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Case Report

Track Running Shoes: A Case Report of the Transition from Classical Spikes to "Super Spikes" in Track Running

Luca Russo [1,†], Eleonora Montagnani [2,†], Daniel Buttari [3], Luca Paolo Ardigò [4,5,‡], Ionel Melenco [6,‡], Alin Larion [6,‡], Gian Mario Migliaccio [7,‡] and Johnny Padulo [8,*,‡]

1 Department of Human Sciences, Università Telematica degli Studi IUL, 50122 Florence, Italy
2 Department of Sports and Health Sciences, University of Brighton, Brighton BN2 4AT, UK
3 Italian Air Force—Centro Sportivo Areonautica, 00062 Bracciano, Italy
4 Department of Teacher Education, NLA University College, Linstows Gate 3, 0166 Oslo, Norway
5 Department of Neurosciences, Biomedicine and Movement Sciences, School of Exercise and Sport Science, University of Verona, Via Felice Casorati 43, 37131 Verona, Italy
6 Faculty of Physical Education and Sport, Ovidius University of Constanta, 900029 Constanta, Romania
7 Sport Science Academy, 09131 Cagliari, Italy
8 Department of Biomedical Sciences for Health, Università degli Studi di Milano, 20133 Milan, Italy
* Correspondence: johnny.padulo@unimi.it
† These authors contributed equally to this work as first author.
‡ These authors contributed equally to this work as last author.

Abstract: Research on high-tech running shoes is increasing but few studies are available about the use of high-tech track spike shoes (super spikes), despite their growing popularity among running athletes. The aim of this case study was to investigate kinematics, kinetics, and plantar pressures of an Olympic running athlete using two different types of shoes, to provide an easy and replicable method to assess their influence on running biomechanics. The tested athlete performed six running trials, at the same speed, wearing a pair of normal spikes shoes (NSS) and a super spikes shoe (SSS), in random order. SSS increased contact time, vertical impact, and swing force (Effect Size 3.70, 7.86, and 1.31, respectively), while it reduced foot-strike type and vertical ground reaction force rate (Effect Size 3.62 and 7.21, respectively). Moreover, a significant change was observed in medial and lateral load, with SSS inducing a more symmetrical load distribution between the left and right feet compared to the NSS (SSS left medial load 57.1 ± 2.1%, left lateral load 42.9 ± 1.4%, right medial load 55.1 ± 2.6%, right lateral load 44.9 ± 2.6%; NSS left medial load 58.4 ± 2.6%, left lateral load 41.6 ± 2.1%, right medial load 49.2 ±3.7%, right lateral load 50.8 ± 3.7%). The results of this case study suggest the importance of using individual evaluation methods to assess shoe adaptations in running athletes, which can induce biomechanical modifications and should be considered by coaches to ensure optimal running performance.

Keywords: running gait; running performance; running biomechanics; foot pressure; running shoes; spike shoes; track and field athletics

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1. Introduction

Running on the track is very different compared to street running. Accordingly, it is well known that the speed, running disciplines (e.g., hurdles, short and long distances), trial duration, and shoes of track runners differ from street runners, along with the specific running technique [1,2]. Among the various factors affecting running performance, shoes play an important role because the construction characteristics can have implications for running injuries and performance [3]. The volume of literature about running shoes has strongly increased in the past decade [4–6]. At the same time, the attention of researchers has mainly focused on shoes for long-distance running rather than track shoes. This is well documented by using, on PubMed.gov, the generic key words "running shoes" and the specific key words "track running shoes" (1183 and 56 records, respectively, from 1975 to 2022—last access on 26 July 2022).

Both long-distance and track running shoes are available on the market with new high-tech materials (i.e., carbon fiber plate in the midsole) [7]. However, the literature has focused mainly on reporting strengths and limitations of long-distance running shoes [8–10]. Accordingly, there are no definitive data available for high-tech track running shoes [7], although their use is increasing among athletes. A recent article published by Healey et al. [11] suggests how the so-called "super spikes" shoes might provide advantages over traditional track spikes, but these can depend on the athlete's perception of the shoes and are based on specific competitions. Moreover, the authors suggest that the testing procedures on the field are not always easy, because of the aerobic and anaerobic metabolic demand of the track disciplines [11]. Therefore, it is difficult to give an exact answer about the benefits related to the use of the super spike shoes. Furthermore, the use of shoes during running must be considered in relation to the type of advantages that are produced in terms of running economy, muscle and tendon stress, and perceptions of shoe comfort. For example, it is known that the traditional track spikes help save energy at high speed for middle distances [12] but there is no knowledge of how spikes can affect the kinetics and kinematics parameters due to the lack of evidence. From a practical point of view, it is likely that running athletes can switch to "super spikes", and, therefore, understanding the effects of a new pair of shoes on kinetics and kinematics parameters should be the first goal of coaches. For this reason, the aim of this work was to provide an easy method to assess the implications of the different shoes on the biomechanics of running athletes to understand the modification of the running technique induced by high-tech shoes. This was achieved by reporting and analyzing kinematics, kinetics, and plantar pressure parameters of an Olympic-level running athlete using both the normal spike shoes (NSS) and the super spike shoes (SSS).

2. Materials and Methods

2.1. Participant

An Italian Olympic female athlete was recruited, and informed consent was obtained. The participant was 34 years old, (weight: 59.5 kg; height: 1.70 m; BMI: 20.58; FMM: 86.3%; FM: 13.7%). She specialized in the 400 m hurdles, had 15 years of high-level training experience, and an Italian record at this distance. The study was conducted on only one participant because of the specific condition of the athlete at the time of the test. In fact, the athlete did not report any injury in the last year, and was performing the last training session of the season after the Olympic Games of Tokyo 2020. Moreover, the subject was at the end of the transition phase between NSS to SSS, as she used the SSS in the last month of training. Therefore, she was perfectly accustomed to both the old shoes (NSS) and the new ones (SSS).

No invasive or risky procedures were carried out, and the athlete was not exposed to any kind of risk during the test day. Accordingly, it was decided to perform the tests during her scheduled training, to avoid any sort of adjunctive stress.

2.2. Instrumentation

Running trials were performed at a national Track and Field stadium (Stadio "Paolo Rosi", Rome, Italy), from 10.00 to 12.30 a.m., with a mean temperature of 24 °C and 63% humidity. The shoes used were two models, as noted earlier:

1. The Nike track shoes: "Nike Zoom Jafly 2017", which are hereafter referred to as normal spike shoes (NSS).
2. The "Nike Air Zoom Victory 2021", which are referred to as super spike shoes (SSS).

The NSS were normal typical track shoes commonly used among professional and non-professional athletes before the rise of carbon fiber shoes (Figure 1). The SSS has a carbon fiber plate inside the midsole, aiming to increase the flexion rigidity at the forefoot.

Even in the forefoot, the midsole has an air capsule with a new generation foam, aiming to increase the rebound on the ground in the push-off phase (Figure 2).

Figure 1. NSS Nike Zoom Jafly 2017.

Figure 2. SSS Nike Air Zoom Victory 2021.

To evaluate the kinetics and kinematics of the running trials, two instruments were used (Figure 3): a pair of inertial measurement units (IMUs) directly applied on the shoes (RunScribe, Scribe Lab. Inc. San Francisco CA, USA) [13–15] and a pair of sensorized insoles able to detect the plantar pressures inside the shoes (FlexInFit, Sensor Medica, Guidonia Montecelio, Italy).

To record each running trial, a camera at 120 fps was used (GoPro Hero Black 7) to measure the running time, and videos were analyzed with Kinovea software V.0.9.5 (http://www.kinovea.org; accessed on 12 March 2022).

2.3. Testing Protocol

The athlete performed a standard warm up as she was used to performing before each running training. The warmup was 30 min long and consisted of: self-myofascial release, static stretching, low intensity running, dynamic stretching [16] and joint mobility, core exercises, low intensity plyometrics, running drills, accelerations.

Next, the athlete ran six trials of 80 m at 95% of maximal speed for that distance, which was confirmed by her coach who always controlled the run speed during the trainings. The instruments were calibrated before each running trial. The athlete wore the two types of shoes randomly for each trial. A complete rest period of 12 min was observed between the trials.

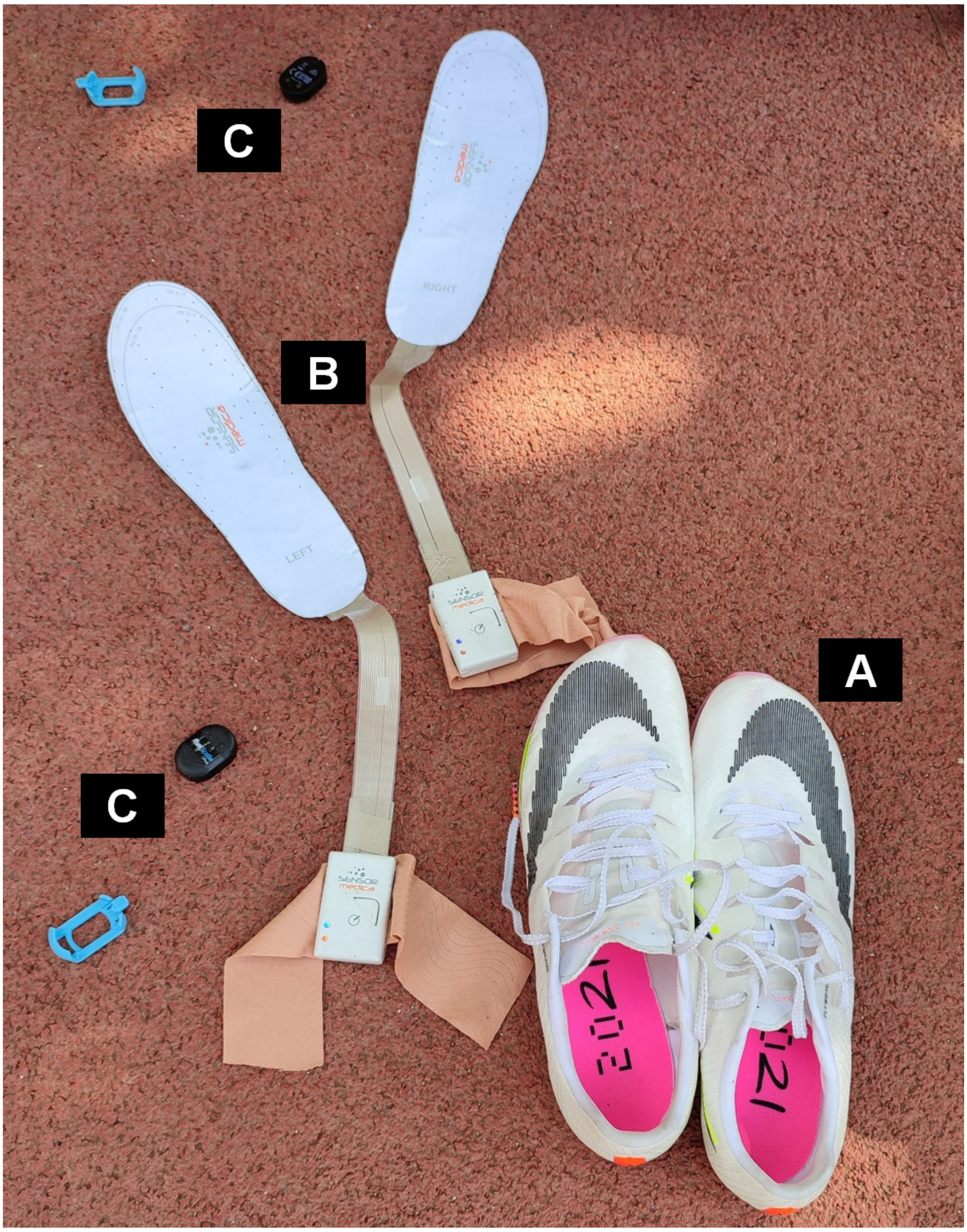

Figure 3. Instruments used during the running trials. (**A**) SSS Nike Air Zoom Victory 2021; (**B**) sensorized insoles, FlexInFit; (**C**) IMU applied on the laces of shoes, Runscribe.

The data obtained by the IMU analysis were step rate, contact time, step length, vertical impact, horizontal braking, foot-strike type, vertical ground reaction force rate (VGRFR), and swing force rate. The data obtained by the sensorized pressure insoles were plantar surface, medial load percentage, and lateral load percentage. A description of the variables is reported in Table 1.

The study had the ethical approval of the Ovidius Univeristy of Constanta N. 43 8 February 2022.

Table 1. Glossary of the kinematic, kinetic, and plantar pressure variables used in this study.

Parameter	Unit of Measure	Description
Step rate	Steps/min	Number of steps taken per minute
Contact time	Milliseconds (ms)	Time spent on the ground during the foot contact phase
Step length	Meters (m)	Distance between two successive placements of different foot (right to left and left to right)
Vertical impact	Gravitational acceleration (G)	Amount of vertical acceleration at foot strike
Horizontal braking	Gravitational acceleration (G)	Amount of horizontal acceleration and braking at foot strike
Foot-strike type	Arbitrary Unit (a.u.)	Parameter assessed by the RunScribe that ranged from 0 to 15 to give a resume of the foot strike tendency; 0–6 heel strike, 6–9 mid foot strike, 9–15 fore foot strike [14]
Vertical ground reaction force rate (VGRFR)	Newton per kilos per seconds (N/kg/s)	Mean vertical force rate during stance
Swing force rate	Newton per kilos per seconds (N/kg/s)	Mean force rate to swing the limb in a stride
Foot plantar surface	Centimeters squared (cm^2)	Foot plantar surface
Medial load percentage	%	Percentage of surface and pressure load in the medial area of the foot during each step
Lateral load percentage	%	Percentage of surface and pressure load in the lateral area of the foot during each step

2.4. Statistical Analysis

Statistical analysis was performed to identify differences between the two running shoes. Data of each variable are expressed with means and standard deviation (SD). Due to the nature of this case report and the few samples of used data, the Cohen's effect size with the Hopkins scale was adopted, considering the values range of <0.2, 0.2–0.6, 0.6–1.2, 1.2–2.0, and >2.0 as trivial, small, moderate, large, and very large effects, respectively. Moreover, Student's *t*-test was used to detect significant changes between NSS and SSS for the plantar pressure parameters used ($p < 0.05$).

3. Results

3.1. Kinematics and Kinetics

The running time for each trial was around 95% of the best time for the distance of 80 m, and the total number of steps in all the trials ranged from a minimum of 39 to a maximum of 41 steps.

Average data for each spike shoes are described in Table 2. A large to very large effect size was measured for contact time, vertical impact, foot strike type, rate of vGRF, and swing force rate. The average trends of contact time, rate of vGRF, and swing force rate during the running trials are shown in Figure 4, to enhance interpretation of the results.

Table 2. Kinematics and kinetics values for NSS and SSS.

Variables	NSS (Mean ± S.D.)	SSS (Mean ± S.D.)	Effect Size
Step rate (step/min)	235.3 ± 9.5	241.3 ± 8.1	0.68
Contact time (ms)	168.3 ± 9.1	196.3 ± 5.7	3.70 **
Step length (m)	2.0 ± 0.1	2.0 ± 0.1	0.09
Vertical impact (G)	7.4 ± 0.8	12.8 ± 0.6	7.86 **
Horizontal braking (G)	10.5 ± 0.7	10.5 ± 0.4	0.00
Foot strike type (a.u.)	11.3 ± 2.1	4.0 ± 2.0	3.62 **
Vertical ground reaction force rate (N/kg/s)	61.9 ± 1.6	52.2 ± 1.0	7.21 **
Swing force (N/kg/s)	3,4 ± 0.6	4.1 ± 0.4	1.31 *

* Effect size large; ** Effect size very large. NSS: Normal spike shoes; SSS: Super spike shoes.

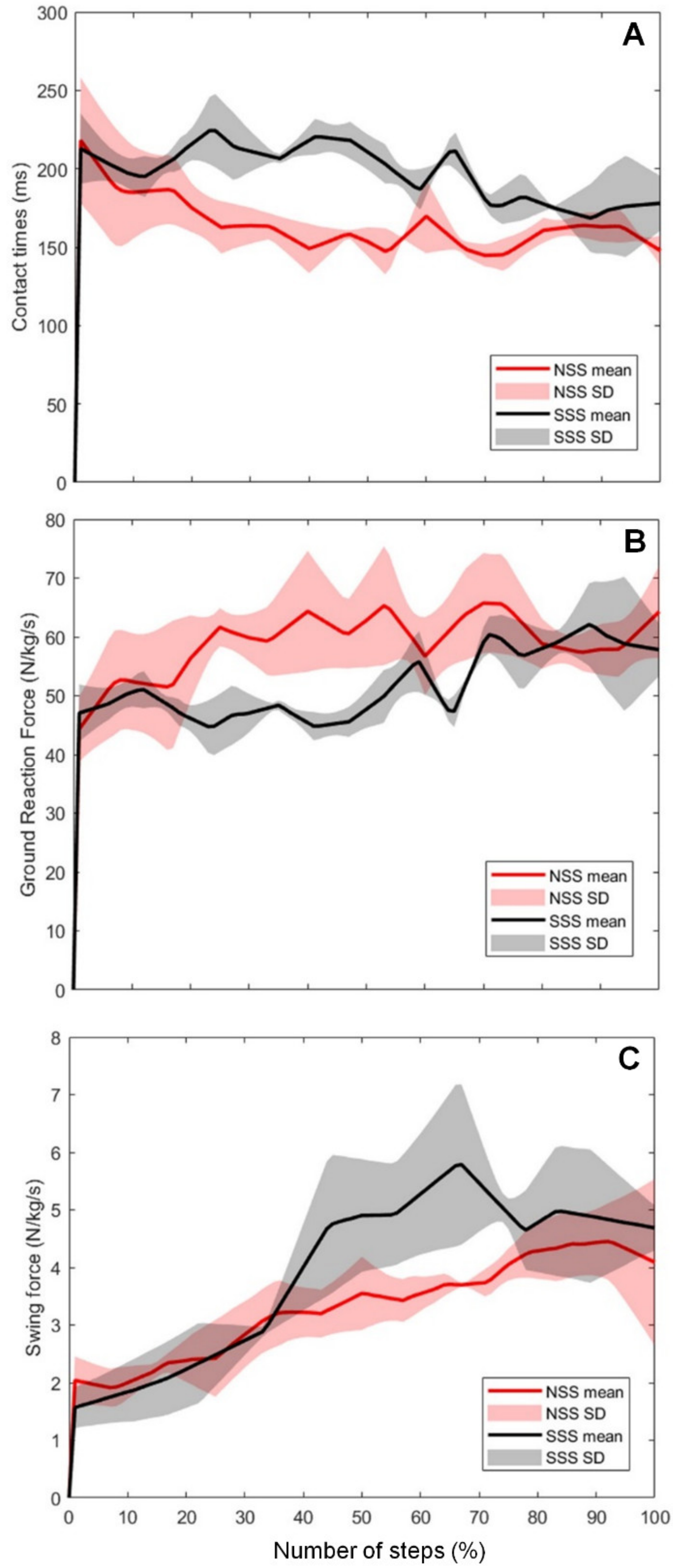

Figure 4. Average trend of contact time (**A**), vertical ground reaction force rate (**B**), and swing force rate (**C**) during the running trials. The number of steps of the trials was normalized on a 0–100% scale to compare the different curves by plotting the scalar field of each running trial. NSS: normal spike shoes, SSS: super spike shoes.

3.2. Plantar Pressure

With respect to plantar pressure analysis, 10 steps were used for each trial. The first step was selected as the sixth step from the beginning of the trial to the 16th. The statistical analysis with the Student *t*-test agrees with the Cohen's effect size (Table 3), which found that medial and lateral percent loading of the right feet had a large effect size. In fact, no significant difference was found in left and right plantar surface between the two shoes (p = 0.414 and p = 0.713, respectively) but a significant difference was observed for the medial and lateral load percentage of the right foot comparing the two shoes (p = 0.000).

Table 3. Plantar pressure values for NSS and SSS between Left and Right foot.

	Variables	NSS (Mean ± S.D.)	SSS (Mean ± S.D.)	Effect Size
Left foot	Plantar surface (cm^2)	138.1 ± 6.7	139.7 ± 8.6	0.2
	Medial loading (%)	58.4 ± 2.6	57.1 ± 2.1	0.6
	Lateral loading (%)	41.6 ± 2.1	42.9 ± 1.4	0.6
Right foot	Plantar surface (cm^2)	146.1 ± 10.7	147.0 ± 7.0	0.1
	Medial loading (%)	49.2 ±3.7	55.1 ± 2.6	1.8 *
	Lateral loading (%)	50.8 ± 3.7	44.9 ± 2.6	1.8 *

* Effect size large; NSS: Normal spike shoes; SSS: Super spike shoes.

Plantar surface was always higher in the right foot with respect to the left, with both shoes (Figure 5). A difference in terms of the medial and lateral parts of the foot was measured for the loading percentage. In fact, the NSS showed an asymmetric behavior between the two feet in terms of medial and lateral loading percentage, while the use of SSS showed a much more symmetric percentage of foot loading strategy between the two feet (Figure 6).

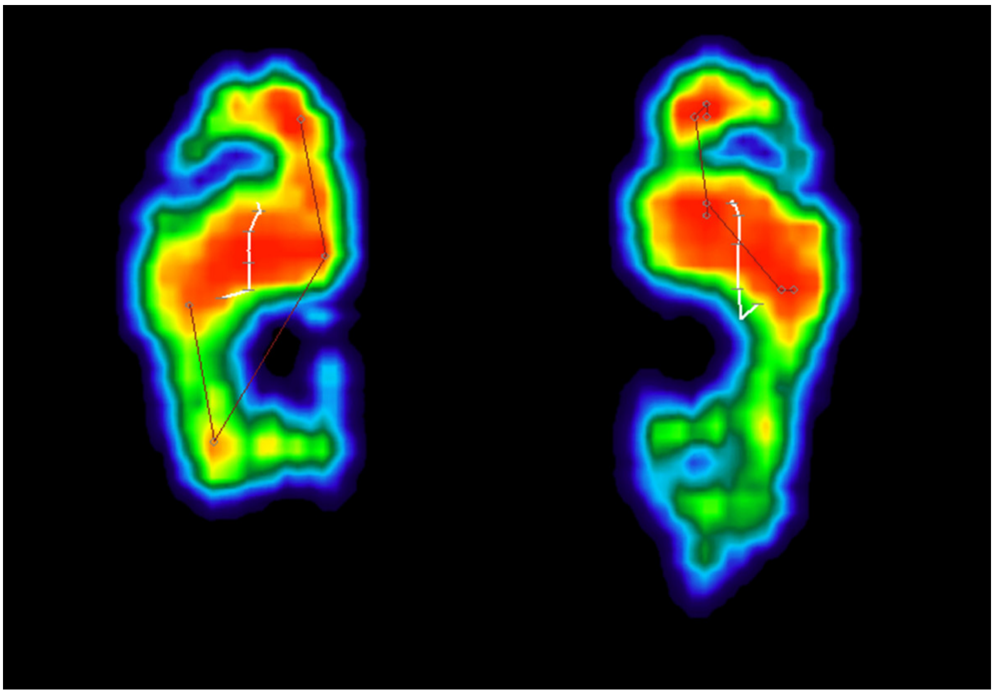

Figure 5. Example of foot plantar pressure global image of left and right feet during a running trial. There is a clear difference between the two feet in the plantar surface that is touching the ground.

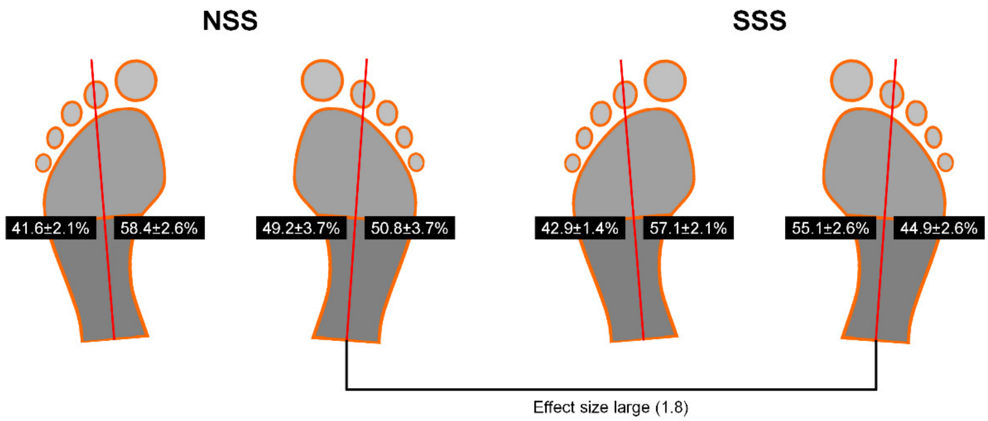

Figure 6. Schematic representation of the medial and lateral percentage of load in the two different shoes. NSS led to an asymmetric loading behavior between the left and right feet, with a higher medial load percentage on the left foot, and a more distributed load percentage between the medial and lateral part of the right foot. By comparison, the SSS led to a more symmetric behavior between the left and right feet, increasing the medial load on the right foot, with similar values with respect to the left foot.

4. Discussion

The aim of this study was to create a specific case study providing a method to assess the influence of NSS and SSS on the biomechanics of an Olympic-level running using kinematics, kinetics, and plantar pressure profiles. This assessment protocol was developed to be easy and practical to use, so that all running coaches can replicate it directly on the field.

4.1. Kinematics and Kinetics

The results of this case study suggest that the SSS offer some changes in both kinetics and kinematics running-related parameters. One of the most interesting aspects to underline is the increasing contact time captured with the SSS, alongside an increased swing force rate and a reduced rate of vGRF (Figure 4), which possibly caused less stress on the foot musculoskeletal structures. The reduced contact times can seem counter-intuitive, considering that these shoes should help the athlete during the push-off phase of the run, as the carbon fiber plate enhances elastic force restitution [10]. Although contact time increased, no change was detected for step rate and length, which could be expected given the higher amount of time spent in contact with the ground. It can be reasonable to surmise that such modifications do not occur, as there are movement compensations elsewhere. Accordingly, an increasing swing force rate was captured. As a result, the athlete recovered from the longer times spent on the ground with a quicker swing phase.

Even the vertical impact at the foot strike instant changed, and it was higher with the SSS. The increase in vertical impact could be related to two aspects: (1) the higher intrinsic rigidity of the SSS due to the carbon fiber plate [8]; (2) the concurrent change in the foot strike type [14], which showed a more horizontal position of the feet when the SSS were used. This value, however, does not fit with the athlete perception, because she felt less heavy on the ground. This is an important aspect to consider, especially given the high proficiency of the athlete analyzed in this study.

The reduction in forefoot foot strike decreased Achilles tendon involvement as the first shock-absorbing joint, increasing the vertical impact acceleration [17]. This change should not be downplayed for two reasons. First, the foot strike patterns changed the vertical impact but not the horizontal braking; therefore, the amount of braking for each step was the same between the two shoes, meaning that no dissipation of energy was present. Second, the increase in vertical impact was only at the instant of the foot strike, but the acceleration was absorbed by the high-tech material of the shoes and not by the athlete's soft tissues because the vertical ground reaction force was lower with the SSS.

4.2. Plantar Pressure

The behavior of the foot inside the two different shoes seemed very similar in terms of foot surface, meaning that the transition from using the NSS to the SSS should be trivial in terms of wearing comfort [18,19].

With respect to the behavior of the foot inside the NSS, there was a difference between left and right foot in terms of medial and lateral percent loading (approx. 9%). Specifically, the left foot showed significantly higher medial load compared to the right foot. It has to be considered that our athlete had a serious injury and surgery on the right hamstrings five years prior to this work; therefore, it is likely that the different medio-lateral loading strategies between right and left feet could be related to her injury history. This was also supported by the athlete, who stated that, since the injury, she repeatedly reported to her coach a different medio-lateral loading distribution between the two feet.

Using the SSS, the loading difference between the two feet in terms medial and lateral percent loading reduced (approx. 2%), as the right foot loading distribution became more similar to the left one. Such modifications are important as a more symmetric medial loading distribution between the two feet optimizes the propulsion as the athlete similarly engages the left and right halluces in the push-off phase during running [20]. This might also be facilitated by the wider toe box of the SSS compared to the NSS, which allows a position of the hallux within the shoe [21], and thus a typical function.

4.3. Limitations

It was anticipated that the results of this work are specific only to our athlete, but they can give an indication about what to expect from using these two shoes in a similar case. In addition, this case study also provided an assessment method for running athletes. Nevertheless, working with a very high-qualified athlete is not easy and it can sometimes be difficult to apply evidence from the literature, especially when there is a lack of research, as in the case of the SSS effects on running. This is only one example of how the technology can help the athletes. However, it is fundamental to create specific test sessions with each athlete in order to easily understand the individual effect of high-tech sport apparel, because it is not obvious that every athlete could benefit from the use of certain apparel.

5. Conclusions

The results of this work suggest that coaches should adopt individual evaluation methods to assess the influence of different shoes on biomechanics of high-level running athletes, which have the potential to improve running performance. A practical and general example of the evaluation method is provided, aiming to help coaches and researchers (see Supplemental Material, Figure S1).

When using the SSS, the increase in contact time without changes reported for the step rate and length can be considered one of the most interesting points of discussion, indicating new scenarios in terms of running technique and training methods.

Our results are specific to our athlete. Nonetheless, these results strongly suggest increasing the sample to understand the broader effects of SSS on high-level runners. This study provided new insights for this field of research, and it is desirable to test the same SSS on other athletes with different levels of qualification, or different running disciplines and distances on the track, aiming to explore the real effects of SSS on running kinetics and kinematics.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app122010195/s1, Figure S1: Experimental setting.

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Informed Consent Statement: Informed consent was obtained from the participant involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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