally, the effect of surface type (grass, tartan, carpet field, etc.) and training intensity on insole effectiveness should be investigated. The use of artificial intelligence-supported modelling systems in insole design based on individual foot morphology can enhance both orthotic fit and performance optimisation. Prioritising randomised controlled trials is of great importance. Future research should also investigate the long-term effects of insoles, performance adaptations on different surfaces, and athletes' subjective comfort experiences in greater depth.

Conflict of Interest: There is no conflict of interest between the authors.

Statement of Contribution of Researchers:

1.Author: %20

2.Author: %20

3.Author: %15

4.Author: %15

5.Author: %15

6.Author: %15

Information about the Ethics Committee Permission: This study does not require ethics committee approval. All responsibility belongs to the authors.

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