Advanced spike technology enhances sprinting speed

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ABSTRACT

Recent advances in spiked shoe design, characterized by increased longitudinal stiffness, thicker midsole foams, and reconfigured geometry are considered to improve sprint performance. However, so far there is no empirical data on the effects of advanced spikes technology on maximal sprinting speed (MSS) published yet. Consequently, we assessed MSS via 'flying 30m' sprints of 44 trained male (PR: 10.32 s - 12.08 s) and female (PR: 11.56 s - 14.18 s) athletes, wearing both traditional and advanced spikes in a randomized, repeated measures design. The results revealed a statistically significant increase in MSS by 1.21% on average when using advanced spikes technology. Notably, 87% of participants showed improved MSS with the use of advanced spikes. A cluster analysis unveiled that athletes with higher MSS may benefit to a greater extent. However, individual responses varied widely, suggesting the influence of multiple factors that need detailed exploration. Therefore, coaches and athletes are advised to interpret the promising performance enhancements cautiously and evaluate the appropriateness of the advanced spike technology for their athletes critically.

INTRODUCTION

In recent years, athletic footwear technology has evolved significantly, driven by advances in materials and motion sciences. Most notably, this has led to improved distance running economy (Knopp et al., 2023; Hoogekamer et al., 2018; Barnes & Kilding, 2019; Joubert & Jones, 2022) and race performance (Hebert-Losier & Pamment, 2023; Ruiz-Alias et al., 2023). While most of the attention has been on advanced distance running shoe technology, spiked track shoes for short distance races have also evolved (Healy et al., 2022; Russo et al., 2022; Willwacher et al., 2023). Traditionally, the design of these spikes has focused on maximizing traction and minimizing weight (Healy et al., 2022). However, recent advances in spiked shoe design, characterized by increased longitudinal stiffness, thicker midsole foams, and reconfigured geometry, have sparked interest and speculation about their potential to improve sprint performance (Healy et al., 2022). There is indirect observational evidence that advanced spike technology can improve performance by approximately 0.5% or more (Willwacher et al., 2023). However, while these potential improvements are intriguing, our understanding of how these 'super spikes' affect sprinting speed, particularly maximal sprinting speed (MSS), is still emerging. Several studies have examined various shoe characteristics and their influence on performance-related factors and biomechanics (Stefanyshyn & Nigg, 1997; Stefanyshyn & Wannop, 2016; Stefanyshyn & Fusco, 2004; Willwacher et al., 2016; Nagahara et al., 2017; Lake & Smith, 2016). However, these studies focused mainly on the effects of longitudinal bending stiffness. No study has addressed the effects of differing cushioning material properties and sole geometries on sprint performance and biomechanics. Consequently, whether and how the designs of recently developed advanced spiked shoe technologies affect maximal sprint speed has not been thoroughly investigated. Sprint performance, especially at the elite level, often depends on very small margins. Therefore, even small improvements in MSS can have a profound effect on competitive outcomes. This potential for impact highlights the importance of empirical studies designed to investigate the effects of advanced spike technology on sprinting speed. Accordingly, the purpose of this study was to provide an empirical examination of the effects of advanced spike technology on MSS. In a randomized, repeated measures design, we assessed the MSS of male and female athletes wearing traditional and advanced spike technologies. We hypothesized that the use of advanced spike technology results in an increase in maximal sprint speed compared to traditional spikes. By better understanding the potential benefits and mechanisms of advanced spike technology, we can contribute to the understanding of how technology can improve human performance.

MATERIALS AND METHODS

Participants

A total of 44 trained athletes (22 males and 22 females) participated in this multicenter trial conducted at track and field training centers in Bremen, Hannover, Leipzig, and Leverkusen (Germany). Male athletes had an average leg length of 87.6 ± 4.8 cm, body mass of 75.4 ± 9.0 kg, and a 100m personal best time of 11.03 ± 0.49 seconds. Female athletes had an average leg length of 84.7 ± 3.3 cm, body mass of 60.9 ± 5.7 kg, and a 100m personal best time of 12.5 ± 0.7 seconds. To qualify for participation, athletes were required to have a minimum of 2 years of competitive sprinting experience, be free from any musculoskeletal injuries or medical conditions that could affect sprint performance and own a pair of advanced and traditional spikes.

Experimental Procedures

This research followed a randomized, repeated measures design. Each participant performed four 'flying 30 m' sprints using two different spike shoes in a randomized order, with full recovery between efforts. The 'flying 30 m' sprints represent a well-established training tool for developing and evaluating MSS, aiming to attain the highest achievable sprinting speed while minimizing velocity decrease over the sprint distance (Skoglund, Strand & Haugen, 2023; Haugen et al., 2019). Participants were familiar with the 'flying 30' test modality, having routinely engaged in it during training. Testing took place on indoor athletics tracks during normal maximal sprinting training sessions. All athletes were in the preparation phase of training, in advance of the competitive outdoor season. After completing their pre-competition warm-up program, each participant performed four 'flying 30 m' sprints in total. Two sprints were performed using traditional spikes, and the remaining two sprints were performed using advanced spikes. The order of spike conditions (traditional and advanced) was randomized and counterbalanced across participants to minimize potential order effects. All sprints were executed at maximal effort. The run-up distance was selected by each participant, with a minimum requirement of 30 m. Advanced spikes were defined by features including a lightweight, compliant foam and a stiff plate, in accordance with recent publications (Healy et al., 2022; Hebert-Losier & Pamment, 2023). Specifically, 34 subjects utilized the 'Nike Air Zoom Maxfly' by Nike, while 10 subjects wore the 'Adizero Prime SP2' by Adidas. Traditional spikes consisted of Nike ('Nike Zoom Superfly Elite 2', 'Nike Zoom Celar 5', 'Nike Zoom Rival S9'), Adidas ('Adidas Sprintstar', 'Adizero Finesse') and

Puma ('Puma Evospeed Prep Sprint') shoes. Flying 30 m times were measured using dual-beam timing gates in Leverkusen, Bremen (Witty Gate, Microgate, Bolzano, Italy) and Hannover (DLS/F03, Sporttronic, Leutenbach-Nellmersbach, Germany) and single-beam timing gates in Leipzig (TCi, Brower Timing System Draper, USA). All methods used in the study were approved by the institutional research ethics committee, in the spirit of the Helsinki Declaration.

Data Analysis

Split times were recorded by the timing gates and subject data (i.e. anthropometric data, 100m PR and spike type) were exported to R Statistical Software (v4.3.1; R Core Team 2023) and further processed. MSS was defined as V_{mean} and calculated using the formula $\bar{v} = \frac{\Delta x}{\Delta t}$ with Δx being the distance of 30 meters and Δt being the individual time to complete the distance (i.e. $t_{Flying30m}$). In accordance with the findings of Denny (2017), the best trial with the advanced spikes and the best trial with the traditional spike was utilized to provide a more accurate representation of the outcome.

Statistics

Scatter plots were formed with the individual difference (Δ) of V_{mean} between the two shoe conditions (i.e. Advanced Spikes – Traditional Spikes) on the vertical and individual V_{mean} on the horizontal axes, respectively, to generate a visual representation of each individual effect of the type of shoe on the MSS. Furthermore, a hierarchical agglomerative cluster analysis (Everitt et al., 2011) was conducted to determine homogeneous participant clusters according to their maximum sprinting capabilities. The 'ward.D2' approach was used to cluster the data (Murtagh & Legendre, 2014). The final number of clusters was determined using a combination of computational and visual methods. Specifically, we computed gap statistics (Tibshirani et al., 2001) and Hartigan index (Hartigan, 1975) to estimate optimal number of clusters (Charad et al., 2014). In addition, the dendrogram was visually inspected to confirm the number of clusters identified (Phinyomark et al., 2015). One-way between-group ANOVA was computed to test for the cluster effect. When a cluster effect existed, post hoc tests with Benjamini-Hochberg correction (Benjamini & Hochberg, 1995) were computed to identify differences in-between clusters. The effect size was calculated using Cohen's d (Cohen, 1988). The following scale of magnitude was used to interpret effect sizes: large effect for $d > 0.8$, medium effect for $0.5 < d < 0.8$, small effect for $0.2 < d < 0.5$, and insignificant effect for $d < 0.2$. Moreover, Spearman test

(Spearman, 1987) was used to analyze the correlations between measured variables. The significance level was set at $p < 0.05$.

Results

MSS increased by a statistically significant 0.11 ms^{-1} (1.21%) when sprinters used the advanced spike technology (p = 0.004), with 87% (n = 38) of participants improving their MSS. Significant correlations were observed between ΔV_{mean} and sprinters' 100 m personal records ($p < 0.001$; $r = -0.45$) as well as between ΔV_{mean} and MSS ($p < 0.001$; $r = 0.53$). Individual responses to the shoe interventions are shown in Figure 1. ANOVA revealed statistically significant cluster effects ($p < 0.001$) with MSS and ΔV_{mean} becoming progressively larger from cluster 3 to cluster 1 (Table 1).

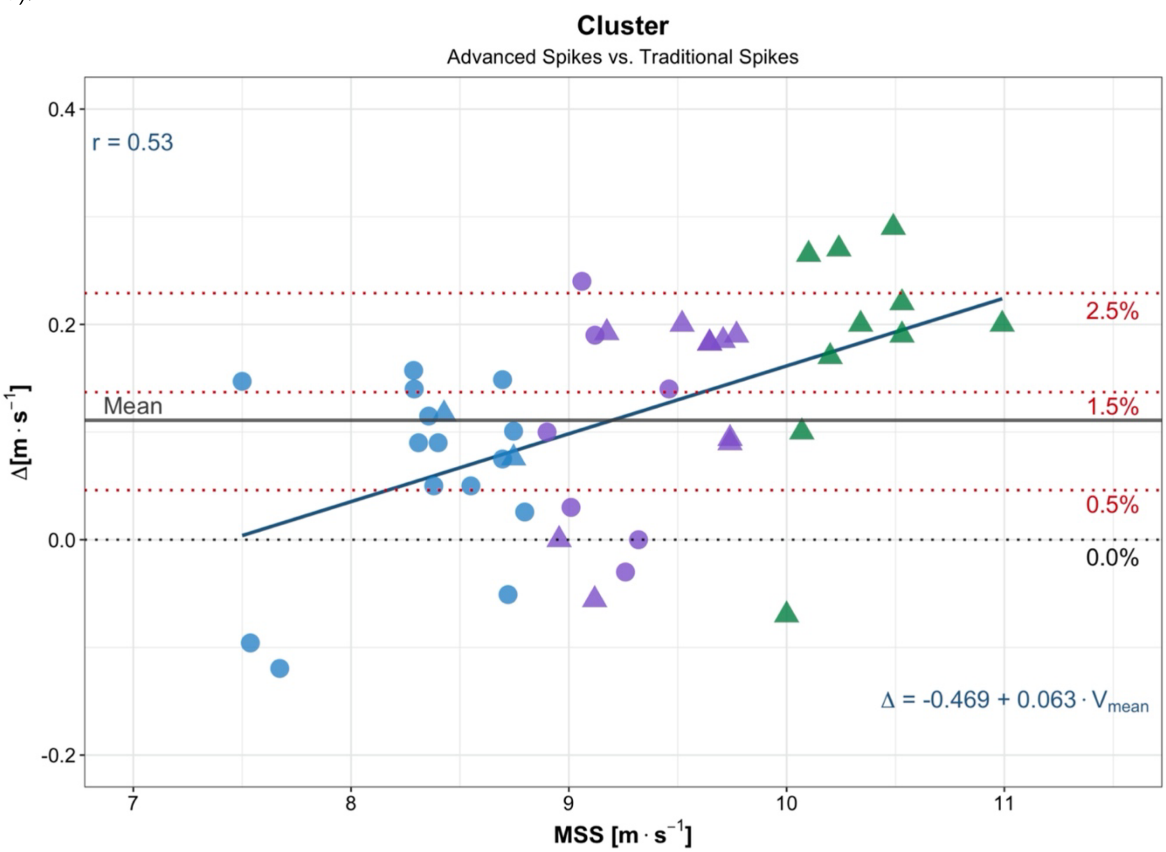

Figure 1: Scatter plot for MSS (calculated as the Vmean of 'flying 30 m' sprint test) and the ΔVmean between advanced and traditional spikes condition. The individual data of male (n = 22) and female (n = 22) athletes are presented by triangles and cycles for each respective cluster (blue: cluster 3; purple: cluster 2; green: cluster 1). The solid grey line indicates mean difference; the dashed lines indicate fixed percentual effects of 0.0%, 0.5%, 1.5% and 2.5%; the solid blue line represents the fitted linear regression

Table 1: Performance measures and number of participants in each cluster.

Cluster	n	V_{mean} [$m \cdot s^{-1}$]	ΔV_{mean} [$m \cdot s^{-1}$]	p-Value	Cohen's d	ES
1	10	10.30	0.18	<0.001[ab]	1.7	large
2	17	9.32	0.11	<0.001[ac]	1.2	large
3	17	8.34	0.06	<0.001[bc]	0.7	moderate

$p < 0.05$ indicates a Cluster effect
[a]denotes significant difference between Clusters 1 and 2
[b]denotes significant difference between Clusters 1 and 3
[c]denotes significant difference between Clusters 2 and 3

Discussion

The purpose of this study was to provide an empirical examination of the effects of advanced spike technology on maximal sprinting speed. Our investigation revealed that, by equipping athletes with advanced spikes, MSS increased by 1.21%, translating to an average improvement of 0.11 ms^{-1} in mean velocity over 30 m. These results are in line with the observational study of Willwacher et al. (2023), which proposed indirect evidence for improvements of 0.64 to 1.21% in 100 m performance. Furthermore, the findings of this study exceeded the results of Herrero-Molleda and colleagues (2023), who reported an enhancement of 0.6% in 40 m-sprint performance due to 'super spikes'. Since our study demonstrated a connection between mean sprinting speed and the improvements through advanced spikes, the overall lower performance of female athletes could be a possible explanation of the minor benefits of the shoes in the latter study. Contrary to previous research (Herrero-Molleda et al., 2023), which suggested that 'super spikes' might yield greater benefits for slower sprinters compared to their faster counterparts, our findings indicate a contrary trend. We propose that athletes exhibiting higher MSS might potentially benefit to a greater extent from advanced spike technology, a concept illuminated by our observed correlation and supported by the following regression equation $\Delta = -0.469 + 0.063 \cdot V_{mean}$. As velocity increases, sprinters might take greater advantage of the higher capacity of the advanced spikes to store and return elastic energy (Bergamini, 2011). Thus, the substantial correlation observed between the change in mean sprinting speed (ΔV_{mean}) and athletes' 100 m race times can be partly explained by prior research in this domain. The utilization of the clustering approach provides a deeper insight into the velocity-dependent benefits of wearing advanced spikes, thereby offering novel information. Remarkably, the profound influence of maximal sprinting speed (MSS) on 100 m performance (Haugen, Seiler & Sandbakk et al., 2019) is underscored by the tiny margins distinguishing medal-winning performances (0.297% between 3rd and 4th place) (Willwacher et al., 2023). In light of these intricacies, our results, though initially surprising, assume a promising significance within the broader context of sprint performance optimization. Illustratively, a single athlete's performance benefit of a 3.26% through advanced spike usage, despite their already notable mean sprinting velocity of 10.75 ms^{-1} underscores the substantial potential of the technology even among 'highly-trained' individuals. However, it is essential to recognize the complexities inherent in the utilization of advanced spikes. Our study exposes instances where performance suffered, with six athletes experiencing a decline of up to 1.32% in MSS. This emphasizes the individualized nature of responses to the shoe intervention, yielding distinct, subject-specific outcomes in Δ of sprinting speed. The diversity of these responses can be attributed to a range of factors, possibly including differences in sprint kinematics and biological capacity. Anecdotal insights gathered through conversations with the subjects and their respective coaches proposes that running in 'super spikes' alters sprint kinematics significantly and one has to learn how to interact with the 'springs beneath your feet'. As shown by Mendiguchia et al. (2021), it is possible to modify kinematics of maximal sprinting. Therefore, altering body posture during sprinting could be one strategy to getting the most beneficial effect of advanced spike technology. Biologically, it is hypothesized that the alterations stemming from the utilization of advanced spikes predominantly emanate from the impact of increased bending stiffness on the mechanics of the metatarsal phalangeal joint (MTP). The increased dorsiflexion of the MTP joint during foot touchdown triggers the absorption of mechanical energy. Adjusting the rigidity of the sole can restrict the dorsiflexion, subsequently minimizing the dissipation of energy (Healey et al., 2022). Furthermore, the increased longitudinal stiffness of the spike shifts the point of force application toward the distal region of the foot, thereby resulting in an extended lever arm at the ankle joint (Willwacher et al., 2013; Willwacher et al., 2014). This alteration in the lever arm has the potential to amplify the efficiency of horizontal force application, as suggested by Willwacher et al. (2016). In order to fully utilize the advantages of an increased longitudinal bending stiffness and higher lever arms at the ankle joint, a profound level of strength within the plantar flexor muscles is needed. Failing to meet this requirement could potentially lead to adverse effects on performance (Willwacher et al., 2016). Consequently, this implies that the extent to which an athlete can capitalize on the advantages from advanced spike technology remains highly individual and determined by multiple aspects. As a result, it is crucial for coaches to be not misled by the promising performance enhancements linked to advanced spikes. Instead, they should critically assess whether their athletes possess the necessary sprint kinematics capabilities and meet specific strength thresholds to effectively leverage the benefits of wearing such footwear and handle the associated increased demands.

Despite the strengths of our study, certain limitations warrant consideration when interpreting the results. The multicenter approach, while advantageous in recruiting participants across a range of training centers and performance levels, introduces variations due to non-standardized timing systems. These variations may contribute to measurement errors that need careful acknowledgment. However, at each center, the comparisons between spike conditions were performed with the same timing system. Furthermore, it is important to note that the findings of this work are specific to the tested athletes. While our approach aligns with recommendations (Healey et al., 2022) for quantifying the effects of footwear on sprint performance by measuring speed outcomes in all-out sprinting efforts, this procedure comes with the limitation of day-to-day performance variability. Nonetheless, these results offer valuable insights into the practical applications of super spikes in everyday training and the potential performance enhancements that they might offer. Given the velocity-dependent effect observed with super spikes, future studies should explore their impact on other aspects of the 100 m race, such as the block start, acceleration, and speed endurance. Incorporating spatiotemporal data and investigating different movement patterns could shed light on the mechanisms underlying the observed performance enhancements when utilizing advanced spike technology.

Conclusion

In conclusion, our study demonstrates that advanced spike technology leads to a statistically significant increase in MSS by 1.21% on average, with 87% of the participants experiencing improved MSS with the use of ‘super spikes’ compared to traditional spikes. Cluster analysis suggests velocity-dependent benefits, favoring athletes with higher MSS. However, individual responses vary widely, emphasizing the need for a critical assessment of the suitability of advanced spikes for each athlete. Future research should explore the underlying factors contributing to the individual variability and optimize the use of this technology to improve sprinting speed.

Contributions

All authors contributed to the conception and design of the research. JK, TO, MS, KL acquired the data. JK and TO analyzed and interpreted the data and wrote the initial draft with MS. SW and TS revised the article for important intellectual content. All authors approved the final version of the manuscript to be published.

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Data and Supplementary Material Accessibility

The data that support the findings of this study are available on request from the corresponding author, TO. The data are not publicly available because they are partly dealing with elite athletes who can be identified from this information.

REFERENCES

Barnes, K. R., & Kilding, A. E. (2019). 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.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. Journal of the Royal statistical society: series B (Methodological), 57(1), 289-300.

Bergamini, E. (2011). Biomechanics of sprint running: a methodological contribution (Doctoral dissertation, Arts et Métiers ParisTech).

Charrad, M., Ghazzali, N., Boiteau, V., & Niknafs, A. (2014). NbClust: an R package for determining the relevant number of clusters in a data set. Journal of statistical software, 61, 1-36.

Cohen, J. (1988). The concepts of power analysis. Statistical power analysis for the behavioral sciences, 2, 1-17.

Denny M. (2017). The fallacy of the average: on the ubiquity, utility and continuing novelty of Jensen's inequality. The Journal of experimental biology, 220(Pt 2), 139–146. https://doi.org/10.1242/jeb.140368

Everitt, B., Landau, S., Leese, M., & Stahl, D. (2011). Cluster analysis.

Hartigan, J. (1975). Clustering algorithms wiley. New York.

Haugen, T., Seiler, S., Sandbakk, Ø., & Tønnessen, E. (2019). The training and development of elite sprint performance: an integration of scientific and best practice literature. Sports medicine-open, 5, 1-16.

Healey, L., Bertschy, M., Kipp, S., & Hoogkamer, W. (2022). Can we quantify the benefits of "super spikes" in track running?. Sports Medicine, 52(6), 1211-1218.

Hébert-Losier, K., & Pamment, M. (2023). Advancements in running shoe technology and their effects on running economy and performance–a current concepts overview. Sports Biomechanics, 22(3), 335-350.

Herrero Molleda, Alba; García-Sancho, Ángela; and Garcia-Lopez, Juan (2023) "SUPER SPIKES" INCREASE 40-M SPRINT PERFORMANCE IN NATIONAL-LEVEL WOMEN ATHLETES," ISBS Proceedings Archive: Vol. 41: Iss. 1, Article 80.

Hoogkamer, W., Kipp, S., Frank, J. H., Farina, E. M., Luo, G., & Kram, R. (2018). A comparison of the energetic cost of running in marathon racing shoes. Sports Medicine, 48(4), 1009-1019.

Hopke, P. K., & Kaufman, L. (1990). The use of sampling to cluster large data sets. Chemometrics and intelligent laboratory systems, 8(2), 195-204.

Joubert, D. P., & Jones, G. P. (2022). A comparison of running economy across seven highly cushioned racing shoes with carbon-fibre plates. Footwear Science, 14(2), 71-83.

Knopp, M., Muñiz-Pardos, B., Wackerhage, H., Schönfelder, M., Guppy, F., Pitsiladis, Y., & Ruiz, D. (2023). Variability in Running Economy of Kenyan World-Class and European Amateur

Male Runners with Advanced Footwear Running Technology: Experimental and Meta-analysis Results. Sports Medicine, 53(6), 1255-1271.

Mendiguchia, J., Castaño-Zambudio, A., Jiménez-Reyes, P., Morin, J. B., Edouard, P., Conceição, F., ... & Colyer, S. L. (2021). Can we modify maximal speed running posture? implications for performance and hamstring injury management. International Journal of Sports Physiology and Performance, 17(3), 374-383.

Murtagh, F., & Legendre, P. (2014). Ward's hierarchical agglomerative clustering method: which algorithms implement Ward's criterion?. Journal of classification, 31, 274-295.

Nagahara, R., Kanehisa, H., & Fukunaga, T. (2017). Influence of shoe sole bending stiffness on sprinting performance. The Journal of Sports Medicine and Physical Fitness, 58(12), 1735-1740.

Phinyomark, A., Osis, S., Hettinga, B. A., & Ferber, R. (2015). Kinematic gait patterns in healthy runners: A hierarchical cluster analysis. Journal of biomechanics, 48(14), 3897-3904.

Ruiz-Alias, S. A., Molina-Molina, A., Soto-Hermoso, V. M., & García-Pinillos, F. (2023). A systematic review of the effect of running shoes on running economy, performance and biomechanics: analysis by brand and model. Sports Biomechanics, 22(3), 388-409.

Russo, L., Montagnani, E., Buttari, D., Ardigò, L. P., Melenco, I., Larion, A., ... & Padulo, J. (2022). Track Running Shoes: A Case Report of the Transition from Classical Spikes to "Super Spikes" in Track Running. Applied Sciences, 12(20), 10195.

Skoglund, A., Strand, M. F., & Haugen, T. A. (2023). The Effect of Flying Sprints at 90% to 95% of Maximal Velocity on Sprint Performance. International Journal of Sports Physiology and Performance, 18(3), 248-254.

Smith, G., Lake, M., Sterzing, T., & Milani, T. (2016). The influence of sprint spike bending stiffness on sprinting performance and metatarsophalangeal joint function. Footwear Science, 8(2), 109-118.

Spearman, C. (1987). The proof and measurement of association between two things. The American journal of psychology, 100(3/4), 441-471.

Stefanyshyn, D. J., & Nigg, B. M. (1997). Mechanical energy contribution of the metatarsophalangeal joint to running and sprinting. Journal of biomechanics, 30(11-12), 1081-1085.

Stefanyshyn, D. J., & Wannop, J. W. (2016). The influence of forefoot bending stiffness of footwear on athletic injury and performance. Footwear Science, 8(2), 51-63.

Stefanyshyn, D., & Fusco, C. (2004). Athletics: Increased shoe bending stiffness increases sprint performance. Sports Biomechanics, 3(1), 55-66.

Tibshirani, R., Walther, G., & Hastie, T. (2001). Estimating the number of clusters in

data set via the gap statistic. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 63(2), 411-423.

Willwacher, S., Kurz, M., Menne, C., Schrödter, E., & Brüggemann, G. P. (2016).

Biomechanical response to altered footwear longitudinal bending stiffness in the early acceleration phase of sprinting. Footwear Science, 8(2), 99-108.

Willwacher, S., König, M., Braunstein, B., Goldmann, J. P., & Brüggemann, G. P. (2014). The gearing function of running shoe longitudinal bending stiffness. Gait & posture, 40(3), 386-390

Willwacher, S., König, M., Potthast, W., & Brüggemann, G. (2013). Does Specific Footwear Facilitate Energy Storage and Return at the Metatarsophalangeal Joint in Running?. *Journal of Applied Biomechanics*, *29*(5), 583-592. Retrieved Aug 23, 2023, from https://doi.org/10.1123/jab.29.5.583

Willwacher, S., Mai, P., Helwig, J., Hipper, M., Utku, B., Robbin, J. (2023). Does advanced footwear technology improve track and road racing performance? An explorative analysis based on the 100 best yearly performances in the world between 2010 and 2022. SportArxiv