CHALMERS
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Long distance track spike design

Maximising running performance

Master's thesis in Industrial Design Engineering

Johanna Larsson
Adam Rasmussen

Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2018

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Adam Rasmussen

Supervisor and examiner
Lars-Ola Bligård

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Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Tel. +46(0) 31-772 1000

Cover Photo: Visualisation of track spike concept. By Johanna Larsson and Adam Rasmussen.
Print: Repro Service Chalmers

Gothenburg, Sweden, 2018

Abstract

This project was performed as a master thesis within the programme Industrial Design Engineering at Chalmers University of Technology during the spring of 2018.

The aim of the thesis project was to identify the suitable properties of a spike-equipped shoe for long distance running in track and field, and develop a concept shoe for Salming Sports AB. This was achieved through delving into research on running dynamics and performing activities centred around the track runner. Interviews, spike shoe user tests, and a survey were complemented with interviews of experts in fields such as biomechanics and sports medicine.
The concept ideation approached both desired functionality and design elements in parallel process loops, featuring problem analysis, sketching, material mapping, evaluation, and a final merger of the parallel processes to a concept shoe design.

A discrepancy was found between the properties prioritised by runners and what the typical track spike offers. Both runners and experts were sceptical of the market's fixation with low ultra-low weight, feeling that properties such as stability and durability suffered from the compromises that are made to shave off additional grams.

Focusing on speed, efficiency, and injury prevention, the design process lead to several solution sets, as well as a final design concept reflecting the functions and attributes prioritised by the runners. The final design proposal took the form of a shoe equipped with five spikes and a spike plate covering the forefoot, as well as extending back under the midfoot to provide torsional rigidity and elastic rebound. The spike plate was designed to stand out visually, conveying Salming's brand identity during elite competition events. Apart from the intricate spike plate design, the concept consists of a minimalistic shoe to keep the weight low while still prioritising some stability and support needed for the longest distances. By having five spikes instead of the conventional four, and ventilation holes allowing drainage, the design is also suitable for steeplechase, where extra traction is needed and water jumps subjects the shoe to large amounts of water.

Keywords: *track spike, product development, running, performance, shoe, industrial design engineering, track and field*

Preface and acknowledgements

This master's thesis project was performed during spring 2018 by Adam Rasmussen and Johanna Larsson as a part of the programme Industrial Design Engineering at Chalmers University of Technology. It was a collaboration with Salming Sports AB, a Swedish sportswear and sports equipment brand.

We, Adam and Johanna, would like to thank all of those who have lent their efforts to the project. The runners who participated in the interviews and user tests were invaluable to us, and all track runners responding to the survey deserve thanks as well. With the collective experiences from these runners, the shoe decidedly got a good grip on both their needs and the track. We extend our thanks to the experts in various fields who have contributed to our work, both in academia or otherwise, such as orthopaedists, running coaches, and researchers. Their intricate knowledge of running dynamics, injuries, and running shoe design has strengthened the outcome of the project. Major thanks also go to our project supervisor, Lars-Ola Bligård, who patiently guided us through the project, even as our questions delved into report minutiae.

We want to thank all those we worked with at Salming, especially Thomas Nord and Tomas Solin, who launched the project with us and provided no-nonsense support by making the resources and knowledge at Salming available to us. In addition to all the employees at Salming, we also greatly appreciated the presence of the office dogs, especially the very sociable Bella who made slow days less dull.

Not to be forgotten, our fellow industrial design engineering students deserves thanks as well, as the camaraderie kept the spirits high, even when we all prioritised thesis work over conventional holiday leave, and as the days started to take on the attributes of summer.

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1 Introduction

What makes a great running shoe? This question will likely bring the person asking to the revelation that there exist as many answers as there are runners in the world. Running is not simply running - the ground beneath our feet, how fast we run, our individual stride and anatomy, and the distances we put behind us make running something more than what the lone word suggests. Running is, depending on the perspective, either the simplest of concepts, putting one foot in front of the other, or an incredibly complex motion, which is reflected in the variation and intricacy of modern running shoe designs. A great running shoe, then, needs to consider the needs of its user and the context, which in the case of the elite runner points toward a highly specialised shoe with extraordinary performance. This project took aim at such a shoe, a long distance running spike for track athletes.

1.1 Background

Salming makes several types of shoes, but not all running conditions are currently met fully with a dedicated product, and it is one of these gaps in their product line that this project addresses. The gap in question is track running. A Salming running spike has been requested by their brand ambassadors, runners who now use other brands when the conditions call for a spike-equipped shoe. The main distances for the ambassadors are 5 000 and 10 000 meters, and a running spike made for those distances would allow Salming-sponsored athletes to rely fully on their products for training and competition. Track and field athletes often use shoes equipped spikes to gain more traction than a regular outsole can provide on the rubberised surface of competition tracks. Track spike shoes are built for performance during competition, which comes at the expense of comfort, and may increases the risk of contracting pain and injuries if the functional priorities of the shoe do not meet the physical needs of the runner. A long-distance track spike needs to be well balanced in this regard, as the designs typically are minimalistic, and finding a compromise that suits most the intended users is therefore not a straightforward task.

1.2 Aim

The request from Salming was for us to investigate the suitable properties of a spike equipped shoe for long distance running in athletics, and based on what is uncovered develop solutions for the requirements most characteristic for a track spike. Reformulating that request into a master's thesis lead to the following aim:

To understand and translate the needs and preferences of runners who train and compete at tracks into requirements for a long distance running spike, and then develop a design concept for such a shoe.

1.3 Deliverables

The concrete parts required to fulfill the aim of the project were chosen to so thet they would contain unearthed knowledge of the problem, potential solutions, and an example of how they could be combined and implemented. The deliverables were formulated as follows:

- A set of qualitatively described product requirements derived from user centred research.
- A set of solution suggestions addressing important design variables.
- A final design proposal combining a selection of solutions to form a concept track spike for long distance track running.

1.4 Objectives

To further frame the project goals the following objectives were developed. They acted to limit the scope of the project and guide the process so that the results would meet both the requirements put forth by Salming and the acadeamic purpose.

- The targeted concept product should be a spike-equipped shoe, incurring that spikes are a predetermined solution to the issue of creating traction.
- The project should arrive at a comprehensive mapping of the functional requirements.
- The result should include design proposals of design elements identified as especially relevant in long distance track spikes.
- From the range of solutions developed, a selection should be combined and refined to form a final principle design concept.
- The concept proposal should aim to follow Salming's principles and philosophy as well as express their current brand identity.
- Developed concepts should be implementable from a practical perspective, meaning they need to comply with both standards and limitations imposed by available technology and manufacturing techniques.
- Construction elements, geometries, and materials need not be specified with more detail than a functional description, but higher level of detail may be included if they are adequately explored and specified.
- The proposals of principle design elements should address specific requirements emblematic of running spikes. Other design elements, i.e. those not substantially affected by the requirements imposed by the context-specific circumstances, are not necessary to develop in detail beyond a generic description.
- Documentation from the project should provide a rigid background for Salming when deciding whether to add a running spike segment into their selection of shoes.

1.5 Report outline

While largely conventional in its structure, the result section of this report is divided into chapters that both mirror the process and the concept. Due to the wide variety of topics investigated, the project structure does not organise the results into discrete sections that correspond to specific activities performed in the project. Instead, the results are organised according to their relevance to design elements and topics, e.g. the chapters *Heel section* or *Lacing system*.

The results section's structure reflects the project's two major phases - the *exploratory* and the *creative* - with the former focusing on mapping the problem space and the latter on the solution space. The problem exploration transitions into solution synthesis with the chapter *Desired characteristics and design principles*. There, the knowledge that was uncovered in the exploratory phase is condensed into a target image for the shoe, which details the desired functions and properties.

The final design proposal acts as a vessel for the reader as each chapter explores an important design element or function. They do not only explain the solution set chosen for the final design concept, but also the major challenges and alternative solutions.

2 Salming

Salming Sports AB is a Swedish sportswear and -equipment brand, with specialised divisions in floorball, handball, squash, badminton, and running. The name Salming stems from the Swedish ice hockey legend Börje Salming, whose traits as a player mirror those the modern company wants to convey. At the core of the desired image is the slogan *no nonsense* and words like instinct, drive, strength, pure, natural and quality signify their products. Many are professional and high-end products directed toward experienced users, but the range covers users at recreational- and novice level as well.

Salming Running was launched in 2014 with a philosophy based on the idea of natural running. The philosophy is substantiated through a collection of select articles delving into several aspects of running performance and injuries. The philosophy includes research underlining that no discernible improvements of performance and injuries occurrence has been conclusively observed in shoes that are more supportive and corrective in their features (Ryan, et al. 2010; Goss, et al. 2012; Richards, et al. 2009). Natural running manifests in their shoes through five articulated focuses that shape their properties; light, flexible, flat, thin and comfort. This is reflected in the running shoes by having a maximum heel-to-toe drop of 6 mm, which is relatively low in comparison to many other brands. As the shoes are constructed for a natural running stride, there is greater individual control over the motion and running stride. This requires a driven and active stride, making their shoes suitable for those invested in their running, and who appreciate the self-reliance and high level of control they offer.

Salming's visual aesthetics are associated with bright, contrasting, and sometimes clashing colour schemes, making the products stand out. As a smaller brand than many of their competitors, and consequently, often lower brand recognition, the name Salming has been part of the visual branding strategy, often appearing in large letters on several places across their products.

Figure 2.1 Collage exemplifying how Salming markets their products and brand, and examples of Salming running shoe designs. Images courtesy of Salming Sports AB.

3 The long distance track runner

Track running is almost exclusively performed by athletes who compete in track and field events. It is a sport commonly engaged in by people who have specialised in running from the wide range of disciplines and events present in track and field. Apart from that path into track running, some interviewees described themselves as recreational runners who had joined running clubs, and then made the move from road racing and other forms of running to competing at track events. While motivation for running in races may vary between runners, the stakes are still generally high. There is prestige in good performance and the athletes are highly motivated to perform at the highest level of their capability. This means training hard and sometimes close to the physical limits of the body. Injuries are common and the strain and subsequent wear on the body is often the reason for quitting the sport. During interviews, runners testified to the limits they pushed themselves to, and that eyebrows are not raised when feet are covered in blood blisters and calves are so stiff the day after racing that a set of stairs may appear insurmountable.

Running in track spikes demands both adequate strength and endurance to maintain proper technique during the race. During several of the interviews with runners, coaches, and orthopaedists, failure to maintain a good technique during longer races was brought up, both regarding themselves as runners and other athletes. For some, the uncompromising nature of the track spike and the requirements they place on the runner's abilities make a net benefit of using them doubtful. As one runner put it during an interview:

"I haven't previously liked spike shoes because my stride hasn't been that good, but now when I have gained strength I have been able to use thinner shoes."

Even though these athletes are well-trained, they are often in need of some level of support from their shoes, especially during longer races.

Figure 3.1 Runners warming up at Slottskogsvallen.

4 Running dynamics

It is considered running when, during the stride cycle, there are instances when both feet are off the ground, otherwise you are walking (Romanov et al., 2014). Apart from this fundamental aspect, the dynamics of running include a fair bit of variation across different circumstances; speed, duration and individual differences are all great influencers on the running form, but there are also external factors affecting how runner propel themselves forward.

By running faster, the stride typically moves more toward front foot striking (Hasegawa et al. 2007). Speaking to a researcher in biomechanics and several orthopaedists, it was found that practically all runners in long distance races plant the heel, although not at initial contact, which can be compared to sprinters who may run without planting the heel at all. The longer the distance the less likely the runner is to omit heel planting, and as they become increasingly fatigued they may plant it harder and longer, shifting reliance from their own strength and technique toward the supporting structures of the shoe. Track runners typically strive toward a natural and powered stride. It closely resembles what a barefoot running stride looks like, using the body's evolutionarily derived mechanisms for fast propulsion. The surface of the track is highly consistent compared to what a foot might otherwise encounter, making the motion regular and predictable, allowing the runner to fine tune natural mechanisms to run as efficiently as possible. The close resemblance between the preferred stride of elite runners and that of barefoot running makes it easy to display concepts of foot motion as there is no shoe covering the interesting parts. Compared to recreational runners, the track running forefoot strikers have less contact time with ground, which is logical considering that a heel striker needs to roll all the way from the heel to the front foot, instead of briefly planting the heel mid stance.

4.1 Gait cycle

The gait cycle of the running stride is often divided into phases, but how they are defined varies among researchers, often depending on what aspect of the stride is of interest to the observer. The definitions and vocabulary used in this project are gathered from several sources to establish reference frame that is complete, relevant, and able to describe the mechanics of running at an appropriate level of detail. The main contributors to the reference frame definitions is the review paper *The biomechanics of running* by Tom F. Novacheck (1997) and *The running revolution: How to run faster, farther, and injury-free-for life* (Romanov et al., 2014).

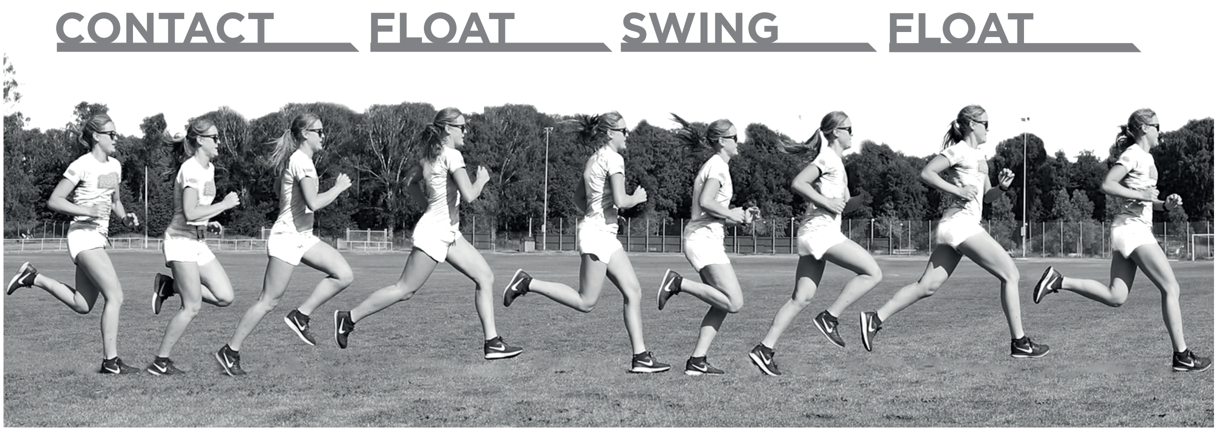


Figure 4.1 The phases of a full running stride cycle of the right leg starting at initial contact.

4.2 Contact phase

As shown in figure 4.2, the initial ground contact happens when the runner plants the outside of the forefoot, a result of rotating the foot outward, i.e. supination. Following initial contact, the rest of the forefoot is planted while muscles and tendons absorb some of the impact forces. As the heel comes down, the foot may be momentarily relaxed depending on the speed and technique, distributing the forces more evenly as the arch is lowered and becomes less rigid. This happens as the foot rolls inward, i.e. pronates, which positions the foot before push off. Moving through mid-stance, the point at which the vertical forces peak, the muscles in the foot are activated, and create a stable platform for pushing off. As this happens the heel leaves the ground, and the windlass mechanism is activated, raising and tightening the arch, allowing the foot to act like a spring blade for pushing off. When the heel is somewhat raised, the active push off from the leg seizes, typically ending around the point where the ankle joint is at 0 degrees (Powell et al., 2014). After this point the vertical forces rapidly drops and the foot gradually rolls off.

Figure 4.2 The contact phase from the side and back.

4.3 The natural spring function

To provide the runner with a strong and efficient platform for absorbing the impact of landing and releasing the energy when pushing off, the foot adjusts accordingly. Before initial impact, the toes dorsiflex, as seen in figure 4.3, pulling on the plantar fascia, shortening the arch tightening the internal structures of the foot (Bolgla et al., 2004; Griffin et al. 2015). This is called the windlass mechanism, which works together with active muscular regulation of the arch (Kelly et al., 2015) to achieve a sort of spring blade in the foot.

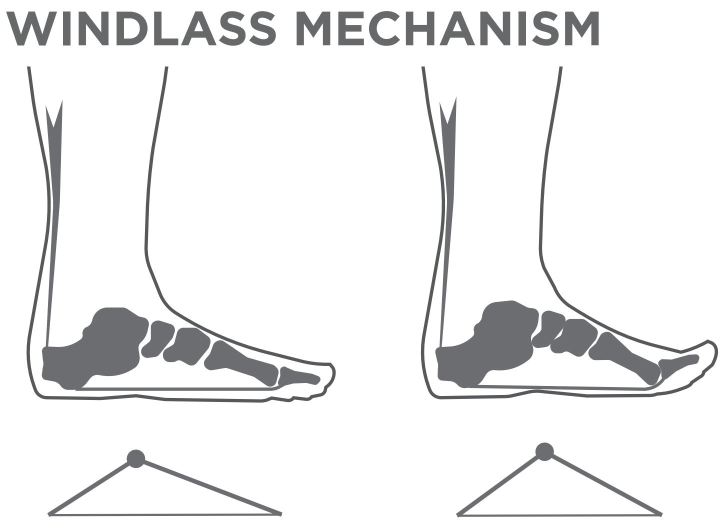


Figure 4.3 Illustration of the windlass mechanism. The relaxed state compared to dorsiflexed toes.

An addition to the spring function of the foot blade, other tissues such as the achilles tendon elastically absorb the initial impact when front foot striking. After stretching, it contracts again, releasing the energy into the stride. This mechanism in the tendons and muscles can reduce the energy cost of running by 50 percent (Romanov et al., 2014). Ker et al. (1987) have estimated the distribution of energy turnover by the ligament in a 70 kg man, a total of 100 J stored strain energy was distributed by 35 J in the achilles tendon and 17 J in the arch of the foot. A minimalistic shoe has higher return of energy to the runner, so that the elasticity in the soft tissues are used more for an efficient stride (Perl et al., 2012).

4.4 Ankle rotation - pronation and supination

The ankle joint is complex in its structure, restricting the ways it can move to specific axes (Brockett et al., 2016). This controls much of the foot's motion during the stride. In the push off phase, it transfers the force from the pushing done by the leg to the spring blade below, i.e. the foot (Powell et al., 2014). While the joint is active and changes angleduring the roll-off, its contribution in terms of force is minimal as it is among the slowest joints in the body (Romanov et al., 2014). In running, pronation of the foot is frequently discussed, which is the inward roll facilitated by the ankle joint, typically reaching its maximum close to mid stance at 40 percent into the stance phase, (Novacheck, 1998). Supination is rotation in the opposite direction, which can be observed upon initial contact (Figure 4.2).

4.5 Ground reaction force

The ground reaction force pushing on the foot from the ground when running may reach up to 3 times the body weight of a track runner in spikes (Logan, 2010). During more normal conditions, a peak of 2.6 times the body weight seem to be optimal as the body naturally compensates to reach that value when the surface hardness changes both in shod and barefoot running (Dixon et al., 2000). A runner that strikes with the heel first have two force peaks (Lieberman et al., 2010; Romanov et al., 2014), the first when the heel first contacts with the ground, and the second during midstance as the active push off is performed with much muscle activity, seen in figure 8.5 (Kelly et al., 2015; Novacheck, 1998; Romanov et al., 2014). The long distance track runner should preferably not land on the heel, but toward the end of a long race, as fatigue takes its toll, it may happen occasionally.

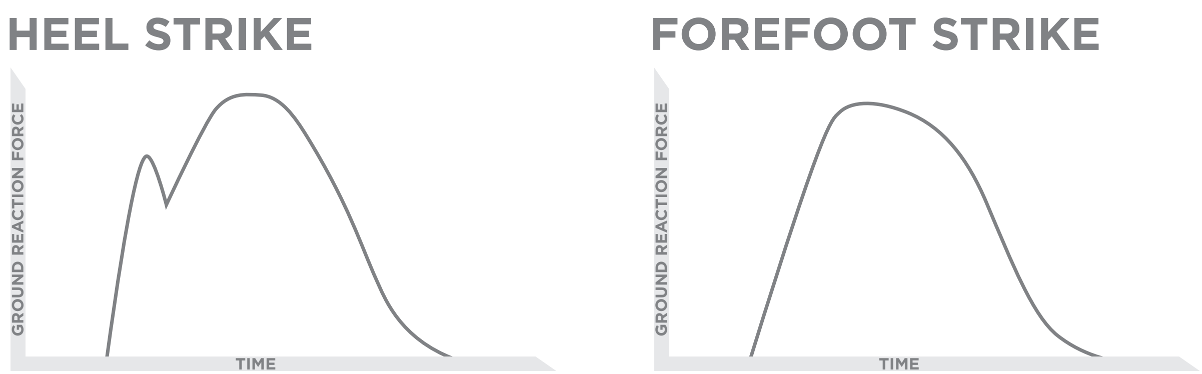


Figure 4.4 Illustration comparing typical ground reaction force profiles.

4.6 Centre of pressure

The centre of pressure is the centre point of the ground reaction force, and depending on the kind of strike, heel-, midfoot-, or forefoot, its takes different paths under the foot throughout the strike (Romanov et al., 2014). For the target group of this track spike, most users are mid- or forefoot strikers, landing on the outside of the foot, and then rolling inward before pushing off, as shown below in figure 4.5.

Figure 4.5 Point of initial contact and typical pressure paths for heel-, mid-, and forefoot striking runners (Romanov et al., 2014).

5 Injuries in running

Athletes put high strain on their bodies to maximise performance, making running related injuries a common occurrence (Lysholm et al., 1987). Many injuries can be prevented by increasing strength or technique; a stronger body can better handle the high dynamic loads of running (Romanov et al., 2014). For runners, increasing mileage slowly during training is a common way to prevent injuries (Kozinc, 2017). Both increase of sustained load and getting used to equipment such as running shoes, is best done gradually because of the changing force dynamics (Logan, 2010). The prevalence of the most common injuries, how they happen and their consequences, can inform the design choices of a track spike in several ways, perhaps most importantly by not actively inflicting unnecessary harm to the runner. Due to the high injury frequency expected among elite runners, considerations for runners with a pre-existing injury could affect the desired attributes. While much of injury prevention appear to be behavioural (Lysholm et al., 1987) and should to some extent be regarded to be about balance, moderation, and knowledge, the role of the equipment in influencing injury prevention in athletes should not be overlooked.

According to one interviewed physiotherapist and several runners, achilles tendonitis is a common injury among track runners. The frequent and violent lengthening of the tendon is likely to blame (Kvist, 1994). Issues with the plantar fascia, which consists of thick connective tissue from the heel to the base of the toes, are also common, often causing pain at the heel (Kozinc, 2017). Plantar fasciopathy is the blanket term for pain issues of a degenerated plantar fascia, including both the inflamed state, plantar fasciitis, and the non-inflamed state plantar fasciosis. The plantar fascia experiences heavy loads at the same time as the achilles tendon, acting as a spring which in addition to returning energy in the stride, and additionally has an important role in the essential windlass mechanism detailed in the chapter *Running dynamics*. Medial tibia stress syndrome, commonly known as shin splints, is another condition often affecting runners (Moen et al., 2009). The pain it causes arises during dynamic loading of the leg, such as running, and it may lead to stress fractures if left unchecked (Romanov, N. et al., 2014). A correlation between high vertical impact forces and tibia shock and stress fractures has been established (Milner et al., 2006), and it is suggested that reducing dynamic load and shocks is important, rest being the proven remedy. The properties of the shoes, such as cushioning, may help reduce the shock when hitting the ground. Limiting excessive pronation could potentially reduce the prevalence of the condition, as it has been shown to be a prominent risk factor for shin splints (Moen et al., 2009). Blisters, blood blisters, and chafes are superficial injuries often caused by abrasion, poorly fitting shoes, or moisture in the fabrics that are in contact with the skin.

6 Methodology and implementation

Informed by the prestudy into the topics summarised in chapters two to five, the following key questions were identified, and that provided the basis for shaping the process and choose suitable activities to initiate the practical investigation.

What are the requirements of a long distance running spike?
What design elements of the shoe are most influenced by the identified requirements?
How can form and material properties combine to create the functional design elements required?
How does the brand identity of Salming influence the requirements of form and function of a running spike?
How can the design elements be combined toward a final principle design proposal?

6.1 Project structure

The design process covered the journey from user need to final concept, and it was characterised by the phases illustrated in figure 6.1. The two major project phases were exploration and creation, but they should be seen as characteristics of different parts of the process rather than exclusively following each other chronologically. The exploratory phase included mapping of context, user, and use cases, resulting in the fundamental needs and requirements of the shoe as a whole, and the creative pase included designing the shoe and its parts to fulfil the identified needs and requirements.

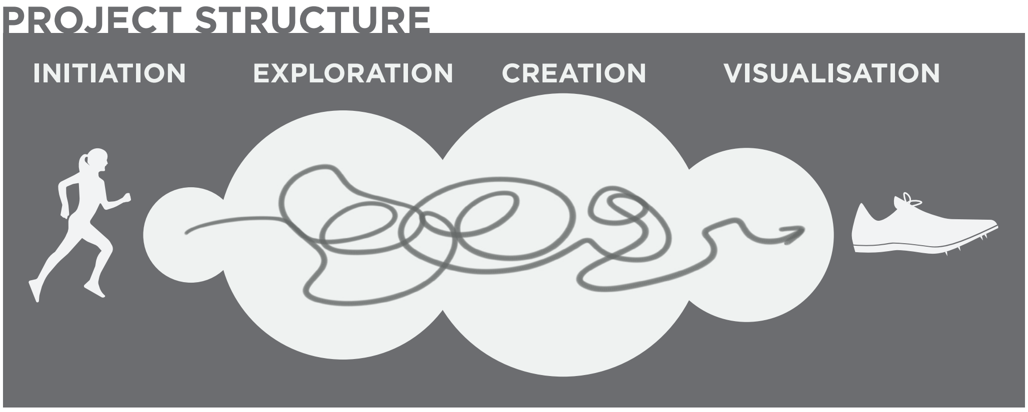


Figure 6.1 The project divided into four phases, illustrating their overlap and iteration both within and between phases.

The nature of the iterative development process has in this project been characterised by medium-sized loops, which was a natural consequence of the level of abstraction and the project boundaries present at the start. At the starting point of the project, part of the solution was already provided, i.e. a track spike was requested. Had the approach been wider, such as finding a way to allow faster track running in general, compared to specifically making a track spike, other solutions for creating grip would have been explored in a large-loop process. Larger loops were featured to some extent, especially in the effect- and use levels. Both questions H*ow does one run fast and efficiently?* and *Can this foam be glued?* needed to be understood, even though they might appear to exist outside of the intended scope. Instead of providing alternatives to the spikes, they were part of understanding how and why it became the preferred standard in track running, and how the spikes could be complemented by other features to make a high performance shoe. In the end of the process there is the final concept, the result of iterations with progressively lower levels of abstraction. As the abstraction level was lowered and the solution space became more narrow, the loops inherently became tighter until the targeted resolution of the final concept was reached.

This perspective of product development fits within the framework ACD³ - activity centred design with three dimensions - which was used to understand problems and solutions, and to organise them into a hierarchical structure. The ACD³ dimensions are design levels, design perspectives and design activities (Bligård, 2015). While it mostly served as an internal support structure during the project, some concepts from the framework was useful for communicating the reasoning behind certain design choices. The concept of design levels was the most utilised, which provided an abstraction hierarchy for the project, especially useful for the more abstract levels. A representation of the project nature is shown in figure 6.2, incorporating the hierarchy and the progression within it, as well as the parallel nature of the work.

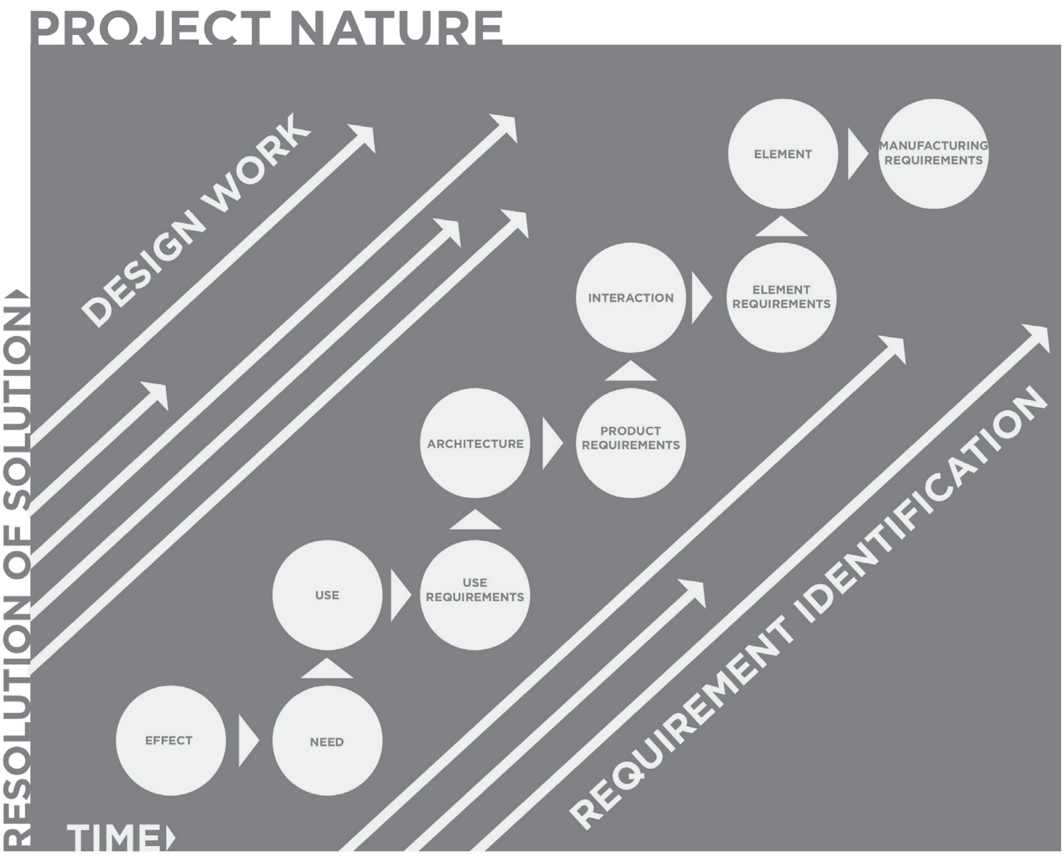


Figure 6.2 Illustration of the parallel nature of tracks in design work and requirement identification as the project progressed, partially based on ACD³ framework (Bligård, 2015).

The way the project's elements are organised in terms of loops within and between abstraction levels is primarily on a structural level, and should not be interpreted as a chronological order. While there are some correlative relationships between chronological progression and e.g. tightness of loops and level of abstraction, for the most part, they all existed and developed in parallel, see figure 6.3. The purpose of this structure is to avoid getting single-tracked, which might lead to dead ends, and cross enriching and -informing the different tracks and levels.

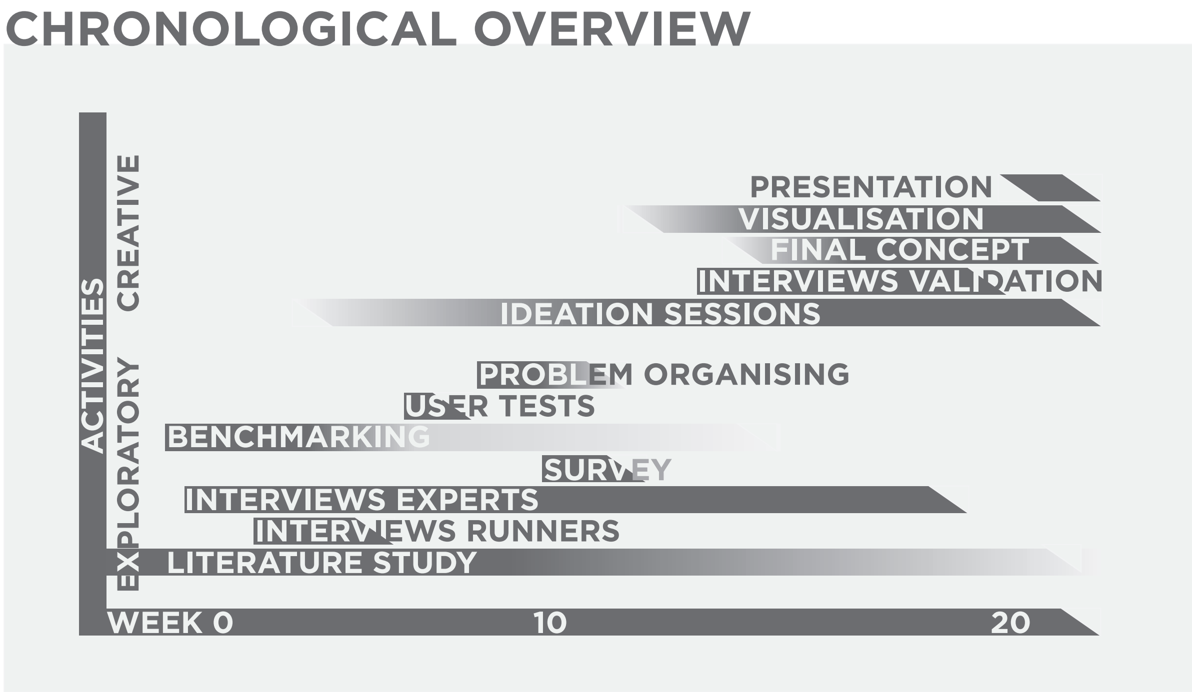


Figure 6.3 Chronological overview of the project.

6.2 Exploratory phase

The full range of methods in the project included, alongside standard practices, some diffuse variations of methods and activities. Below follows a description of performed methods throughout the exploratory phase of the project.

Literature study

The project began with a literature study to establish a theoretical framework for, among other things, understanding the mechanics of running. A wide-ranging collection of papers and research articles were examined. The starting point for the investigation was the research referred to on the website of Salming explaining their running philosophy, which was complemented with further related research on several perspectives on connections between shoe design, running dynamics and injuries. Shoe design, materials, and manufacturing processes were also subjects of investigation.

Interviews
A selection of stakeholders was interviewed during the project, including track runners, athletics- and running coaches, physiotherapists, orthopaedists, academic experts in the fields of biomechanics and sports medicine, and experts in materials interesting to the project, such as textiles and polymers. To make use of these interviews, they were performed after the literature study, as a basic understanding was developed and the interviews could dig deeper into knowledge not available through reading research papers.

Central to the understanding of track runners were four semi-structured interviews with one or two runners. A total of six long distance track runners participated one time each. All long distance events were represented in their current range of distances, and they also possessed experience from middle distance, road races and cross country running. The focus was experiences with track spikes, and how they felt about different features, and what they wanted from a pair of shoes in various circumstances such as training, competing, purchasing, cleaning, storing, and transporting. The interview guide can be seen in *Appendix A*.

Survey
A survey was conducted to gather quantitative data on nteresting findings and issues raised during the interviews. It contained a section evaluating a range of concepts that had been conceived at the time. The survey was aimed at middle- and long distance runners with experience of spike equipped track shoes, and can be examined in *Appendix B*. The processed and translated results of the survey are found in *Appendix C*. The survey contained 39 respondents, who received access to a web form. It was distributed through various channels such as running groups on social media and e-mail.

User tests
The user tests were partly an extension of the benchmarking, but also an opportunity to have experienced runners display how track spikes are used. Three pairs of track spikes in bold above were used for tests. Three long distance track runners with similarly sized feet participated, including one of the authors of this report and two externally recruited runners. The shoes were tested during a session on an indoor track, and the participants then filled out a form with questions about their experiences with the shoes, *Appendix D*. Shorter bursts and intervals of a couple of hundred meters in the different shoes made up the physical activities during the tests. Longer trials were not conducted due to time constraints and for the sake of consistency in energy- and fatigue levels in the runners. Since the test were performed at an indoor track, runs in a banked curve occurred. The passes of the externally recruited runners were recorded on cameras set up to capture the strides in high detail for reference and analysis.

Recording foot planting
Due to the lack of high quality reference material in stride dynamics, foot planting during running was video recorded to provide a detailed view of how the foot behaves at relevant speeds and running techniques. The planting of bare and shod feet was recorded on a treadmill used for running analysis. Two experienced runners, and as it happens, authors of this report, lent their bodies for the experiment, which was recorded from both the side and back to capture the interaction between the sole and the ground. The aim was to validate the often visually lacking descriptions of the details in the motion, and provide reference material for general use in the project.

Benchmarking

The product segment long distance track spikes received the most attention, while other categories of shoes with properties relevant to long distance track spikes were subject to more superficial exploration.

The initial activity was general market research with the main goal of identifying spike shoe brands and currently available models. Consumer oriented retailers and reviewers were researched to gain an idea of brand and models suitable to include in the benchmark. Models for distances somewhere in the range of 5 000 m to 10 000 m were targeted. Additional requirements imposed on the selection were that the models selected should be aimed at expert users rather than novices and available for purchase at the time of research. If several generations of the same shoe model were available, the latest was chosen. The selected models were then compared based on information provided by the respective brands, product images, and reviewing services. The placement of spikes and shape of spike plate was mapped and compared together with other key attributes. Spike placement mapping can be seen in *Appendix F*.

An additional subset of the selection was made including only models recommended for 10 000 m, i.e. the longest track competition distance. Information about the models were gathered from the respective brand and complemented with information posted online by users, retailers, and reviewers. Inconsistencies in the weight reported by the respective brands of the models resulted in the weight being complemented from such sources. The shoe selection was made to isolate the group of shoes which most clearly matched the target distances of the project. Of those shoes, three models were purchased for in-depth comparison and user testing. The selection was decided by the amount of diversity exhibited between them, and interesting design attributes. In addition to the shoes, several types of replacement spikes representing different materials and shapes were obtained and tested together with the shoes.

The spike shoe models were, with those physically obtained for user tests marked in bold:

- Adidas Adizero Avanti
- Asics CosmoRacer LD
- Brooks Wire v5
- **Hoka One One Speed Evo R**
- Hoka One One Rocket LD
- **New Balance LD5000 v5**
- Nike Zoom D
- **Nike Matumbo 3**
- Saucony Endorphin 2

Brand identity mapping and -analysis

The brand identity analysis included looking at Salming's aesthetical profile through marketing material and their products, as well as complementing our own perception with that of employees, runners, customers and brand ambassadors.

Material- and technology mapping

Finding and evaluating available technological resources included research of a wide variety of products with interesting materials and technical solutions. This included, along with the general research, a visit to Smart textiles, which is part of the Swedish school of textiles at Borås University. To explore possible designs and materials for the spike plate, samples of different polymers were obtained. The samples provided a complement to the technical descriptions and a more tangible experience of them. To expand the knowledge of practices common in shoe design and manufacturing, the two books *How shoes are made* and *Shoe material design guide*, both authored by Wade Motawi (2017), proved helpful and were thoroughly read.

Shoe dissection

Two pairs of Asics GT-2000 4 were dissected to gain understanding of part composition, materials and manufacturing techniques. The model is not a track spike, but a regular consumer trainer for longer distances. It was deemed suitable due to its relatively complex construction which included many different materials and manufacturing techniques. They also provided insight into the extent of inter-model differences as they represented both the female and male version of the shoe and were of different sizes.

Competition- and facility imposed regulations

Rules and regulations regarding material, design, and use during competitions, were studied, such as the International Association of Athletics Federations' competition rules. In addition, common track surface materials and properties were investigated.

Problem analysis and hierarchy

Structuring problems, ideas and solutions etc. is often done through affinity diagram based methods, and is can be performed more or less explicitly. In this project, the issues tackled were often discreetly confined and well-defined, but sometimes connections to other parts or problems appeared. E.g. ventilation and drainage can both be solved partially using perforations. However, sporadic connections as such yielded few non-apparent categories when organising the problems. The structure for organising them was instead derived from ACD^3 (Bligård, 2015), whose concepts we utilised to create a comprehensive overview of the problem space. Organising the material into different design levels provided, in addition to exposing connections, the possibility to determine where they intersected - at what level they converged and where they diverged. This was useful to identify sporadic connections without having to choose certain groupings which might have excluded another way of organising the problems. Each problem was divided into its fundamental components with problem, causes, and consequences, which provided several dimensions to compare and connect.

6.3 Creative phase

As information from the exploratory phase was uncovered, activities from the creative phase could be initiated. This did not mean the exploratory phase had ended, but there was naturally a gradual shift from the former to the latter as the project progressed.

Ideation sessions

This part of the project was one of the more substantial in terms of time and effort, not the least due to the subsequent evaluation of the ideas. The solution space explored was purposefully initially not restricted, as ideas and solutions beyond what is considered conventional could provide significant insights, despite often later proving to be too obscure or untested to align with the aim of the project. Ideation took several forms during the project, and structured activities such as sketching sessions were frequently used. In addition to pen and paper, tools for exploring solutions included various 3D-modelling- and illustration softwares, as well as physically modifying shoes we had access to.
The creative phase included finding solutions to identified problems and challenges. Their categorisation is mirrored by the chapter division in the results section. The most important areas were tackled with problem break-downs into main problem, causes and consequences, followed by semi-structured ideation with mapping of existing solutions, sketching of additional solutions, evaluation and reiteration. These activities were performed until an appropriate resolution of the solution was reached. Ideation topics are shown in figure 6.4.

Figure 6.4 Categorisation of the major areas of ideation in the creative phase.

Validation of concepts and principles

Validation of principles and ideas were done in several ways. Due to the difficulties of evaluating isolated aspects of the design practically, where a very detailed shoe prototype would have been needed to accurately represent the properties and how they would interact, other more theoretical validation paths were used. Many design solutions could be validated by examining their performance in other shoes, where similar solutions had been used. If it has been shown to work in another shoe, it can likely be implemented in ours as well. The final design was discussed with runners and a professor of biomechanics. The design elements and their functions were presented and explained together with alternative options, and the advantages and disadvantages of each were discussed to identify potential issues and determine if the desired properties could be achieved with the chosen principles and dimensions.

Visualisation

Visualisation of partially complete design elements was used as a tool to develop them further, increasing the level of detail in the design. The colour profile was chosen by experimenting with a finished CAD-model of the shoe. The software tools used were Autodesk Alias Autostudio, Autodesk VRED, Adobe Illustrator and Adobe Photoshop.

6.4 Process-related ethical considerations

The use of user-centred research activities that involved users through interviews and studies, necessitated consideration of their ethical aspects. Permission and mutual understanding of the purposes of collected information, and conditions under which it were to be used, was throughout the project considered a prerequisite for user activities. This was established verbally at the start of the interviews and other activities. Apart from the user-centred activities, the process itself incurred no higher consideration for ethical aspects other than the ordinary; the world of elite track running shoes is rather uncontroversial. However, some athletes and interviewees were part of sponsorship contracts, with Salming or other brands, which potentially contained clauses about what information they could share publicly and in what fashion. This provided further incentive to protect anonymity in not only the public content of the project, also how any gathered material was used and stored during the project. The responsibilities toward stakeholders of the project does, of course, include ethical considerations. In a competitive market, sensitive information regarding the company should be handled as such, and there is a measure of care and respect included in the responsibilities that exist between the company and us, the authors of this report.

7 Long distance track spikes

Fundamental to the project, as they are what a potential Salming shoe would literally compete with, are the long distance track spikes existing on the market. This chapter explores their typical properties, and also unique features of specific shoe models. The results are primarily derived from interviews and user tests with runners a well as benchmarking.

The way a shoe interacts with its immediate environment determines many of its features. Extrinsic influences were found through evaluation of spike equipped track shoes; how they are supposed to be used, how they are actually used, and what elements they come into contact with. The physical elements interacting with the shoe during typical use is shown in figure 7.1. In addition to the physical interaction the shoe also communicates with the spectators and the runner, conveying the brand identity and performance through appearance and feel.

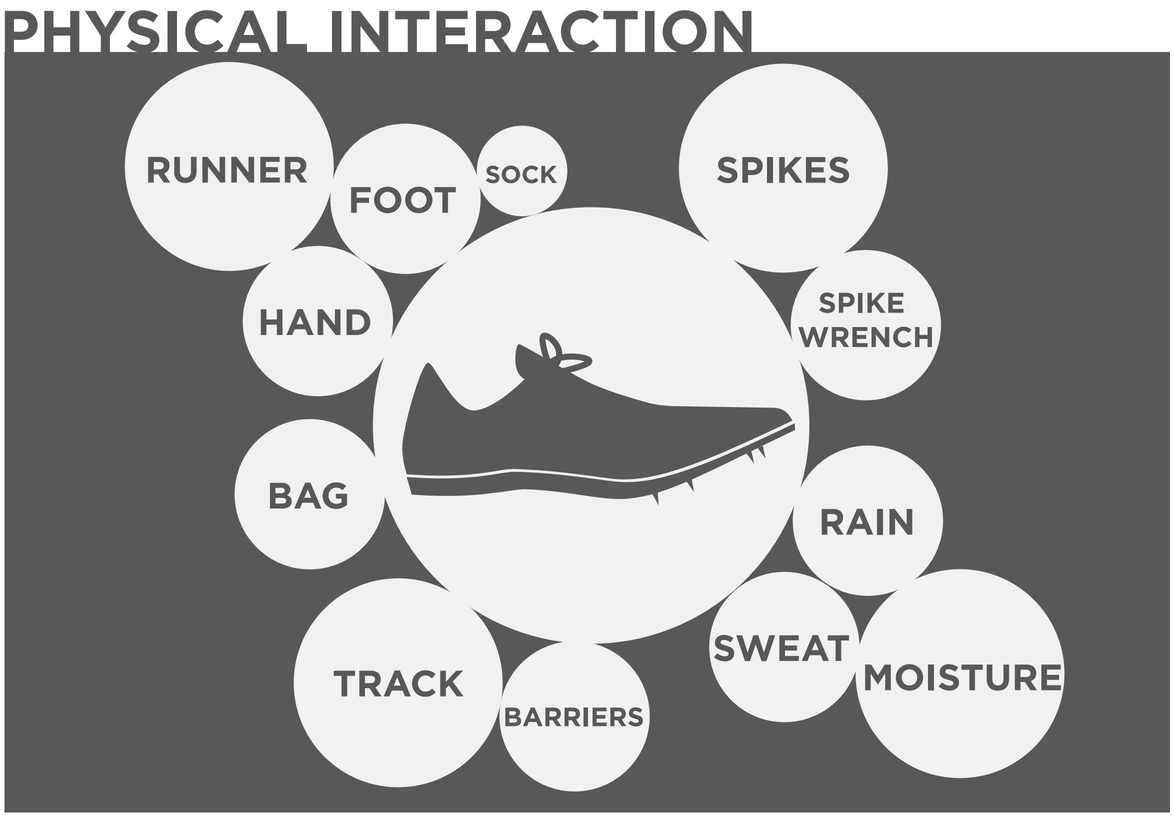


Figure 7.1 Physical extrinsic elements that interact with the shoe during typical use.

7.1 Typical characteristics and features

As it is designed for elite runners, the fit of the shoe is important, not only in physically but also how it makes the runner feel. Generally, a track spike differs from regular running shoes by having a tighter fit, being lighter, and having a spike plate instead of an outsole. The spike plate holds a number of spikes, and to do so it is fairly stiff. In addition to the spikes, there are often other plastic protrusions that increase the grip further. The desired expressions are often lightness and speed, reflected by the aesthetics of the shoe. These shoes often have a very tight fit, wrapping the foot to allow minimal movement relative to the ground. Running spikes are categorised according to the distances or events they are deemed suitable for, such as sprint, middle distance, long distance, cross country, and steeplechase. The price-range for long distance track spikes is about 700 - 1 200 SEK, with the elite shoes being priced at the top of the range. Most elite models are unisex.

According to the International Association of Athletics Federations' *Competition rules 2018-2019* (2017), it is allowed to compete barefoot or with shoes on one or both feet. Runners typically go for the latter option. The design of the shoes should not be so that the user gets an unfair advantage. As the spikes provide traction not feasible with bare skin against the track surface, one might wonder what constitutes an unfair advantage. The rule seems to be interpreted such that any equipment being equally available to all on the market, and not being too outlandish, is acceptable. For running shoes, the sole can be of any thickness, and a shoe strap over the instep is permitted as well.

Track spikes were found to typically feature a fair amount of toe spring due to the taper at the front. The taper angle depends on the type of spike shoe, with sprint shoes featuring large tapers while long distance shoes tend to have a less severe taper angle at around 20 degrees. Compared to faster shoes, long distance spikes featured slightly more heel cushioning, as the heel touches down in longer races. While sprinters may not plant their heel during a race, meaning the sprint shoes do not need heel support, from 1 500 m and upward the heel is typically planted every step of the race. This was observed in elite athletes by one of the interviewed orthopaedists, who was a former track runner as well. Shoes for longer distances should therefore be designed to cope with contact between heel and track surface. Typical features for a long distance track spike are seen in figure 7.2.

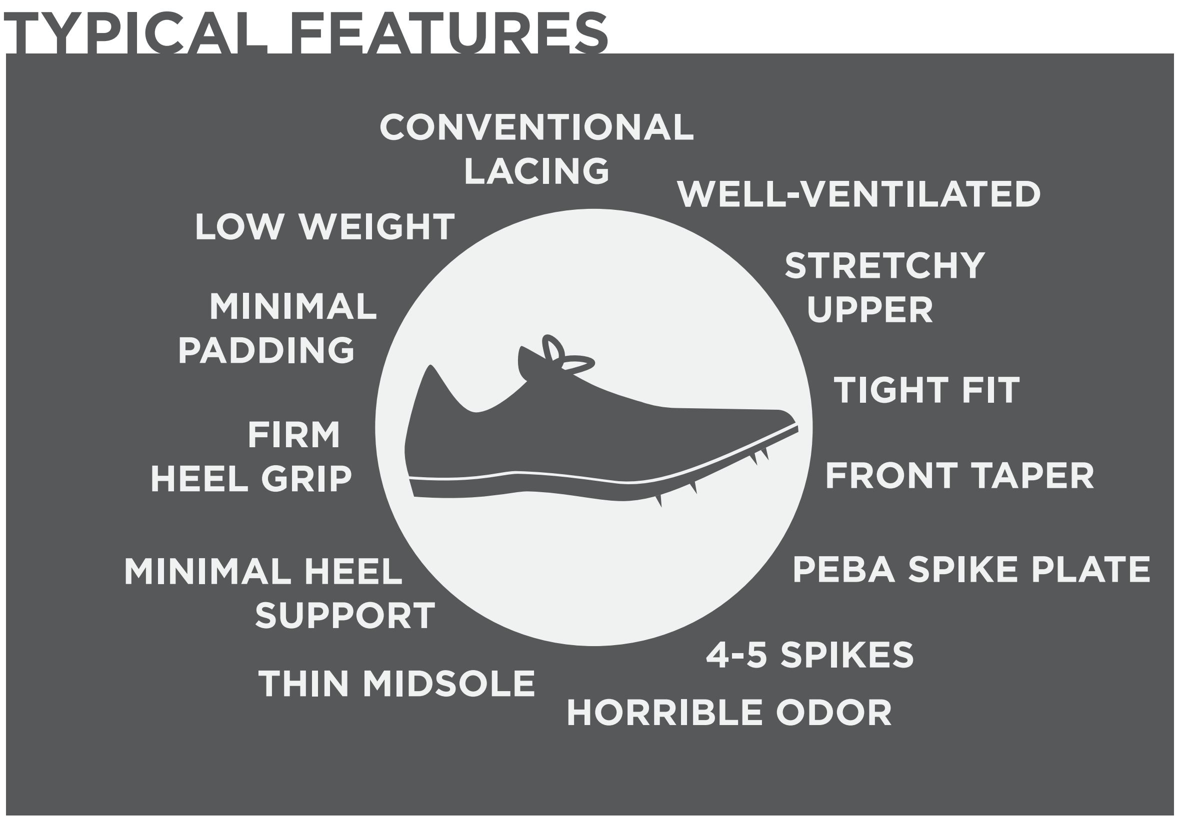


Figure 7.2 Typical features in a long distance track spikes.

7.2 Design variations in track spikes

Features separating distance track spikes from each other may be the number of spikes, shape of spike plate, the taper, amount of cushioning in the heel, and how much stability they offer to support the runner. A sprint shoe have more spikes than middle- and long distance shoes, and their placement is different. The number of spikes in a shoe for sprint can be up to eleven, overing the entire forefoot, while long distance shoes typically have four spikes placed along the outer edge of the spike plate.

The spikes are placed in accordance with to how the foot strikes the ground and where grip is needed for push-off, and while there is variation in placement among track spikes, they generally follow similar patterns. While some shoes were found to have permanently mounted spikes, most models featured removable spikes. This is achieved with threaded inserts in the plate and a dedicated tool called a spike wrench, which allows the runner to choose length and shape of the spikes, as well as replacing worn-out spikes. The different spike options are delved further into in the chapter *Spikes*. When mapping long distance spike plate designs, they were found to vary greatly- from covering the entirety of the sole to only covering the outer edge of the forefoot in a minimalistic horseshoe design, seen in figure 7.3.

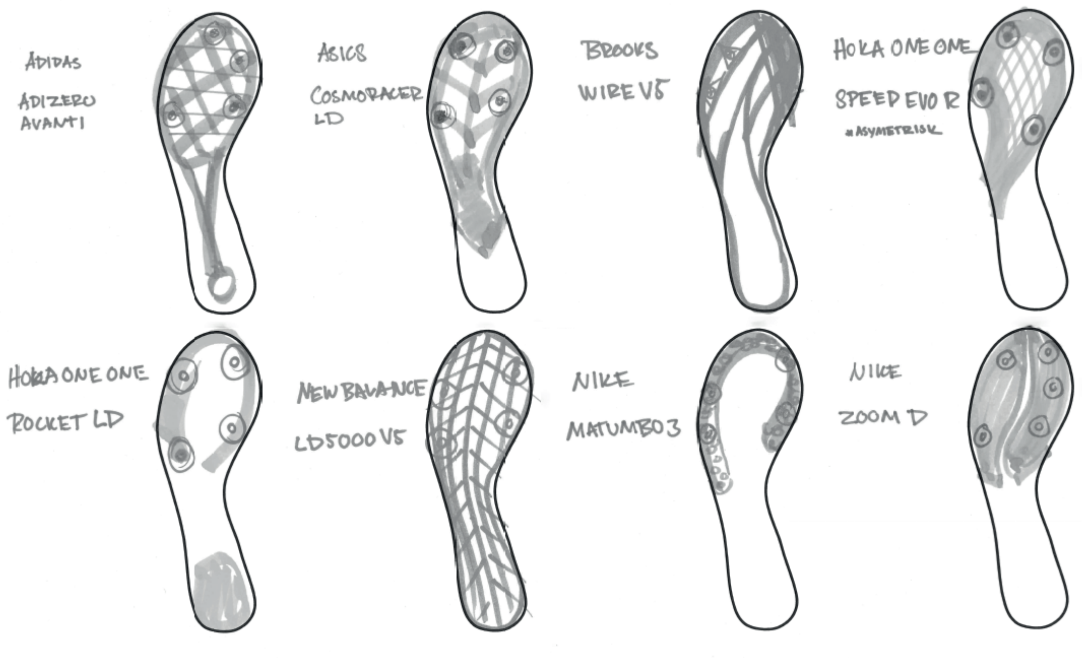


Figure 7.3 Spike plate coverage and spike placement in eight long distance track spikes.

7.3 Weight

Low weight is an important property in long distance track spikes, which is emphasized by marketing material and brand descriptions of the shoes. A race to the lightest shoe as found to to exist between competing brands, somewhat to the dismay of athletes, coaches, and physiotherapists who expressed that the compromises made to shave off grams are not worth it. The low weight is achieved by stripping material, leaving a very thin and minimalistic shoe. The weight of the shoe impacts the runner's performance; less mass at the foot to move around decreases the amount of oxygen used when running, with about a one percent improvement for every 100 grams taken off each shoe (Divert et al, 2008). The weight range of the shoes (US size 9, male model if applicable) was between 99 and 147 grams, including spikes.

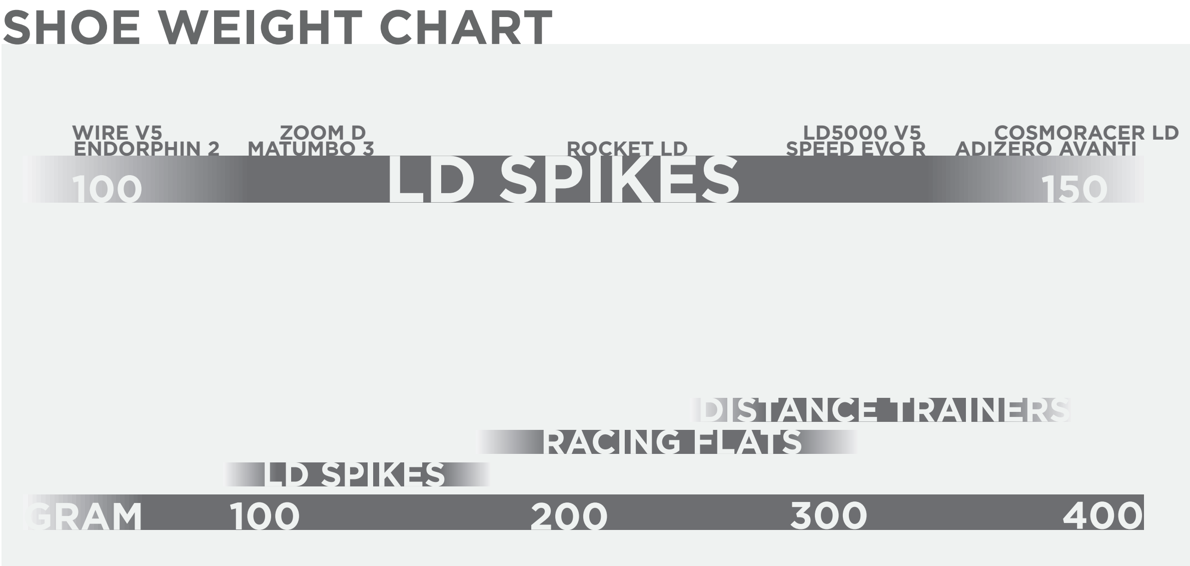


Figure 7.4 Weight of long distance spike shoes and regular running shoes.

7.4 User tests and comparison

The three models selected for physical tests provided insights into specific features that worked well, and some that did not.

USER TEST MODELS

Figure 7.5 Shoes that were tested by users, showing the side profile, sole, and the shoes on a track. New Balance 5000LD V5, Hoka One One Speed Evo R, and Nike Matumbo 3 are shown left to right in the top two images.

Both structurally and visually, the chosen shoes showed considerable variation between them. The major differences included the fit, where the Hoka stood out with a stiffer and more spacious upper. It featured more padding around the heel, where the other shoes only had thin strips of padding around the ankle. The spike plates ranged from minimal in the Nike, to an extended plate on the Hoka One One, and a full coverage plate on the New Balance shoe. The Hoka One One's spike plate and spike placement is asymmetrical. Supposedly, this is to optimise the shoe for turning left, as track runners have a thing for such behaviour. The Hoka One One lacked an outsole under the heel, allowing the midsole to come into direct contact with the track. The amount of cushioning differed slightly, with the Hoka One One and Nike having a thicker midsole toward the back of the shoe. The Nike also featured additional arch support. The New Balance was the only of the three to have a removable footbed, which was a thin compression moulded EVA sole matching the shape of the foot. The other models instead had thin and permanently glued footbeds that provided very little force mediation between the foot and the midsole. The toe spring was more noticeable in the Hoka One One, and it lacked ventilation holes as well. The Nike model had a large round hole at the back of the heel, which did not match any anatomical feature of the foot. This made it apparent that the shoe lacked a heel counter, just as the New Balance did, leaving the Hoka One One the sole bearer of such device. The Nike shoe was the only to have permanently mounted spikes.

Hoka One One Speed Evo R

Hoka One One emerged from the others by being more similar a racing flat rather than a track spike. The first impression of Hoka One One was that it was ugly, plastic, and wide. Expected to be slow, not looking like a spike shoe and less esthetical appealing than the others. The impression was that the shoe should feel clumsy and stiff when using it. The asymmetrical spike plate did not impress. In addition to not making any noticeable difference to the runners who tested the shoes, after speaking to runners, physiotherapist and a biomechanics expert, no other view emerged other than it being a gimmick rather than providing any practical advantage. Instead, concerns were raised regarding the spike placement on the right shoe, where the inner back spike was in a position where it risked causing injury according to a trainer. One user clearly felt the spike behind the ball of the foot on the inside of the shoe, which caused discomfort. The shoe was perceived as too enclosed and bad at handling perspiration. This was exacerbated by the lining in the back quarter of the shoe, as the large section of synthetic suede could become slippery from moisture. The runners preferred to use them with socks instead of barefoot, causing a switch from the normally preferred. While performing better than initial impressions indicated, the Hoka One One was not perceived to be snug enough. During running it felt slightly clumsy, though the shoe felt better at higher speeds, possibly because of the aggressive taper angle which kept the runners on their toes.

New Balance LD5000 V5

Users thought the shoe followed the foot while still prociding adequate tension and it struck a good balance between having a snug, minimalistic feel and providing some stability. A negative aspect of this shoe was the fit of the heel, which collapsed at the lower section for some runners, likely due to them having less heel to fill out the space. The tongue of the shoe, which was attached to one side, annoyed one of the runners who had a high dorsum of the foot. The tongue could not be centred as a result. While perhaps a minor inconvenience, such annoyances should be avoided as it is not a desired distraction at the start of a high stakes race. The full coverage spike plate was perceived as comfortable, and one of the users testing the shoe explicitly called it perfection. Some of the runners landed slightly further back on the foot compared to the other shoes.

Nike Matumbo 3

Even though visually appearing to be wide across the forefoot, the Nike Matumbo was perceived as more snug, for some too narrow, causing pain. This was attributed to the upper not allowing enough expansion of the forefoot. The best aspects of the shoe were the lightness and snug fit, and the appearance of the shoe appealed to several runners. The spike plate was noticeable through the midsole, causing irritation and discomfort. The heel had the same issue as the New Balance, as it too collapsed when there was not enough heel to fill out the fabric. The placement of hole at the back of the shoe did not correspond to any anatomical feature, as it was low. This caused an odd fit and odd appearance.

Figure 7.6 Heel sections collapsing on the Nike and New Balance.

8 Use of track spikes

Both training and competition in a pair of track spikes was investigated, as well as the general experience of owning and maintaining them. This was done through interviews and a survey, with additional information from e.g. running forums and shoe reviews.

8.1 Training with track spikes

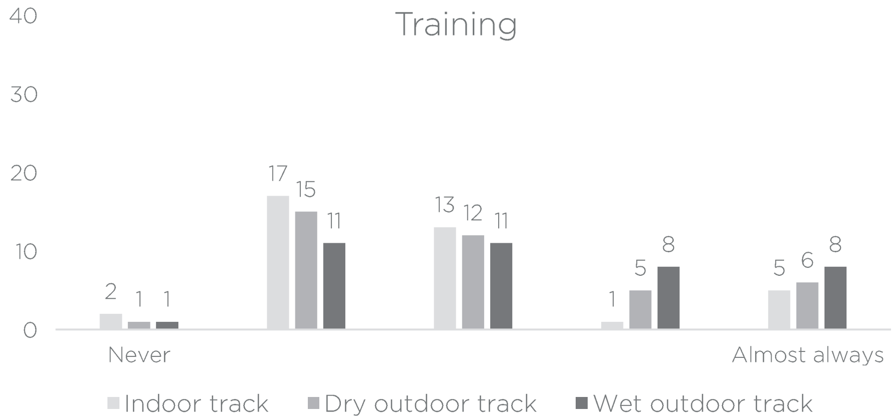
In Sweden, the season for outdoor track and field competitions typically lasts from May to August. The national championship in cross country occurs in late October, and the indoor season is in January and February. While typical use of spikes during the main outdoor season is one to two times every week, there is much difference between individuals. Most runners acknowledge the importance of breaking in and getting used to spikes before competition, but many limit their wear-time during training, even skipping them entirely, due to discomfort and strain on the body.

The training sessions with track spikes were often mixed activity sessions, featuring intervals, bursts, and technique practice. Shorter intervals and higher speeds during training were more commonly associated with track spike use, while longer intervals did not require spike shoes to the same extent. Warming up is close to exclusively done in other shoes. This means that track spikes are almost always used in combination with other shoes, making it possible to switch if they cause too much discomfort. The shape and length of the typical track, ovals of either 200 meters indoor or 400 meters outdoor, means that even during longer training distances, the gym bag is always close by. Some of the interviewed runners stated that the special feeling they got when lacing up and using their track spikes was an important part of preparing for a race, and the act was almost intrinsically tied to the competition context. Subsequently, they felt that limiting their use during training helped keep the track spikes special. The runners also stated that use of track spikes altered their running form and -stride, feeling they were better able to get on their toes and achieve a more efficient push off.

8.2 Competing with track spikes

Competition is a high stakes context, some events perhaps being the culmination of months or even years of intense training and preparation. The physical ability is pushed to its absolute limit, and there is also a large mental component to performing well. There is little tolerance for issues, something that includes the equipment. A significantly higher frequency of track spike use was observed for competitions compared to training, figure 8.1. A noticeable drop of track spike use was found for the longest track competition distance, 10 000 m, with only half of the runners who ran the distance reporting that they used spikes. A corresponding difference could not be observed for other distances. This is logical considering that the benefit of track spikes is less apparent at the lower speeds of long races. The strain of using track spikes for such a long time, between 30 and 40 minutes, is also high and can cause excessive discomfort, wear or injury, meaning more runners choose other shoes at 10 000 m compared to the shorter distances. This reasoning was also voiced during the interviews, even though some could not see themselves making that choice.

"I would find it very difficult not wearing spikes at the start of a 10 000 m race. It would feel extremely off. Like the others had some sort of advantage. Even though they might not."



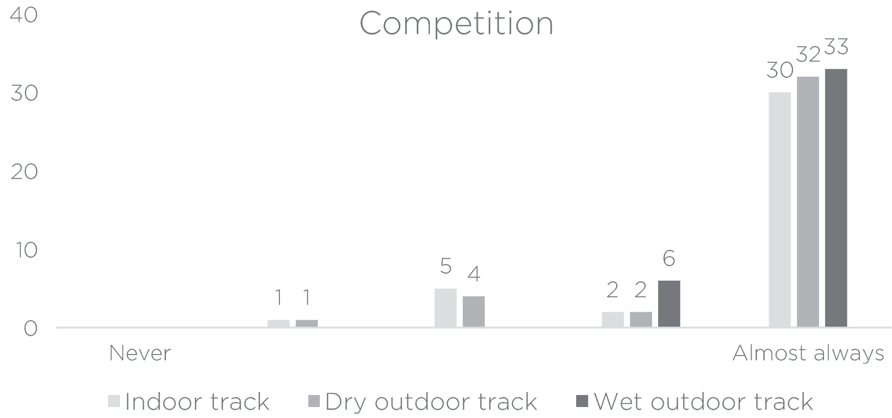


Figure 8.1 Self-reported use of track spikes in different conditions for training and competition respectively. From survey.

8.3 Choosing the right (and left) shoe for the distance

The range of distances considered to be *long distance* in athletics running imposed slightly different requirements than the shorter track distances. While the differences between sprint and long distance are easy to distinguish, the differences within the long distance segment, while smaller, were also apparent. In addition, individual preferences were found to vary, but the general trends should be considered when balancing the properties of a shoe. Runners tended to run several distances, and depending on their range and main event, they had different views on where the limits for a certain type of shoe was. Considering the distances 3 000 m, 5 000 m, and 10 000 m, most runners found it reasonable to have a shoe covering two of the distances, i.e. combining the two shortest or the two longest of the three. Which one they preferred typically depended on their own range of competition distances, and indicated that it was fine to sometimes run a longer race in shoes with typical properties for shorter distances and vice versa. The same reasoning was observed for runners who combined middle distance and long distance events in their range, e.g. a runner who specialised in 1 500 m and 3 000 m found feasible to occasionally use the same shoe for the 5 000 m event. The pattern that emerges from this is that a particular shoe typically works well for about two distances, which ones ultimately depends on personal preference, and that the neighbouring distances to the main two are fine to run occasionally. When it comes to technique and running speed, there is larger difference between the shorter events than the long distance ones, as seen in figure 8.2 detailing the pace and distance of several events. This was to some extent reflected in the preference for the number of track spikes they owned and used, as the long distance runners who were interviewed typically only used one track spike shoe, while the multi- distance runners in the survey reported that they used different shoes for different distances. The multi-distance runners consisted of the responders running at least two distances and included, unlike the interviewees, both middle- and long distance runners, providing a possible explanation as to why a difference between the two groups was observed.

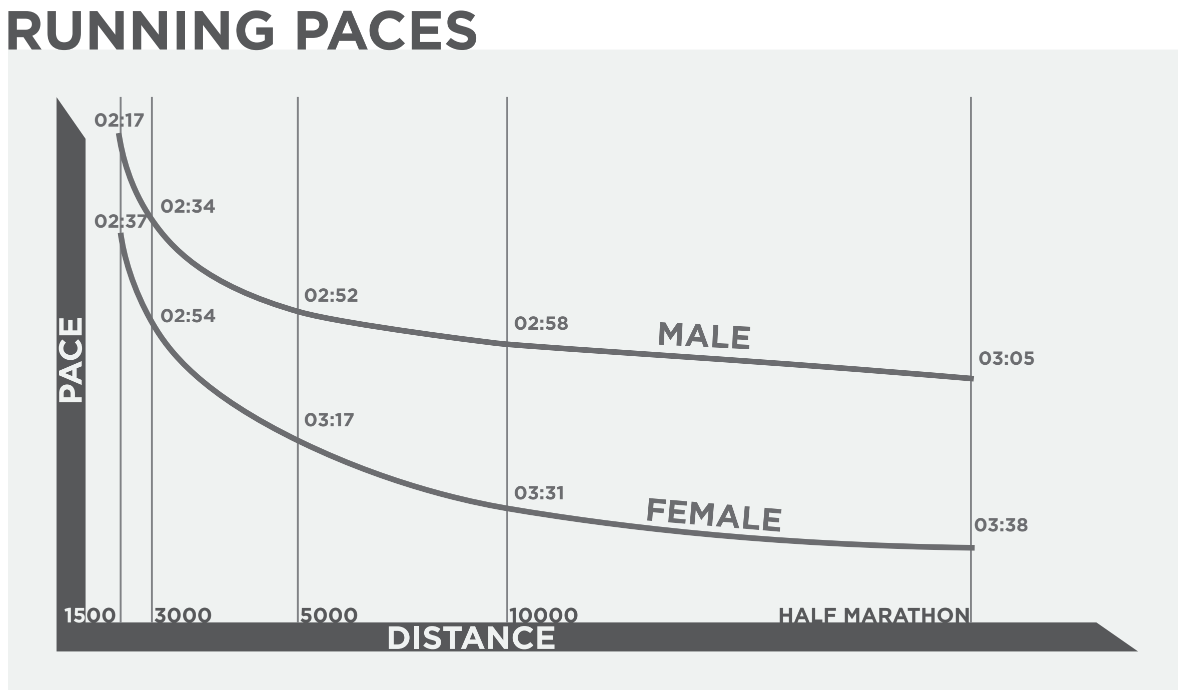


Figure 8.2 Graph showing the average pace [min/km] of the top three runners of several distances at the Swedish National championships 2015, -16 and -17. Data retrieved from official results lists.

77 percent of the runners answering to the survey reported having at least once used track spikes in cross country conditions. Instances of violation against the intended use of the shoe should be considered close to inevitable, as many will not purchase dedicated shoes for a type of race that is not one of their main events. Cross country running can, depending on the conditions, wreck a pair of shoes designed for the consistent and specific environment of the athletics track.

8.4 Running on a wet track

As seen in figure 8.1, a wet track increases the use of track spikes both during training and competition. Runners expressed that they held back when the track was wet, and that wearing spikes made them feel more confident and secure and allowing a more natural stride.

“You can always perform at your maximum - in any curve, any situation.”
- Interviewed long distance runner about using track spikes in wet conditions.

While modern tracks are designed to divert and drain water, they still become more slippery than when dry. In a pair of racing flats, that means the runner needs to adjust their technique so that the orisontal components of the force applied in each step does not exceed the point where they slip. This means lowering the speed, and it becomes extra noticeable when there is much acceleration, such as in the corners where there is radial acceleration from turning. It is during these conditions the benefit of using track spikes is most apparent, and any long distance spike shoe should therefore be well-equipped to handle exposure to water.

8.5 Mental boost from track spikes

Track spikes were for many runners associated with high performance. Both the routine of putting them on, and the way they felt on during the race were stated to contribute to a mental boost. While new and innovative technology and design elements can contribute to the mental boost if implemented in the right way, many of the interviewees expressed scepticism towards what they perceived to be gimmicks and too specialised designs. One of the most important aspects of the shoe in that regard was the weight and perceived lightness. The difference between those two aspects is important to consider, as was demonstrated when comparing the models purchased for the benchmarking. Runners preferred the New Balance LD5000 v5 over the Hoka One One Speed Evo R, often citing weight, even though both weighed around 125 grams per shoe. The former was perceived as lighter for other reasons than its actual weight, showing the importance of perception to convey the properties and feel that by association provide confidence in its performance.

"It's a nice feeling when you put the track spikes on, you feel that you are about to run fast"

"The feeling of being in shape, to be ready. Hopefully you are. You are ready to compete."

"Yes! Ooooh, yes!"
- Runners on the feeling of using spikes and whether they get a mental boost from them.

8.6 Reported injuries and implications

Development of a shoe should take into consideration both the desire for maximising performance but also injury prevention, which ultimately will affects the ability of the runner to perform. There should be a balance that allows great short term performance on the track, but also promotes sustainable use and training that allows the runner to stay uninjured and well-trained throughout their career.

From several of the interviews, stability of the ankle arose as one of the most important parts of injury prevention. It should be noted that all those interviewed who were knowledgeable in the field of sports medicine, including physiotherapists and orthopaedists, argued that supporting structures were necessary, and there was a consensus that many of the track shoes available on the market today are not stable enough for sustainable use. This perspective should be clarified in relation to the similar but different debate regarding recreational running shoes, where excessive correction and support have been criticised of overpromising in terms of injury prevention, interfering too much with the natural stride mechanics, and not being based on scientific evidence (Novacheck, 1998). Track spikes are in comparison extremely minimalistic, and when they are considered stable and cushioned, the levels are still lower than what is typical for a racing flat. The arguments against potentially excessive support structures in running shoes should not be applied to a shoe type that within its own reference frame suffer from the opposite condition, insufficient support. While there are plenty of running related injuries that in some way are affected by the shoe design and -use, only a few had direct implications for the design choices made in this project. The human body can in some ways be considered a mechanical system that is rather complex, and the motion dynamics of one part may influence many others directly or indirectly. Together with the anatomical variation displayed by runners few generalising conclusions can be made with certainty.

During interviews with runners, one of the first things coming mind when discussing physical consequences of track running, was stiff and sore calves. This condition was associated with running primarily on the forefoot, putting much strain on the calf muscles. Pain in the hip also came up specifically in connection to track running. Since both training and competition means running around in the same direction on the track - counterclockwise - the runners believed the left and right halves of the body experienced different loads, influencing where injuries were more or less likely. The banked indoor track curves were mentioned as a potential risk factor, as they are dimensioned for the speeds of a 200 m sprint according to the interviewed running coach, providing a possible explanation as to why some long distance runners experienced uneven muscle fatigue after longer sessions on banked tracks.

It was found that the causes are individual to the runner, as some got blisters in new shoes, some in old, some from using with socks, and some without socks. Poorly placed seems and ridges in the shoes were also frequently blamed. The varying causes seemingly tied to the specific anatomy and use of the individual runner, underlines the need for adjustment possibilities so that the best fit for a wide variety of foot types can be achieved. The long duration of races and the high forces involved in running with spike equipped track shoes makes this an important aspect to consider when designing a shoe for long distance running, compared to sprint shoes as well as the comparatively loose-fitting road racing shoes.

9 Desired characteristics and design principles

The fundamental goal the long distance track spike is maximised performance. While this might seem simple enough from a conceptual perspective, it has been shown in the preceding chapters detailing the fundamentals of track running, that there is a sustainability component to running that affects the long-term prospects of great and consistent performance. Therefore, the main goal was divided into three main components - running fast, efficiently and sustainably. These three components may at times result in contradictory requirements, creating the need for compromise in the shoe. However, they all need to be fulfilled to some extent for the runner to achieve the desired effect. In figure 9.1, the main design challenges of the project are organised in relation to the main goal of maximising performance and its components. Most the design features and properties of a track spike can be traced through one of the branches in the hierarchy below.

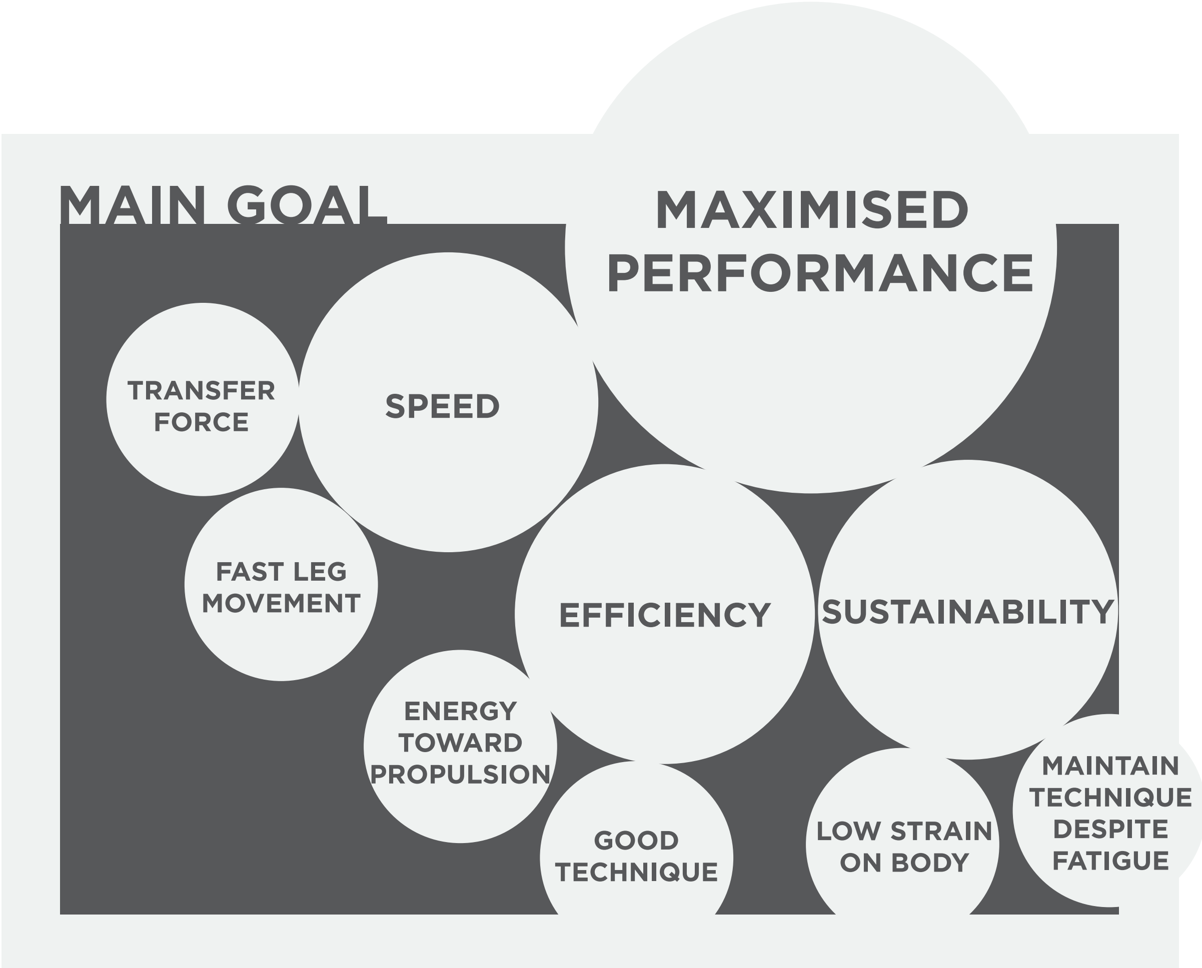


Figure 9.1 The main goal and its components. Shows the desired effect of the shoe and how it is achieved during use.

9.1 What a Salming track spike should be

Weighing the requests and needs identified through product and user research, as well as the expert interviews, and the profile of Salming as a brand, the following summary of the desired shoe properties and functionality was created. It constitutes the goal the constructive part of the design process should fulfill.

The shoe should be suited for several types of use, both competition and training, with support adequate for up to 10 000 m races. It should be light, but not at the expense of adequate durability and support, and have excellent grip with spikes mounted, but also without them. The shoe should be durable, so that it lasts throughout the season. Torsional rigidity should be prioritised, and it should have minimal cushioning while still providing a platform that adapts to the foot for efficient force transfer. It should have longitudinal rigidity that provides a spring action back into the stride propelling the runner, and it should grip the foot and hold it securely, adapting to the shape of the foot to accommodate a wide variety of foot types. It should feel fast and light, like it was built to win races.

9.2 Sizing and unisex

The shoe should be a unisex model, as the small differences in anatomy do not merit the cost of producing two models. Important to consider when making unisex model is clarity when it comes to sizing; for regular shoes, a size 9 may not of same length and width in female and male models. Shoes are recommended to be chosen based on length rather than sizes, which Salming today marks clearly in their shoes. The interval of Salmings sizing today is 5 mm intervals, which is suitable for a track spike as well.

9.3 Weight

Weightwise, the shoe should be comparable to other long distance track spikes. While several runners expressed that the feeling was more important than the actual weight, it is reasonable to assume that there is a certain amount of correlation between these two properties. The performance benefit of lower weight when running is also supported by research (Divert, 2008). It can be argued to have psychological benefits as well, knowing the shoe is light could influence confidence before a race, a notion that was heavily implied during interviews with runners.

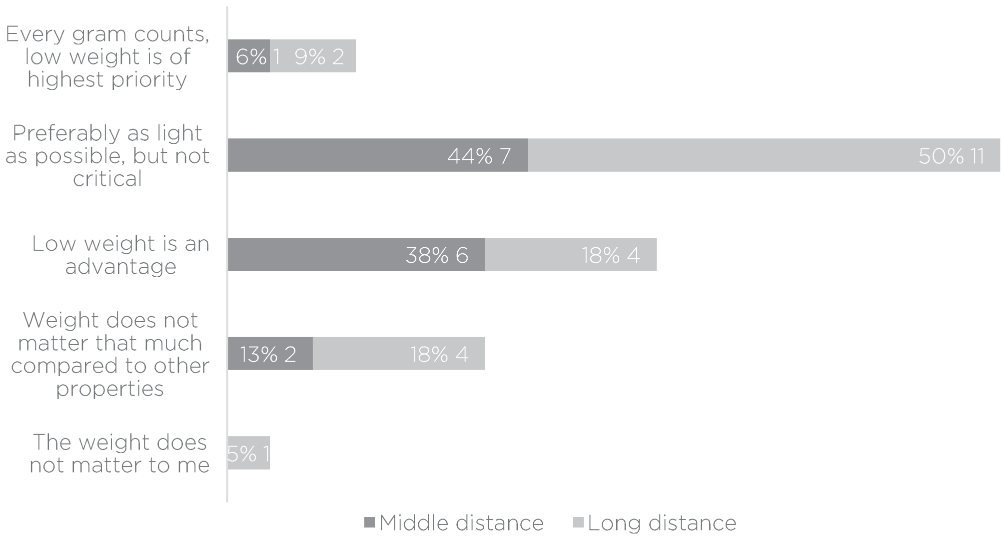


Figure 9.2 Attitudes toward weight of track spikes. From survey.

"It is very psychological I guess. It feels good, a feeling of lightness and you get better grip."
- Long distance runner about the differences between spikes and regular running shoes.

Both *feel light* and *low-weight* topped the list of desired properties from the compiled answers of the survey, figure 9.3, further emphasising the importance of these aspects. It seems that lightness in both these regards, should be defining characteristics of a track spike, second only to the presence of spikes. In the benchmarking process, it was noted that low weight was emphasised in marketing material, givung the impression that the manufacturers with every new iteration make significant efforts to shave off a few grams. The large emphasis on weight was questioned by most interviewed experts and runners, often expressing that contrary to the current approach by many shoe makers, manufacturers should prioritise it less as other important properties are compromised. It was also found that long distance runners prioritised weight slightly less than middle distance runners, at least when prioritising between the properties low weight, stability, and durability.

"It could easily be slightly, slightly heavier, if it then becomes a little more stable. That's how I feel. How light can a track spike become before you start taking too much damage?"
- Interviewed runner expressing doubt about the current prioritisation in track spike properties.

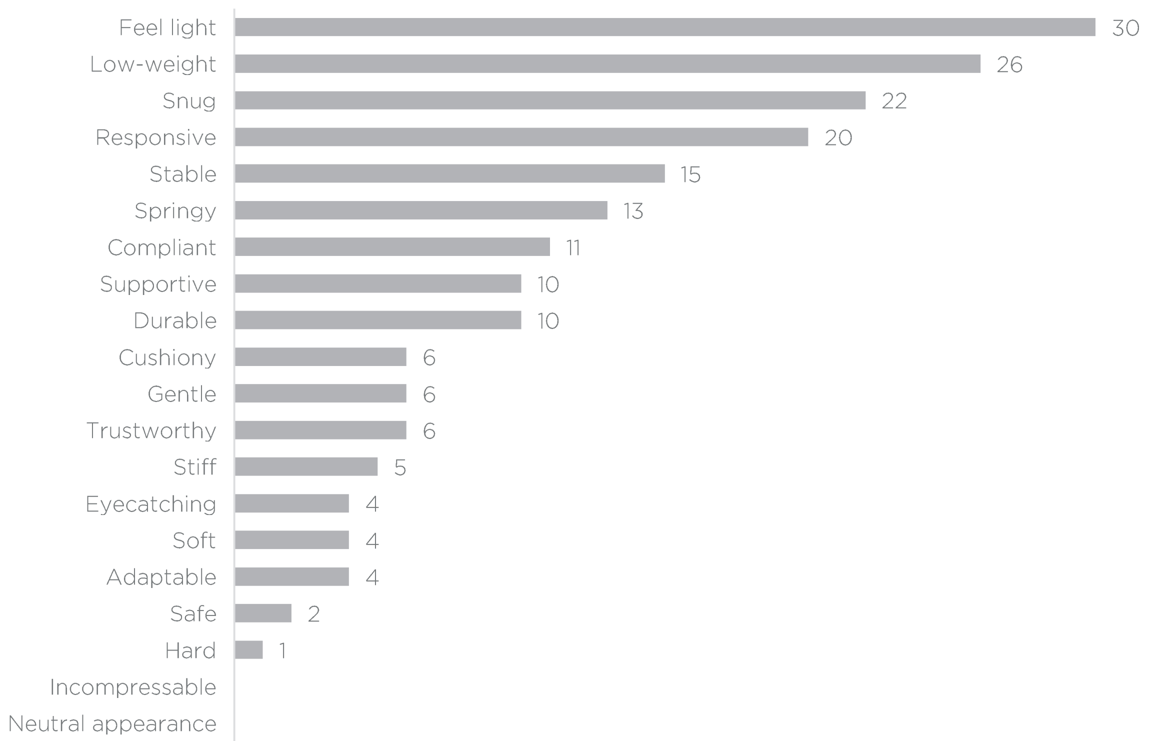


Figure 9.3 Distribution of desired properties in a track spike chosen from a list of words provided in the survey. Five choices per responder.

So, what is a reasonable weight for a track spike? Comparable models identified in the benchmark lay in the span 100 g to 150 g per shoe, and that provides a basic idea of what is reasonable. It would not be acceptable to be significantly heavier than the shoes in this market segment. Weight can be viewed as a currency, the more supporting structures you want the more it is going to cost. Establishing the weight budget was an approximation based on several factors, which should take into consideration that it would be a first generation shoe from a company who have not made track spikes before. There might be a need fore some extra overhead to ensure a sound construction. Given the desired properties outlined later in this chapter, a shoe in the weight range 150 to 160 grams is our suggested target. Now, what can be bought for those grams?

9.4 Support

Lack of support for the heel was a frequent complaint, both from long distance runners and other interview participants knowledgeable in running dynamics. Lacking supporting structures has been determined to be the result of removing material from the shoes to make them lighter, and omitting construction elements such as the heel counter. The shoe should prioritise stability in the heel, as long distance runners will plant it, relying quite heavily on heel support toward the end of long races. As seen in figure 9.4, stability was prioritised slightly lower than low weight, but more than durability, and that does not reflect the perceived prioritisation in the long distance track spikes available on the market. It was also the fifth highest ranked property among the twenty selected for the survey, figure 10.3, and on a scale from neutral to supportive the answers were centred around the middle, again choosing a level of support that appeared to be lacking in many long distance track spikes on the market.

Figure 9.4 Distribution of survey respondents choosing from five discrete levels between the properties neutral and supportive.

In addition to heel stability, the shoe should provide sufficient torsional rigidity. Speaking to an expert in sports related biomechanics, torsional rigidity in the shoe emerged as highly important. The typically thin midsoles of track spikes provide little torsional rigidity, often too little to meet the needs of runners, and thus needs to be complemented with other construction elements. The torsional rigidity of a shoe helps create overall stability, but primarily for the heel, limiting eversion/inversion across the foot (Morio et al., 2009). There is evidence suggesting that pronation increases when a runner becomes fatigued, as those changes are seen in runners who participated in long distance trials (Schlee et al., 2009; Escamilla-Martínez et al. 2013). This further supports the need for torsion rigidity in long distance shoes. This was described by runners during the interviews as well, describing “falling inward” or failing to hold the foot upright when getting tired. However, many runners also requested that a shoe should be soft and flexible, showing the difficulties of meeting requests as they appear to lie on opposite ends of the spectrum. The level of rigidity or stiffness associated with full coverage spike plates was too much for some runners’ liking.

9.5 Cushioning

The amount cushioning should be low. Some amount will help distribute forces and create a dynamic platform for pushing off, and it helps the runner upon landing as a portion of the impact can be absorbed, reducing the amount of work required by the foot to absorb the shock. However, track runners are well trained to perform that function, reducing the need for cushioning which additionally can steal energy from propulsion. The forefoot landing technique of track runners utilises a natural and slower absorption of the impact (Romanov et al., 2014), which limits the need for midsole cushioning material. This notion was shared by the interviewed experts. Ultimatley there is some need for cushioning, but it should be kept minimal.

9.6 Elastic rebound

The shoe should feel and act like a spring; the ability to provide elastic flex along the length of the sole. This can provide a small amount of energy return. It is noticeable to the runner as the shoe feels more responsive, a property that ranked fourth in list of desired attributes, as seen in figure 9.3. This could be beneficial to the runner both from a motion dynamics standpoint, but also psychologically. Much of the dynamic rebound comes from the body itself, by elastically absorbing and releasing energy from landing, detailed in the *Running dynamics* chapter. A shoe that manages to provide a small sensation of energy return could potentially reinforce the utilisation of such mechanisms. Efforts should be made to make sure the return action is timed to the body's natural elastic energy return. Given the difference in ankle joint angles between high- and low arched feet throughout the contact phase (Powell et al., 2014), differences in timing could potentially be significant to the function and choosing optimal mechanical properties of the material.

9.7 Fit and feel

Users preferred an extremely snug fit compared to other shoes. The shoe should be tight, but adaptive to the shape of the foot, not the other way around. For practical reasons, most track spikes are unisex, which would be reasonable for a Salming spike as well. It potentially increases the need for adaptability to a wider range of dimensions, both across the range of sizes and also each individual size. Snug was the third most desired attribute for a long distance track spike, just behind *feel light* and *low-weight*. Compliant also ranked high, but it should be noted that the translated word from the survey, and frequently mentioned as a desired attribute in interviews, was *följsam*. While compliant perhaps is the closest translation, the Swedish word implies following the shape and motion of the foot more dynamically than reflected by the meaning of *compliant*. Sock-like feel was also frequently used to convey a similar notion, although that does not accurately reflect the level of tightness required to hold the foot in place when running in track spikes. As the shoe is often worn without a sock, efforts should be made to limit abrasion against the skin. This is not only for comfort, but important to mitigate formation of blisters which, if severe, may affect performance and ability to train. The shoe should also feel responsive, nimble and light.

9.8 Grip

A defining property of a track spike, grip, may be achieved in several ways. The grip between the track and the shoe should be instantaneous and reliable. This grip should exclusively restrict movement the horizontal plane, so that planting and rolling off can be done without resistance. The spikes available are designed to not stick as they are pulled out of the track, and the same should be the case for other gripping geometries that are part of the plate. A spike plate should be manufactured in a flexible, tough, and light material. It also serves the purpose of anchoring the spikes and distributing their loads, as well as providing additional traction. While instantaneous grip should come from the spikes themselves, the plate geometry should provide traction too. That distributes the forces across the forefoot even more, and creates redundancy. The heel section of the track spikes sometimes lack traction. It is true that most grip should be at the forefoot, but there are situations when the heel requires grip as well. In steeplechase, the runners jump over barriers in crowded conditions, creating situations where they might land on the heel. While the underside of the heel should have material to provide support and protect the midsole, there might as well be gripping geometries placed there to make the shoe attractive to more runners. The placement of grip should primarily be under the ball of the foot, avoiding point loads to far behind the metatarsal heads, where they may cause discomfort and do harm according to the interviewed running coach and a physiotherapist. The need of traction is lower at the longer distances due to the lower speeds, but they still improve performance for most runners according to the interviews. In special conditions, such as rain, they were described as a necessity for all track distances. Some runners reported losing spikes, along the track, meaning there is a need for redundancy in traction. This especially affects steeplechase runners, who have a higher need for traction when planting the shoe on the obstacles.

"It makes sense to make sure that when you run steeplechase, the spikes are placed so that you get grip on the obstacle."

"If you lose it, what do you do then? When you land, it feels secure because you have instant grip. Knowing that makes it possible to run more relaxed and focus on what you have to do."
- Long distance runners on the benefit of confidence in their grip.

The guidelines listed below focus on properties identified to be of importance in relation to current track spike design conventions, such as when there is misalignment between user priorities and typical properties, and properties of importance relative to slower shoes such as racing flats. An overview of goals, requirements, and guidelines can be found in *Appendix E.*

- *The shoe should have low weight.*
- *The shoe should not retain moisture.*
- *The shoe should provide heel support.*
- *The shoe should provide torsional rigidity across the midfoot.*
- *Cushioning should be minimal.*
- *Energy input should propel the runner.*
- *The shoe should provide a sensation of elastic rebound.*
- *The foot should be held more securely than in other running shoes.*
- *The fit should be tight.*
- *The shoe should adapt to the shape of the foot.*
- *The shoe should grip the heel securely.*
- *The shoe should allow the forefoot to expand on impact.*
- *Bacterial growth should be limited.*
- *Inner surfaces of the shoe should limit skin abrasion.*
- *The shoe should provide instantaneous grip under the forefoot.*
- *The shoe should provide traction redundancy compared to a typical four-spike configuration.*
- *The shoe should not inhibit the natural elastic rebound of the body.*
- *The shoe should be built to last an entire season cycle of use.*
- *The shoe should be perceived as fast, light, and performance-enhancing.*

10 Salming track concept

Below is a summary of the final concept, outlining important design elements and functions of a long distance track spike. The concept shoe acts as a vessel guiding us through different design elements and features, not only detailing the chosen solution, but also a wider solution space with alternative design options.

The concept is a light, fast and stable unisex long distance shoe, featuring a two-part spike plate holding five replaceable spikes under the forefoot.

Figure 10.1 Collage of the concept shoe.

The following division of functions and parts describe the concept in further detail. Each topic corresponds to a chapter in the results, where each design element is explained in relation to the function it serves, the reasoning behind the design choices, and other possible design outcomes. They are, in order of appearance:

Aesthetic profile
Appearance and expression of the shoe in its entirety.

Upper
The main fabric of the shoe, responsible for many of its functions, such as breathability, holding the foot in place, conforming to the foot etc.

Lacing system
Provides adjustment of tension and fit. Includes laces, eyelets and the tongue which distributes forces

Heel section
Consists of several elements working together to grip the heel of the runner and provides stability in the stride.

Midsole
Structural element making up the base of the shoe, defining the shape of the footprint and the load bearing surface under the foot.

Footbed
Provides a force-mediating layer between the foots irregular shape and the midsole, increasing fit, support, comfort, and distributes loads.

Spike plate
Provides a mounting platform for the spikes and adds traction through its shape. Provides elastic rebound and torsional rigidity to the shoe and grip at the heel.

Spikes
The defining characteristic of track spikes, providing grip in all track conditions.

Accessories
Additional features to complement the shoe, such as a spike wrench, transport bag, and care instructions.

11 Aesthetic profile

Compared to other types of shoes, the general shape of the track spike is to a greater extent defined by the shape of the foot, limiting the freedom of design. Instead, the functional elements of the shoe define its form, and that can be used to the shoes advantage. Removing material in the midsection of the sole, for example, not only makes the shoe lighter, it also contributes to the light expression of the shoe. The minimalistic and revealing design creates a shoe that shows its own properties. The element with the most freedom of form is the spike plate, and that was exploited in this design. The recurring pattern was developed to express traction, with sharp angles and facets, resembeling a hard crystal whose orners can dig into the track surface. The geometries were inspired by deltahedron, which can be altered into different patterns and shapes without straying too far from the core expression. The pattern was translated into a two dimensional four-sided shape, a quadrilateral, which is present in Salming's logotype also featured on the side of the left shoe and the back of the heel sections. The shape appears in the ventilation holes, where an elongated variant is used.

While the ventilation holes show some of the interior of the shoe, or the foot inside, so does the fabric of the upper. The upper fabric is partially see-through due to the structure of the mesh, exposing the reinforcements behind it. This may contribute to the runners' confidence in the shoe, that it will last through the abuse of both training and races.

The shoe uses two existing logos of Salming, putting them prominently on display during competitions and anytime they are used. The use of the logotype matches the style of other products from Salming, making it instantly recognisable. The combination of the logotype and the, at the time of writing, newly launched logo with more ideographic and pictographic elements, creates a product that helps create a connection between the new logo and the Salming brand. The logos can also be seen on the heel section and on the exposed bottom part of the EVA midsole, between the twoo spike plate sections. To be consistent with other shoes from Salming, a Swedish flag is placed on the tongue where the laces are held in place over the tongue.

The primary colour of the shoe is a red with slight weight toward the orange side of the spectrum. It was chosen to stand out in competition events and works well with the high performance expression of the shoe. As the shoe is worn, the red and white of the fabrics are clearly visible, but between the midsole and the track there is a hint of dark blue as the thin spike plate is apparent from the side. As the runner begins to move, the bottom of the shoe is exposed, revealing the spike plate, shifting the colour balance of the shoe. The colours of the shoe are a cosmetic feature which changes from season to season, but generally, effort should go towards choosing colours that work well with the sportswear collection the runners use. Using a set of primary colours, or staying close to them, allows runners to mix and match slightly more without creating a mismatch, as the primary colours are more forgiving compared to otherwise visually striking options.

12 Upper

In addition to being the construction element largely responsible for containing the foot, the upper contributes to the expression of the shoe. It is clearly visible, making the upper a suitable place for brand communication. Together with the lacing system, the upper is tightened around the foot, holding it securely. Due to the snug fit in combination barefoot use, the material of the upper is more important to consider than in other shoes, in order to limit and abrasion against the skin. Below follows an in depth description of how to achieve the desired properties of the upper, followed by how that manifests in the final design concept.

12.1 Achieving a good fit

The upper works together with the sole to create a tight fit, which was found to be especially important to get right across toe box. The lack of adjustability combined with the delicate balance between tightness and a need for forefoot expansion space make it hard to find the dimensions that suits a majority runners. Somehow, the shoe should conform to the shape of the foot. To achieve this, the fabric of the upper should have a certain amount of stretch. This would allow greater individual differences between the runners, making the shoe more forgiving and adaptable compared to a less stretchy fabric. Additionally, creating a tight fit using stretch distributes pressure more evenly, reducing the risk of point loads causing discomfort. Stretch may be achieved from the composition of the materials used, such as incorporating elastic fibers, the structure of the fibers, and the pattern of the fabric. The need for stretch varies across different areas of the upper, and overdooing it was found to be important as well. Allowing too much movement back and forth the upper could cause abrasion between the footbed and the foot, a place where runners reported they sometimes developed blisters. It could also compromise the secure hold of the foot and make the shoes unstable when much force is transferred. The amount of side-to-side stretch in the upper fabric, as measured across the forefoot, differed between the benchmarked models. The Hoka On One, which was experienced as stiff, stretched about 7 percent and the Nike and New Balance both around 16 percent. The latter value should be considered a target amount, the runners who tried them had no complaints about the stretch and it was found to be fully adequate to achieve a snug, adaptable, and secure hold.

12.2 Fabric

The choice of fabric in the upper defines the expression and properties. Two options were found to best suit this application, either a uniform fabric that could be die cut to the correct shape. Such a fabric would need to have small holes in its woven or knitted structure, allowing water and heat to escape. The elasticity would have to be evaluated to work well both side to side as well as along the length of the shoe. While two different levels of elasticity can be achieved in two perpendicular directions of the fabric, further variation in stretch in specific areas is not possible. Such specific distribution of elasticity is possible with a fabric that is knitted with a non-uniform pattern. Such specialised upper fabric could provide the same properties as the first option, and incorporate larger ventilation holes and other irregular patterns in the fabric knit. One such technology is 4D knitting (Motawi, 2017), but the whole family of custom piece by piece knitting techniques should be considered. For a shoe with small manufacturing volumes, this technology could be suitable despite the advanced technology perhaps discouraging the expense aware. After a pattern has been designed, the cost of production has a more linear relation to the number of units produced compared to the investment cost of tools for die cutting. A non-uniform pattern could allow an upper that feels more carefully designed and dedicated towards the desired functions and expression.

12.3 Toe box

The three shoe models tested by users showed that there were large differences in the space available for the toes, despite similar width and shape of the sole. Since the toes extend beyond the side edges of their support platform, i.e. the sole, the length of the fabric over the forefoot may constrict the width. Therefore, the combined width of the sole and the width of the upper fabric, i.e. ball girth if measured around the forefoot at the first and fifth metatarsal, needs to be of sufficient length. So, a tight fit is wanted, but not an overly restricted and compressed forefoot. In support of this notion, it has been shown that adequate room for toe expansion is of importance for a natural foot motion and that the foot spreads wider with a hard sole (Morio et al., 2009).

"I think it's important with some space for the toes, so that they can do some work and push. Then I want them to be super tight over the dorsum, that is really important"

As exemplified by one of the runners, most of the interviewees wanted a tight fit close following the shape of the foot, but still allowing the toes space to expand. Space between the foot and the upper was negatively experienced during user tests with Hoka One One Speed Evo R; the rigid fabric did not wrap the foot and was likened to a tent, creating discomfort and annoyance.

The tight fit around the toes and the often thin fabrics in the upper was determined to increase the risk of structural failure along the toe line of the upper and where it meets the midsole. Tearing in these areas was mentioned as the node of failure by several runners, potentially ruining a race if the timing were to be poor. Therefore, the front of the toe box should be reinforced, which also would help support and define its shape while no foot is present to do the job. This reinforcement was not present in the Nike model, and it was accused of breaking there frequently by those who had experience with it, often within only a couple of uses. Reinforcements are preferably placed on the inside of the shoe if possible, keeping the visual expression of the shoe clean. An effort should be made to match the colour of the upper, as the fabric of the upper might have some transparency, making the reinforcement slightly visible. The material should be synthetic, a woven polyester laminated to the upper material would work well. Woven polyester limits abrasion and it can handle sweat and moisture produced by the feet during running. This was preferred over the commonly used TPU plastic film, which become slippery in contact with water and thus would need to be placed on the outside, compromising the clean look of the shoe.

12.4 Ball girth

The ball girth is the circumference at the metatarsal heads, and the implied measurement for the shoe as shown in figure 12.1. The term may apply to the foot, last, or inner measurement of the shoe, and the elastic properties makes it even more unclear as it then changes depending on the foot. In the following section, it is the inner shoe measurement with the fabric of the upper being relaxed.

Given the proposed width of the shoe - at 33 percent of the inner length, detailed in the chapter *Midsole* - the upper should have a relaxed inner measurement that corresponds to a total ball girth of 84 percent of the length. This entails that the relaxed upper should measure 50 percent of the length of the shoe from where it attaches to the midsole by the first and fifth metatarsal heads. These proportions should, together with the proposed shape produce a tight shoe whose upper wraps the foot, but allow some forefoot expansion during the contact phase of the stride. It should be noted that the round numbers of the proportions are coincidental, and should not be interpreted as the result of rough approximations and round-offs. These proportions were determined by measuring the dimensions of the benchmark shoes and a size range of a racing flat model, the Salming Race 6. For a shoe so close to the lower limit of the dimensions, pushing the limits slightly may prove to be too far for many feet. The Nike shoe was found to be too tight across the forefoot while the Hoka One One was too loose. The New Balance on the other hand - or perhaps foot - hit the sweet spot in the middle of three spike shoe models. Both the measured and proposed dimensions are shown in figure 12.2.

As the shoe is used, there is a possibility that the fabric loses some of its elasticity. However, that is likely to happen in such a way that the shoe adjusts to the shape of the foot, creating a better fit than when it was brand new.

Figure 12.1 Ball girth.

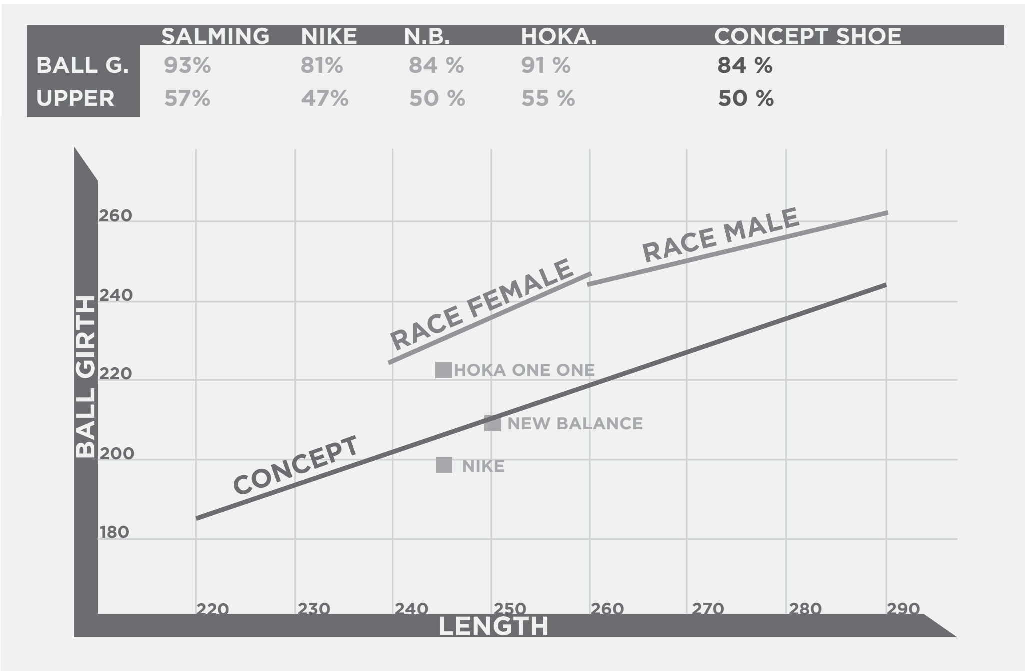


Figure 12.2 Ball girth of concept in relation to benchmarked shoes and Salming Race 6.

12.5 Reinforcements in the upper

In addition to the toe box reinforcement fabric, the mid-section of shoe should have an internal backing- and reinforcement fabric on the inside, as shown in figure 12.3. This serves several purposes, the first being additional strength to containing the foot across the mid section of the shoe. Secondly, it distributes the forces from the lacing system better than through the upper fabric alone. Lastly, as this reinforcement extends backward, it aids in achieving a firm heel grip, which is detailed further in the chapter *Heel section*. The shape of the reinforcement was designed to distribute tension with a small amount of material. This solution, and similar variants, can be found in many shoe models from different segments, such as in some of Salming's own models. Whether to put this reinforcement on the inside or the outside was discussed. Having it outside of the upper could create a visually interesting feature, but we ultimately determined we preferred the hidden placement leading to a cleaner design. The slight transparency in the upper fabric still makes the support structure visible, but not as prominently. Depending on the contrast in the fabrics used, the feature may be displayed more or less explicitly. The material of the reinforcement should be a spun polyester suede. The material is strong and tear resistant, will not fray, and works well against the skin if there is ventilation around it. It can possibly be combined with a woven backing fabric for additional strength if necessary, while reamaining very thin. It should be made out of the same piece as the cutout reinforcement detailed in *Lacing system* to avoid unnecessary seams. Apart from the laminated structure around the edge of the cutout and where it attaches to midsole, the reinforcement should be free, i.e. not be attached to the sides of the upper. This allows the upper to stretch and cover the sided without restriction.

Figure 12.3 Upper reinforcements..

12.6 Ventilation in the upper

During intense physical activities, to which running certainly qualifies, perspiration needs to be considered. To allow moisture and heat to escape the shoe, ventilation holes should be plentiful. While the upper material will be thin, allowing moisture to escape, there should also be larger ventilation holes.

A modern knitting technique would allow the holes to be incorporated directly into the fabric structure, meaning they ay be placed in the specific areas where ventilation is more important. This solution provides more control of the stretch as the holes allow the fabric to deform in specific directions depending on how they are oriented. This added control can increase the fit of the shoe, which is especially important when it comes to the width at the forefoot. Ventilation should be implemented on the top of the toe box as well as on the side of the upper. These larger holes allow faster drainage of water in excessively wet conditions such as during heavy rain and when encountering water obstacles during steeplechase. An alternative would be to rely on the thin fabric and uniformly distributed holes, which would be the case if die cutting the uppers from a uniform fabric. Larger holes could be added through punching but would require backing support to avoid fraying and tearing. This limits the possibility to use such holes to control the amount of stretch, making it the inferior solution on a functional level. The concept proposal utilises modern knitting technique to allow custom placement of the holes, adding to the feeling of a dedicated and well-thought out design for its highly specialised purpose. The holes will be placed at the top of the forefoot and on the sides, seen in figure 12.4.

Figure 12.4 Ventilation holes in the upper.

12.7 Strobel construction

Due to the edges present on the spike plate and the thin midsole, a strobel construction was deemed suitable for the shoe. The strobel, a thin sheet between the footbed and the midsole, may be omitted from light sport shoes, instead having the upper fold in under the foot and being glued directly to the midsole. The strobel construction, where the upper is stitched to the strobel before the whole package is attached to the midsole, makes the platform for the footbed and the foot more rigid, creating a stable platform for the ground contact phase of the stride. This feature suits the requirements of track spike well, motivating the addition of this component.

13 Lacing system

The lacing system is of high importance in a track spike, as the shoes are laced tightly to secure the foot. There is no relative movement between the track and the shoe once planted, so the lacing system and the upper does all the work handling the forces. Gliding in the shoe should be limited to an absolute minimum to allow effective force transfer. Apart from the horisontal forces that needs to be contained, there is the function of keeping the foot inside the shoe, which is done not only by tightening downward along the upper, but also by pulling on the heel section of the shoe. While there are other lacing systems than the conventional lace and eyelet, their benefit in a track spike is doubtful. A simple system is suggested, which allows the runner to secure the shoe tightly and at the same time allowing adjustment in the pressure distribution across the dorsum of the foot.

13.1 Eyelets

The main eyelets for the lacing system consists of six pairs of perforations through the upper around the edge of the cutout with an additional grouping toward the back. The edge around the top cutout is reinforced with a tough tear-resistant material which can be in contact with the skin without causing discomfort. A spun polyester fabric would be suitable for this application. This solution is elegant, as there are few components, and gives the shoe a clean, uncluttered and light expression. No nonsense.

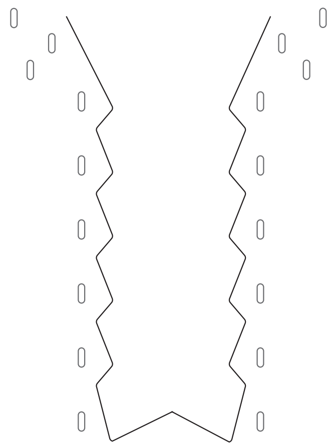


Figure 13.1. Perforation pattern.

The eyelets should be punched from the laminated rim around the cutout over the dorsum. The holes should match the cross section of the laces, detailed later in the chapter, and allow the them to run across the foot neatly without twisting the lace. Due to the laminated construction, there is no need to treat the raw edges of the holes. The ritual of tying the shoes should not be overlooked when it comes to the design, it should be a simple lacing system that does not require fidgeting with small components such externally mounted eyelets. This simple design is in our opinion both satisfactory to use as well as functional thanks to the tightness thant can be achieved, the ease with which it self-adjusts, and the smooth gliding movement of the lace through the perforations.

Creating adequate tension toward the heel section can be accomplished in several ways. We suggest extending the reinforcement around the dorsum cutout toward the back, attaching to the midsole by the heel counter on both sides of the shoe. While that reinforcement band pulls on the bottom part of the heel section, there is also a need to have horizontal tension toward the back. Those mechanics are detailed in the chapter about the heel section. To allow detailed adjustment of the tension toward the back, at least one extra eyelet pair should be added to the main six. This allows runners to utilise special lacing techniques such as the heel lock. While the conventional design often sports this extra eyelet, a small array of them might as well be added, allowing larger customisation in a shoe with extraordinary requirements for the fit. This could be especially important considering the wide variety of foot types included in the intended users of a unisex track spike.

13.2 Laces

In the spirit of a light expression, an unpadded, flat lace was chosen. A flat lace distributes pressure better than a thin round lace, which at the tight tensions necessary for a track spike could cause discomfort. Pressure across the dorsum of the foot and tight lacing is in running shoes associated with discomfort, but also better performance and running technique, and has subsequently been suggested to lower the risk of injury (Hagen, et al., 2009; 2010). However, compared to recreational runners, track runners seem to have little issue tightlacing their feet as if they were Victorian era waistlines; no pain, no gain. As the foot morphs somewhat in different parts of the stride, such as the raising of the arch on push-off or the widening of the forefoot when under load during ground contact, there needs to be some give in the structure to avoid sudden bottoming which can be painful. A little bit of flexibility can be built into the lacing system by having a lace that stretches. This was observed in the laces of both New Balance and Hoka One One benchmarking models. They were measured to bottom out at about 25 percent elongation, which felt like a reasonable amount both to us and those who participated in user tests and interviews. With stretch, the pressure distribution becomes more dynamic and point loads across the dorsum can be curbed. It also makes the knot more resilient to spontaneous unravelling compared to an entirely rigid lace. It adds internal tension to the knot, and if there is a small amount of slipping, the tension is retained instead of instantly disappearing. Shoelace knots tend to unravel in just a few steps after the initial knot-slip, which can be caused by the 7 g acceleration the free ends of the lace may experience during running (Daily-Diamond et al., 2017). This is a simple solution to avoid untimely unravelling at important moments, such as in the case of John Kagwe, who managed to win the 1997 New York City Marathon despite the right shoe untying itself three times during the race (Jackson, 2000). Suitable dimensions for the lace are 4-5 mm in width and 2 mm in thickness. Aglets should be about 18 mm long, which is common in other running shoes. One runner mentioned that they tuck their loose lace ends which is made easier with the aid of the aglets.

Figure 13.2 Laces with white aglets.

13.3 Tongue

The tongue mediates the pressure exerted across the dorsum of the foot and limits abrasion from the laces which may otherwise cut into the foot. An alternative to the conventional tongue is to have monosock design, where the sides of the dorsum cover transitions to the sides of the upper without interruption like, well, a sock. This was investigated as a possible solution as it may avoid seams or edges that otherwise are in contact with the dorsum of the foot. It is also a literal interpretation of the request that a track spike should have a sock-like fit and feel, which was made by several runners. However, it was found to be difficult to manufacture without adding more fabric layers, and the survey showed little support for the idea, see figure 13.3.

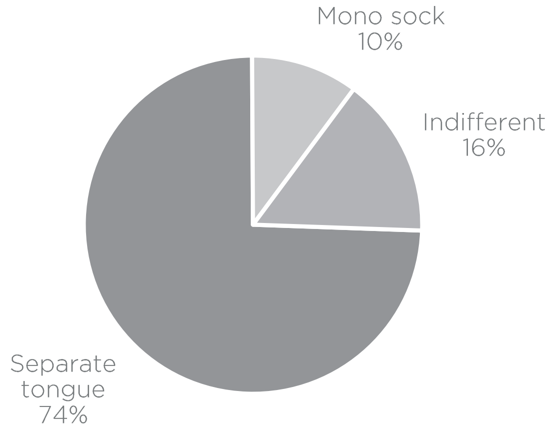


Figure 13.3 Preferred dorsum cover solutions among survey responders.

Instead, we propose a conventional design. A thin two-layer tongue, with a foam insert in the shape of the four sided prism that appears in several design elements across the shoe. This extra padding across the top ridge of the dorsum creates relief as it is the place where laces applies the most pressure. The laminated fabric should have perforations to allow heat and perspiration to escape. Much like with the perforated eyelets, the edges of these holes will not fray. The double layer construction was chosen so that no seams or edges would be present across the top of the dorsum. Due to the tightness of the lacing compared to other running shoes, extra consideration to limit abrasion was found to be necessary. The tongue needs to extend far enough at the top to allow pulling and adjustment of its position by the runner. From discussions with runners and user tests, it became clear that some have a desire to align the tongue neatly before using the shoes. On New Balance LD 5000 v5 that was benchmarked, aligning the tongue was impossible for some as one side was stitched to the upper, causing it to end up off-centre relative to the dorsum of the foot. This was frustrating to the runner, and us, the observers, much like noticing a crookedly hung painting without being able to level it. The runner should have full control to place the tongue to their liking and according to their anatomy. Attaching the tongue to the upper at the front of the cutout should be done conventionally with stitches, which due to the shape of the cutout are partially covered by the lower lacing. Exposed stitches in this area are not as problematic regarding abrasion against the foot, as there is significantly less pressure over this part thanks to the less acute curvature over the forefoot. The tongue in the design proposal features a flag-equipped loop through which the laces can run through to roughly position the tongue.

14 Heel section

A secure fit of the shoe is dependent on a heel section that grips the heel of the runner well, more than recreational running shoes and racing flats. Without a proper and tight fit around the heel, the runner is at risk of stepping out of the shoe; the moment the heel slips there is nothing containing the foot at the back of the shoe. The high propulsive forces in track spike running and the instantaneous grip they create contributes to the increased need for a secure fit. The firm grip of the heel was heavily emphasized during one of the interviews with an expert on running biomechanics, and corroborated by the testimonies of several runners who explicitly expressed that they wanted a firm grip of the heel and limited movement between the foot and the shoe. This could potentially limits abrasion and lower the risk of chafe around the heel.

14.1 Heel counter

Conventionally, the heel is held with the aid of a heel counter and foam padding which provides adaptability to different heel shapes. This solution is not well-suited in a track spike due to the limited grip it can provide. The heel counter does not adjust well to the shape of the heel, which varies from person to person, and with the tightness required in a track spike its edges might be noticeable to the runner, and risks agitating the achilles tendon. Several track spikes do away with the heel counter, saving weight in the process, and relies instead on other, more flexible reinforcements to provide rigidity around the heel. They typically rely on tension from the heel cap toward the front of the shoe to hold the heel, with fabric at the back adjusting to the shape of the heel and achilles tendon.

Another function of the heel counter is to hold the foot in place relative to the midsole, which is especially important for longer races when fatigue may cause heavier reliance on heel support structures as the stride shifts towards heavier heel striking. Reinforcing the heel does not necessarily have to be done with a heel counter, other layers of rigid fabrics or sheets can be used, such as TPU film. One of the difficulties of having a thin heel section with a trimmed heel counter is smoothing out the edges so that they do not cause discomfort. This can be achieved with reinforcements as well, making the case for a hybrid heel section with a combination of several elements, such as a rigid counter, film reinforcements, padding, or stretchy fabric.

To create a heel section that both has an adaptable and secure fit, as well as providing adequate heel stability, several alternative shapes of the heel counter were explored. An adaptable geometry can be achieved in sevral ways, as shown in figure 14.1.

Figure 14.1 A set of heel counter options that have a more adaptable shape.

The main issue they aim to solve is the fact that the curvature of the conventional heel counter causes constrained deformation; when the back is pulled forward it becomes wider, and making it more narrow, it extends backward. This issue was present in the Hoka One One model that was benchmarked and tested, and it was the shoe with the worst fit of the tested shoes. While the New Balance and Nike models lacked the heel counter, they were not without issues when it came to fit. For some they adjusted satisfactory to the foot, but the lack of flexibility and rigidness in the lower part of the heel cap caused them to wrinkle and collapse with certain foot shapes, as shown in figure 7.6.

The concepts that extends upward - one to four in figure 14.1 - are suited to be combined with padding, which should be thinner than in conventional shoes to allow a more secure fit. They would provide backing to the padding and can adapt more freely to the shape of the heel than a conventional heel counter. Concepts five and six focus on stabilising the lower section of the heel, and are more suited to be combined with a stretchy heel cap that wraps the heel.

One reason to omit the heel counter or choosing a minimalistic design is the weight it would add to the shoe. However, for heel striking runners, a heel cup reduced VO2 max with 2.4 percent (Jørgensen, 1990), indicating that the stability it provides improves the technique of the runner. Again, this would be beneficial in longer races when heel striking is more prevalent. The need for stability was found to be larger than what is typically present in many currently available long distance track spikes. It was expressed in several interviews with both runners and orthopaedists, and the survey results indicated that long distance runners prioritised it about equally to durability and low weight, as seen in figure 14.2. An adequately stable heel can be a significant contribution to the overall stability of the shoe, and could possibly reduce localised stresses in sections of the achilles tendon and surrounding tissues and joints (Novacheck, 1998).

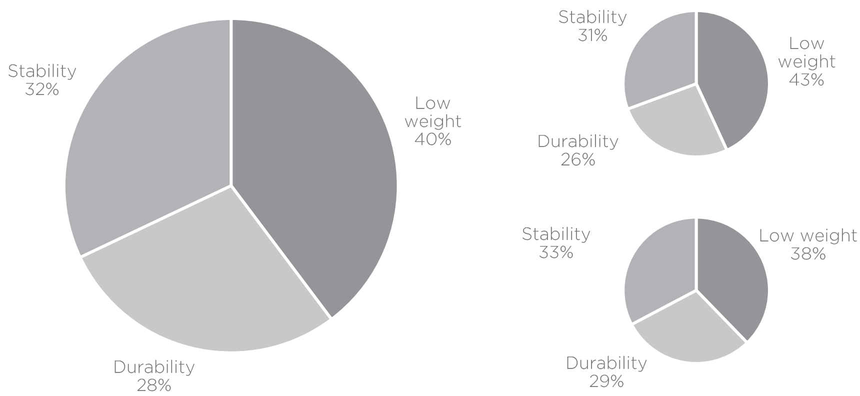


Figure 14.2 Distribution of points across three different properties, (left). Each responder distributed ten points. Middle- and long distance track runners respectively (top right and bottom right).

14.2 Heel padding and lining

Padding should be kept to a minimum, although the distribution and shape of padding elements could potentially improve the grip of the heel significantly depending on the other elements of the design. While excessive padding could allow too much movement of the foot, a thin strip of padding in the upper part of the heel section, wrapping around the back of the heel, would have the benefit of distributing the pressure put on the achilles tendon. Padding was also conceived as a possible solution combined with a larger heel counter, but instaed of a uniform fouam pad, it could have been shaped to better match the sprofaile of the back of the ankle. It could then expand into the concave cavities around the ankle just in front of the achilles tendon. These concavities could be exploited by adding two thicker padding elements which could keep the heel from sliding up as the heel becomes wider at the bottom. This solution would likely require backing, such as the support of one of the three first concepts in figure 14.1. A large reason for keeping the padding to a minimum is that it will absorb water adding weight in wet conditions.

The lining fabric should provide some friction, too smooth and it might allow slipping of the heel. It is important to consider the material properties when the fabric becomes wet, as perspiration, rain, and - if used in steeplechase - water jumps, cause exposure to water to varying degrees. It should have ability to conform to the shape of the foot, and have smooth transitions between different materials and edges in the internal layers of the heel cap construction. Minimising abrasion from edges and seams, which can cause chafes and blisters, should be prioritised as track spikes most often are used without socks.

14.3 Heel section design proposal

Figure 14.3 Collage of heel section and the proposed heel counter.

The solution chosen for the final concept is based on a low heel counter that provides stability by centring the heel over the sole and prevents excessive rolling to either side. This requires that the heel counter is firmly attached to the midsole. The divided heel counter is combined with a reinforcing fabric or alternatively a TPU film on the outside, covering the two pieces, and preventing them from showing through the outer fabric. Due to its thinness it could allow the edges of the heel counter to show through, and, if perforated, would show the surface of the heel counter through the holes. Above the top of the heel counter, the backing fabric transitions to an elastic fabric, rendered in white in the illustrations of the concept. This makes up the rest of the outer layer of the heel section, folding over at the top, and extending down on the inside, lining the entirety of the heel section. Along the top edge which connects to the lacing holes of the upper, a thin section of foam is placed between the two layers of fabric, creating an elongated pad that ensures the fabric can follow the curvature of the foot smoothly and distribute the pressure more evenly, shown in figure 14.4.

The lower two-part heel counter provides less support than a conventional shoe, but more than several of the track spike models available on the market. We believe the slight weight increase compared to those models is justified as the lack of stability was a frequently expressed concern among the interviewed runners and experts. It could prove valuable considering the tendency among long distance runners to lapse in their technique as they become tired. In the words of one interviewed 10 000 meter runner:

"When you become tired in a track spike, I don't find wearing them optimal. You tend to fall down on your heel, and then I feel they do more harm than good."

The stretchy top part of the heel section means that when the shoe is not worn, the heel cap is slightly pulled forward, creating an accelerated and fast appearance. Finding the right amount of stretch for a secure and relatively comfortable fit should be possible, considering the stretchy heel cap of the benchmarked New Balance LD 5000v5. It cannot entirely be considered a proof of concept for this solution as that model omits the rigid heel counter, and in our opinion, had too much stretch. The stretch should be on the stiffer side, ensuring a firm grip while not putting too much pressure on the achilles tendon. This solution would provide more adaptability to differently shaped feet than a model with no additional stretch material other than the comparatively stiffer upper fabric. The elastic heel section relies less on the tightening of the laces to achieve the right amount of tension toward the heel section, which may otherwise be difficult as the laces also has to to achieve the right pressure across the mid- and forefoot.

Figure 14.4 The placement of a thin foam padding strip.

15 Midsole

The midsole should mediate both propulsive forces as well as the ground reaction forces. Some cushioning is necessary to avoid point loads from the spikes and the edges of the spike plate, but the amount should be the bare essential. Aside from this function, it connects many of the other construction elements of the shoe. As is typical for track spikes, the final concept features a footprint of the spike plate that is narrower at the bottom compared to the top. This is most noticable in the midsection, where the waist is narrower in the bottom. The mid-section experiences smaller loads, subsequently making the need for support there lower.

Figure 15.1 The midsole.

15.1 Shape and dimensions

Together with the upper, it is the dimensions and shape of the midsole that define much of the shoe's overall fit. Before deciding how to shape the midsole, the outlines of several track spikes were overlaid, as seen in figure 15.2.

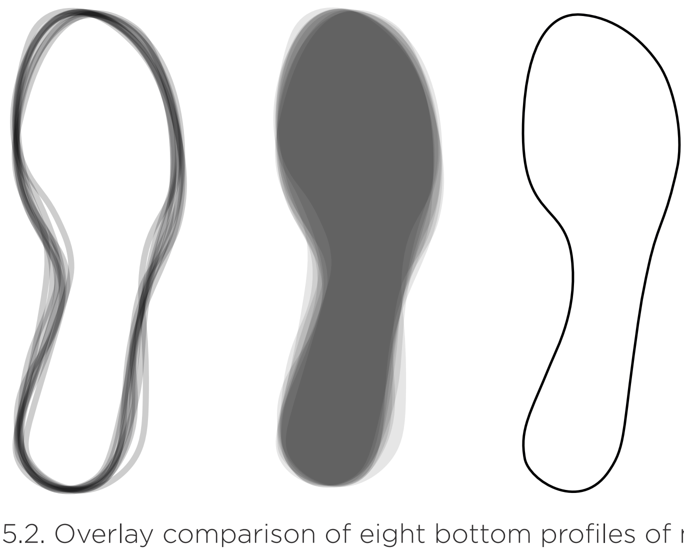


Figure 15.2. Overlay comparison of eight bottom profiles of midsoles, and the concept sole on the right.

The most prominent features identified were the shape of the forefoot, the waist profile, and the widths at different points of the sole. By overlaying the traced soles, the differences between different models became more apparent, and specific features could more clearly be related to their shape. For instance, the extra space at the big toe is present only in a few of the profiles, showing up as a lightly filled area. An outline with the desired attributes was drawn guided by the averaged profiles. The resulting profile prioritises toe space while having a relatively early transition into the waist. Such a profile has a lower weight, while still maintaining an adequate size of the forefoot, as it could be validated through other models who featured similar proportions. When the bottom profile had been determined, the top profile was expanded across the waist to provide a slightly wider platform for the midsection of the foot. Widening the midsole puts less strain on the upper, compared to having the fabric extend further in under the foot to reach the edge of the midsole.

15.2 Width across the forefoot

The main measurement typically associated with the size of a shoe is the length, but the width is of importance as well, and is especially important for the fit of a tight shoe such as a track spike. Offering several widths in a shoe with low production numbers would be unwise for economic reasons, so there is need to define a widely appealing function for the width of the shoe depending on the length. This function's main objective is to allow as many runners as possible to use the shoe and provide them with consistently good performance and characteristics.

Male and female distribution of foot measurements show that the proportions are close to equal between the sexes, which is further supported by Baba (1974), who found that females have marginally narrower feet in relation to the length compared to males. This small difference, amounting to one or two millimetres between the sexes' averages, is much smaller than the individual differences. This favours a unisex shoe, which also was found to be the most common approach among other track spike models.

The implications of the distribution of widths are more problematic. Shoes that allow a looser fit and has room for padding, provide more margins to ensure an adequate fit for many runners. For a track spike, the tolerances are much narrower, and therefore, the parameters need to be set very carefully. The difference of a couple of millimetres of give in the fabric can become painfully obvious in a literal sense, as reported by the runners participating in the interviewes and user tests. The width of the foot typically exceeds the width of the sole. However, the outermost edges of the foot do not need support from beneath because that part does not transfer any significant vertical load. What contains and centres the foot is the upper, and it is largely the expansion it allows that determines the tightness of the fit over the forefoot. The lowest acceptable width of the shoe then, is determined by how much overhang is acceptable. The width for the concept shoe was decided at 33 percent of the length, as it seemed to be how far the market has successfully pushed the limit in track spikes.

The concept line in figure 15.3, showing the recommended width relative to length, is comparable to the corresponding dimensions of the three track spikes examined in the benchmark. Any lower would likely result in discomfort as the edge of the sole would become noticeable to the runner. Having the outline of the sole start to intrude on the load-bearing parts of the sole would eventually affect performance. Runners with very wide feet would likely experience these consequences at the recommended proportions, but that was considered an acceptable compromise given the targeted fit for the wider track running population.

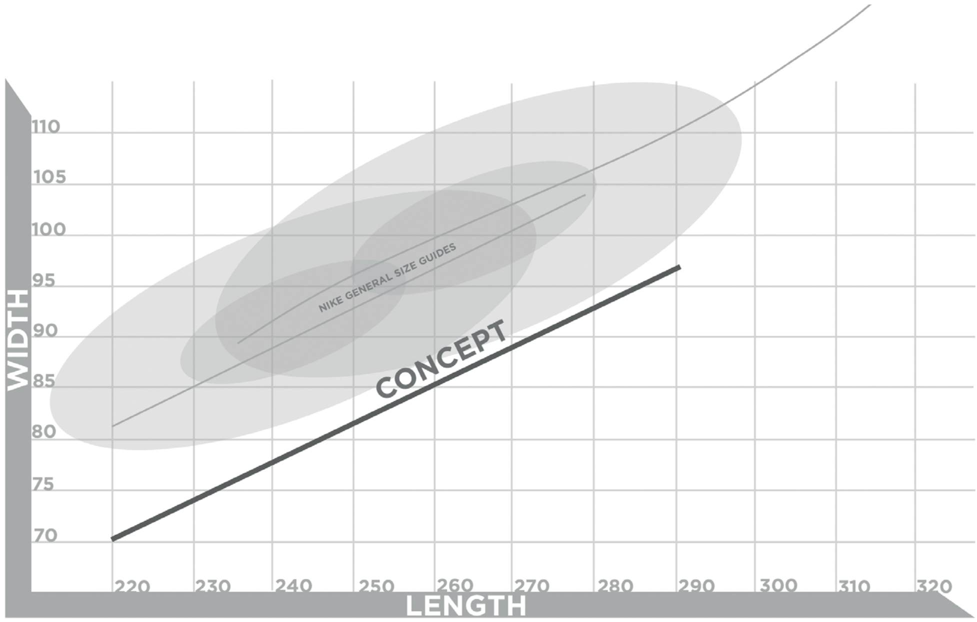


Figure 15.3 Concept width in relation to the length of the shoe. Including male and female at confidence ellipses of 50 percent and 95 percent (Hanson et al., 2009), and reference lines from Nike's general size guide for female and male running shoes.

A slightly wider shoe, i.e. moving the line up on the vertical axes, would allow more movement of the foot inside the shoe, which for some track runners is associated with abrasion and a less responsive feeling. Having the foot width exceed the width of the sole is also important to position and hold the foot. The overhang pushes the upper outward from where it attaches of the midsole, creating a more favourable angle to hold the foot in place.

15.3 Cushioning

During the user tests, is was expressed that a soft midsole may cause a sensation of lost power in the stride, which is a logical conclusion given that deformation of material will dissapate energy. The loss of energy in thicker midsoles has also been shown in research (Roy et al., 2006). Altogether, the long distances and large forces creates a need for mediation from the midsole material, but for efficiency and the responsiveness of the shoe the amount should be low. The distribution of material along the shoe prioritises the heel, where impact can be tough on the body as it travels straight up the leg. The thickness remains the same across the mid-section as further back, which provides support for the arch as it comes down at mid stance. Towards the front of the shoe, the midsole tapers off, becoming narrower to eliminate any sponginess to create a responsive shoe. Should the spike plate have edges at the front of the shoe, such as the horseshoe design of the benchmarked Nike Matumbo 3, there is more need for cushioning under the forefoot to distribute the pressure and make the edges less noticeable. With a spike plate extending backwards toward the heel, the amount of cushioning may be kept low. Irritability regarding the noticeable edges of the Nike shoe was expressed during the user tests, indicating that a minimalistic plae perhaps needs to be complemented with a thicker midsole.

While the preference for softness and cushioning differed among the interviewed subjects, some strongly advicated a harder and more responsive shoe. An interviewed expert in running dynamics and with experience in running shoe design, maintained that cushioning should be minimal and that focusing on stability would do more for injury prevention while maintaining the high performance and responsiveness.

"If you run ten thousand meters it becomes an extreme… Then you need cushioning. Not too much, because you do not compete that often at ten thousand, but you need cushioning. If you lack the cushioning needed when you run in spikes, you will have pain, or get injured."

"I think, that if you run longer, they should be soft… Then I want them to be soft, but still have some stability."
-Interviewed runners advocating cushioning, showing ll do not want a minimalistic midsole..

15.4 Midsole stability and support

In many shoes the midsole is the main provider of torsional rigidity, which was found to be of high importance in a long distance track spike. However, as this property instead is provided primarily by the spike plate, torsional rigidity is explored further in that chapter.
As the heel touches down, which tend to happen in all race distances above 800 m, the achilles tendon absorbs the impact during landing by stretching. The heel thickness is essential to provide the right amount of support that will prevent the tendon to stretch too much. This need increases significantly in longer races where fatigue becomes an issue, and the runner may rely more on the supporting structures of the shoe, such as the heel. In regular running shoes, this is measured by the drop. In track spikes it is seldom mentioned, as it is hard to determine due to the inconsistent depth the spike plate manages to penetrate depending on the spike type, the traction geometries, the track material, and weight of the runner. Some minimal spike shoes would be considered to have negative drop depending on the circomstances. The aim should be to not exceed a couple of millimeters.

15.5 Midsole material

Material used in the midsole is closed cell compression moulded Ethylene Vinyl Acetate foam, EVA. This is a highly conventional midsole material choice, as most running shoe midsoles are made with EVA or by properties similar foams. By using compression moulding, the midsole can have intricate details allowing a good fit against other components. This is of utter importance due to the high loads experienced by track spike midsole, demanding firm adhesion to the spike plate as well as other components. The density of the foam, and subsequently the hardness, depends on how much material is added to the mould. For this shape and application, the hardness of the foam should measure at around 60 on the asker C scale. This is slightly harder than many running shoes, and will give the midsole a responsive feel. This level of hardness was also recommended during a concept validation interview with a professor in biomechanics with experience in running shoe design.

15.6 Footbed

The concept shoe features a removable footbed, common in many types of running shoes, but often omitted in track spikes. A fairly standard EVA footbed with a thin fabric laminated to the top, and with perforations to divert moisture. It should be slightly built up in the arch, providing a smooth transition from the midsole to the sides of the upper. Slightly raised edges around the heel further improves the fit of the shoe, increasing both comfort and stability.

Track spikes with permanently mounted footbeds, such as the thin sheets found in the Nike and Hoka One One, do not provide the same fit due to the lack of raised edges and curvature meeting the shape of the foot. This is a small weight-saving measure, and bypasses the issues of footbeds becomming compressed over time, moving around in the shoe, or making the shoe more spongy than what is desired. However, we did not find such reasons convincing enough, as the fit is important for both feel and function, and a removable footbed also allows some personalised footbeds such as orthopeadic inserts to fit. Support for such a feature was found among a quarter of the runners responding to the survey, as shown in figure 15.4. Specifically designing the shoe with extra space for orthotic inserts has not been prioritised, but for those that have inserts that could fit, and who want to use them, the opportunity is there with this solution. The runners often sustain injuries that are mitigated with such devices, such as issues with the plantar fascia.

The fabric topping the footbed needs to work well in direct contact with the skin as well as allow use with socks. A thin, synthetic fabric should also limit moisture retantion and prevent bacterial growth, as bad smell is an infamous issue with track spikes.

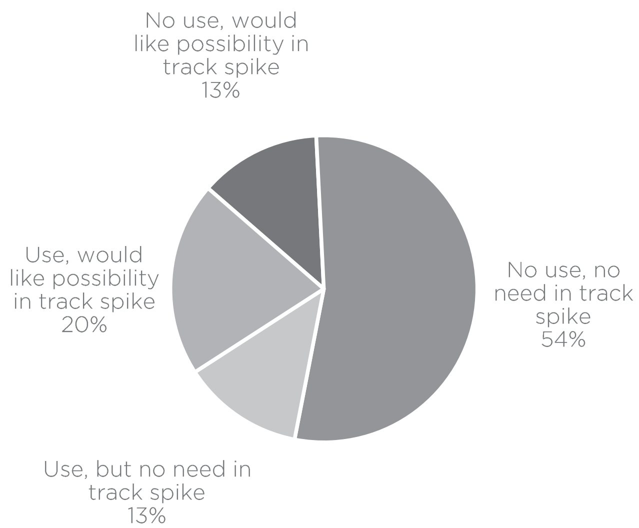


Figure 15.4. Runners general use of inserts or custom footbeds and preference of potential use in a track spike.

16 Spike plate

The materials often comprising the soles of running shoes were quickly determined too soft to contain the forces from the spikes. The torque on the mounting point could easily dislodge the spike anchor, and the local loads from the spikes would transfer through the midsole and cause discomfort. The universal method for mounting the spikes of track shoes is with a spike plate, which was chosen for this project as well as it is tried and tested. No other alternatives were found to be close to equally satisfactory or realistically implementable. The spike plate itself may be shaped in many ways, giving the shoe its properties, but also its appearance. To achieve the desired properties outlined in *Desired characteristics and design principles*, the spike plate was designed to have several functions.

Main functions and properties of the spike plate:

- Hold the spikes
- Distribute spike load across forefoot
- Grip track
- Provide torsional rigidity
- Provide sole stiffness
- Have eye-catching appearance

Primarily, holding the spikes is a question of how to mount them. Standardised exchangeable spikes were highly preferred to permanently mounted by all runners asked. Allowing exchangeable spikes is a matter of moulding threaded inserts into the spike plate. The inserts consist of a socket which is threaded on the inside, and an anchor which increases the amount of force it can take without being pulled out of the plate.

The spike plate must have adequate thickness around the anchor, either through the general thickness of the plate or having the plate protrude slightly around the anchors, which lowers the weight of the plate compared to option one. While anchors may have different shapes, the designs proposed in this project used circular anchors as they are likely a stock part that is cheaper compared to custom designed inserts. Anchors are typically around 15 mm in diameter which means the protrusion that encases them needs to be slightly larger at around 18 mm. The height of the insert was measured at around 4 mm, which corresponds to the threaded length of the spikes, dictating the minimal thickness of the plate at the mounting points.

Distributing the forces from the spikes is done by having adequate support around the spikes, with thickness, shape, and material properties being the main factors. While material may be removed from certain parts of the spike plate, such as adding holes to it or having the geometry vary in thickness, the areas around the spikes should not be compromised. To further distribute the load concentrations, additional traction geometries should be added in the areas around the spikes. In addition to distributing the load, the spike plate grip geometries complements the traction provided by the spikes. They would allow the shoe to be used with blanks. For some runners, a certain spike may cause discomfort due to the placement, and they may then replace it with a blank, relieving the localised pressure. With redundancy in grip, the runner may still have sufficient even without one of the spikes. Certain spikes may be lost due to coming loose or breaking off during running. If the insert is damaged from excessive force in an odd landing or if the threads are damaged from dirt or corrosion, they may be unusable. Extra grip geometries should be placed around the periphery of the forefoot, as there is little need for grip at the centre of the plate. If this part is in contact with the track, the edges are as well, providing sufficient grip.

In addition to the grip, the spike plate increases the torsional rigidity of the shoe, the importance of which is detailed in *Support*. Achieving torsional rigidity in addition to the inherent resistance to torsion of the midsole may be done by extending the plate back under the midfoot as well. The section of the plate extending back does not need grip geometries. To provide adequate rigidity, it should extend to cover at least two thirds of the shoe's length. The longer the midsole alone bridges the distance between forefoot and heel, the less support is achieved. The plate could be extended all the way back to the heel, but that would add weight and perhaps affect the perceived lightness to the shoe and provide relatively little additional rigidity. In the survey, several spike plate designs were evaluated by the respondents, and they clearly preferred designs partially covering the sole over the full coverage plate, further explained in section *Shape of spike plate*.

The stiffness of the plate contributes to a spring effect in the stride. To achieve this, the material should allow severe elastic deformation and have a high return speed, acting like a strong natural spring. The benefit of the spring action is described in more detail in the section about *Elastic rebound*. We suggest the same type of block polymer used in the majority of spike plates, PEBA, a highly engineered elastomer based on polyamide. These block polymers are strong, flexible, resistant to wear, relatively light, and can be customised to a high degree to meet the desired specifications.

16.1 Shape of spike plate

The manufacturing technique of the spike plate would be injection moulding, allowing intricate details in the shape. As each size requires a separate mould for both right and left shoe, there is little difference in cost for a simple design compared to a more elaborate one. Given that the shoe would be a way of conveying the brand image, and that the spike plate is one of the most unique features in a track spike, there is logic to giving the spike plate design thorough thought and aim for an eye-catching, creative and unique look.

Before a spike plate design was chosen for the final concept, many variations were explored, combining different elements and properties. A proper evaluation of function and feel could only be made with physical prototypes, which was beyond the scope of the project, but there were still several known aspects that could be compared. One influence was the preference of the surveyed runners. The fundamental principles for the spike plate designs they chose aligned well with our perception of their merits, partially validating for the reasoning behind the concepts.

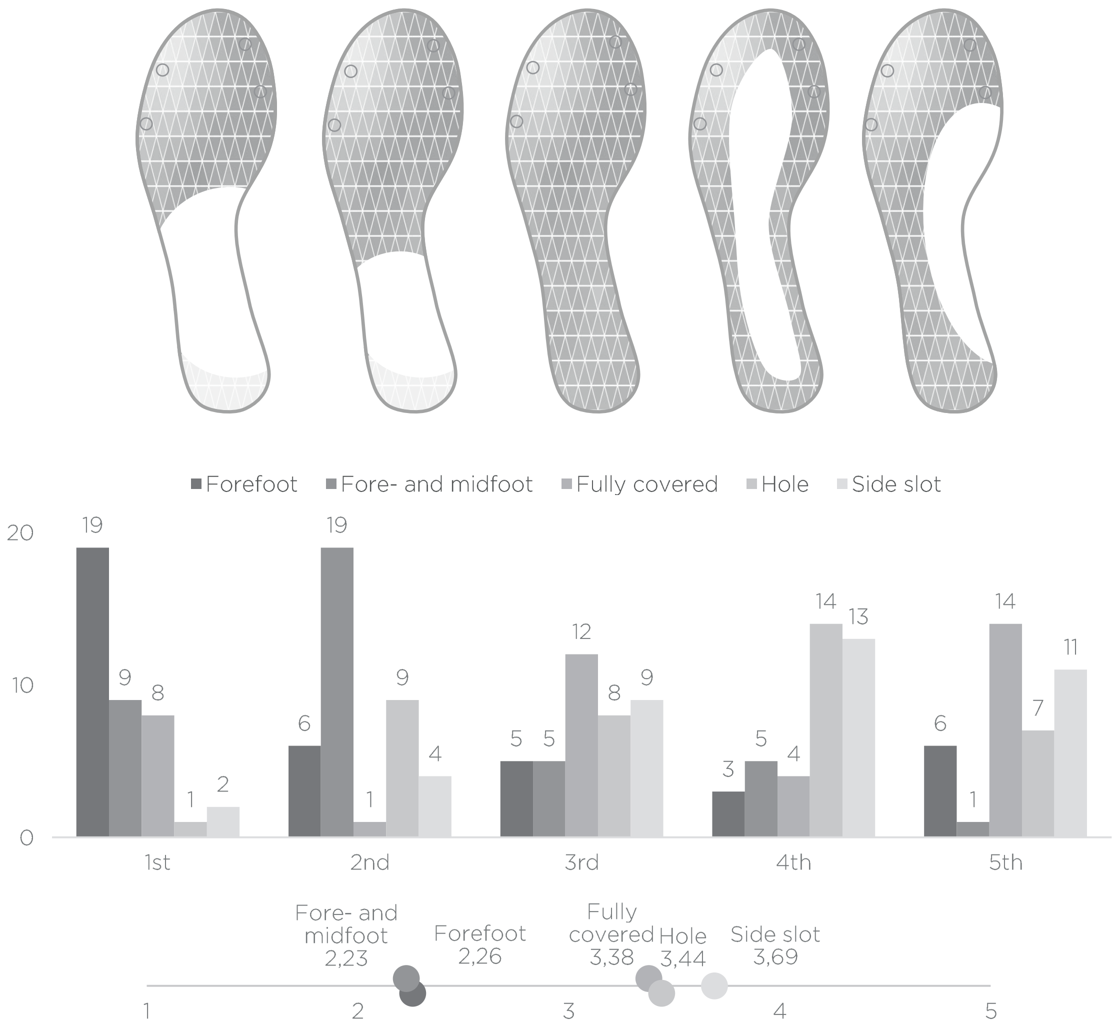


Figure 16.1 Ranking of spike plate options, and average ranking.

Looking at the distribution between the preferred alternatives presented in figure 16.1, the concept *forefoot* and *fore- and midfoot* stood out with high and close average rankings. However, while frequently ranked the highest out of the responders at 19, forefoot was also ranked last by six runners compared to *fore- and midfoot's* single last ranking. A possible explanation is that some runners were aware of their need for extra support, or simply had good experiences with spike plates covering more of the foot, or the opposite, poor experiences with nothing-but-forefoot plates. Support for all these explanations were found in the interviews, and perhaps there is some validity in all of them as they are not mutually exclusive. Regardless of the cause, the uantitative result itself could be used to inform the design choices. We determined it was important to choose a type of plate that had a wide appeal.

The design of the forefoot was of high interest regardless of how far back the plate extended. Therefore, a similar ranking between options only relating to forefoot alternatives was included in the survey, the results of which are seen in figure 16.2. The highest ranked option was the entirely covered forefoot, which provided an indication that removing material to save weight was not seen as an apparent nor prioritised measure to most respondents. It could also be an indication that rigidity was preferred over the alternatives implied to have less plate coverage.

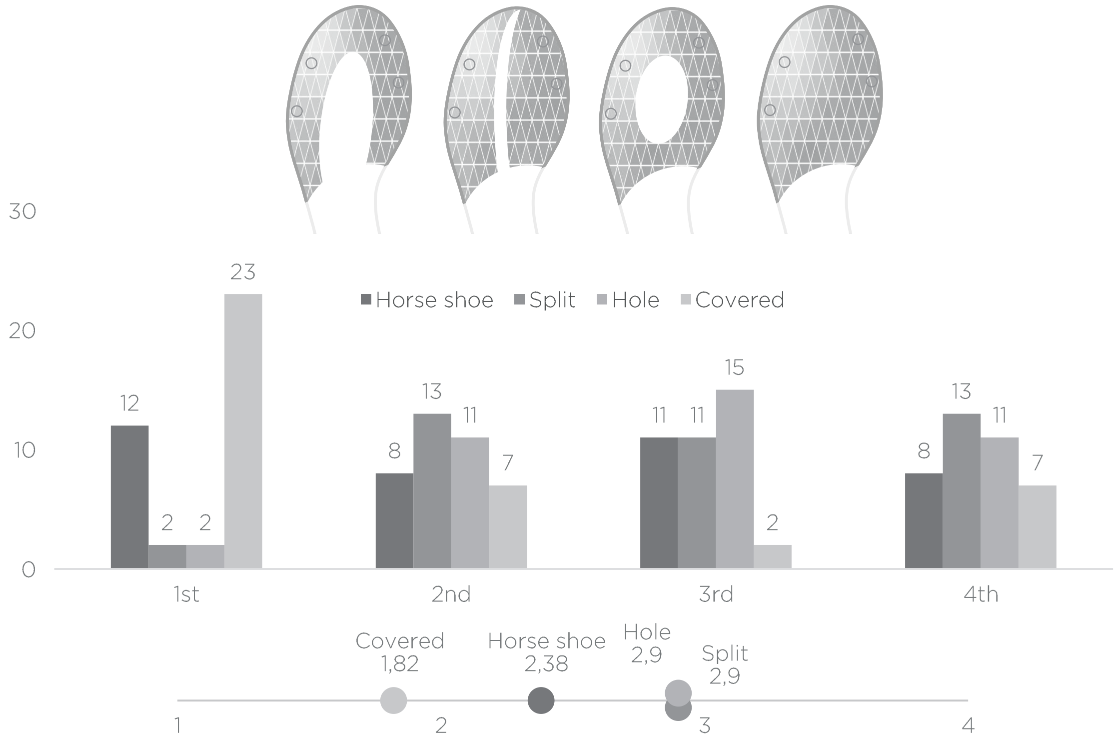


Figure 16.2 Ranking of forefoot spike plate options, and average ranking.

A selection of concepts from the ideation of spike plate designs are shown in figure 16.3 below. They reflect the many directions explored with varying faithfulness to the desired functions. The concept chosen for further refinement was selected based on having an appearance which was easily combined with the brand identity of Salming, as well as having good prospects of meeting the requirements and desired properties.

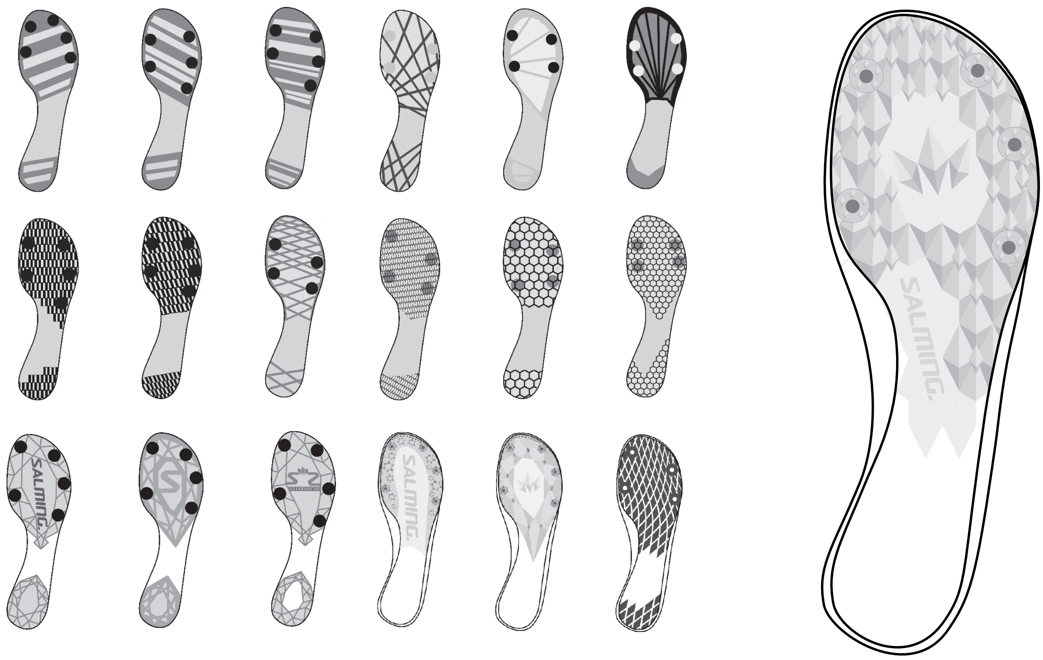
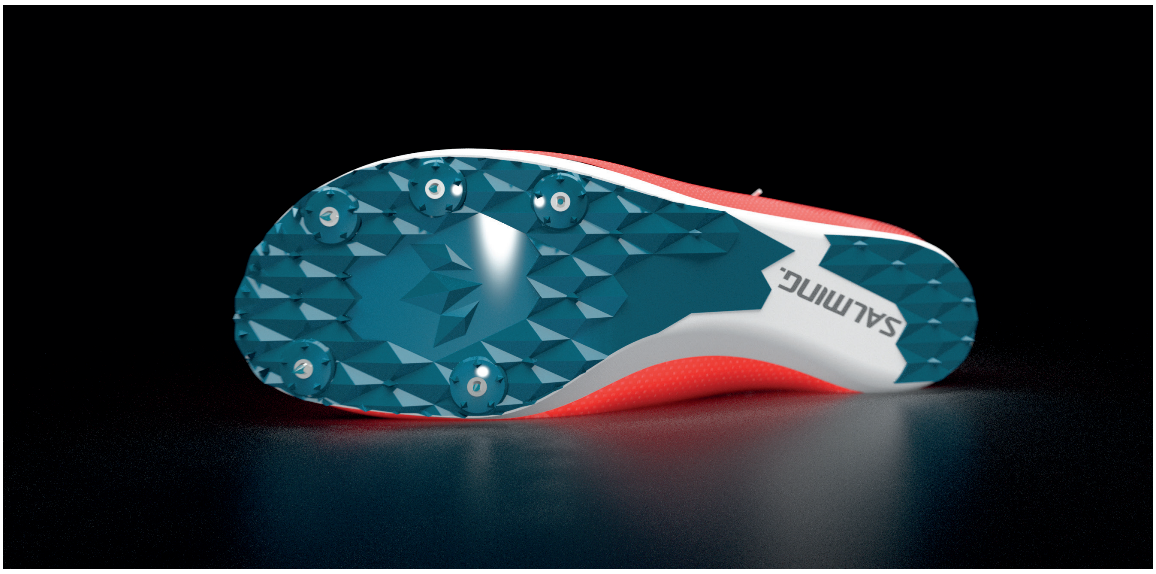


Figure 16.3 Selection of results from ideation and form exploration of spike plates, including the concept that was chosen for further development to the right.

16.2 Spike plate design proposal

A repeating pattern was chosen for the final design. It consisted of flat, triangular surfaces, which could be easily manipulated to different grip geometries. A repeating pattern has the advantage of being modular, meaning different versions of the plates could be easily created for different sizes. Simply scaling the design is also an option, but that requires adjustment of individual elements that have an absolute optimal size rather than relative. The traction geometries are positioned along the outer parts of the plate with a thinner segment in the middle, from which three prisms emerge, providing some support for the middle section. The plate extends back toward the heel where there is a gap between the front plate and the heel section, providing important torsion control and energy return as the shoe rolls off the ground.



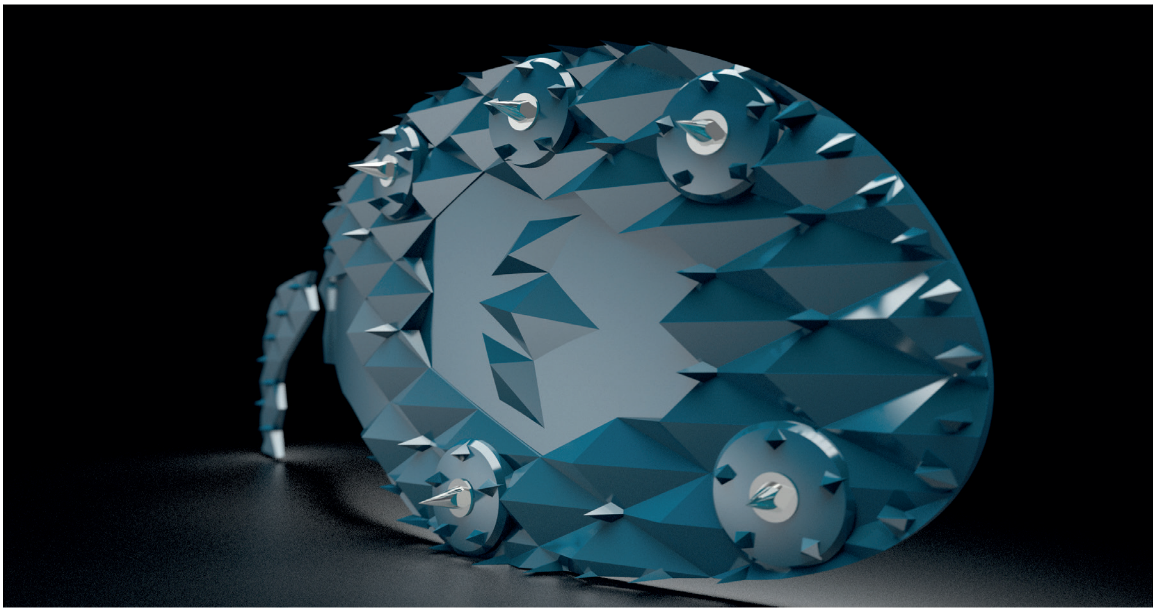


Figure 16.4 Collage of the spike plate design concept.

The geometries were designed to provide traction in all directions, but optimised for forward propulsion through a steeper angle at the back of the spike. Their shape is a derivative of the pattern of the sole to give the entire design a consistent and clear design language. Compared to other feasible grip geometries, seen in figure 16.5, it stood out as having a powerful and solid expression, and should, due to its blunt and compact form, resist bending and wear better than the thinner options. This design should mitigate issues displayed by the thinner plastic geometries on the benchmarked Hoka One One and New Balance, which bent on several places during use and user tests.

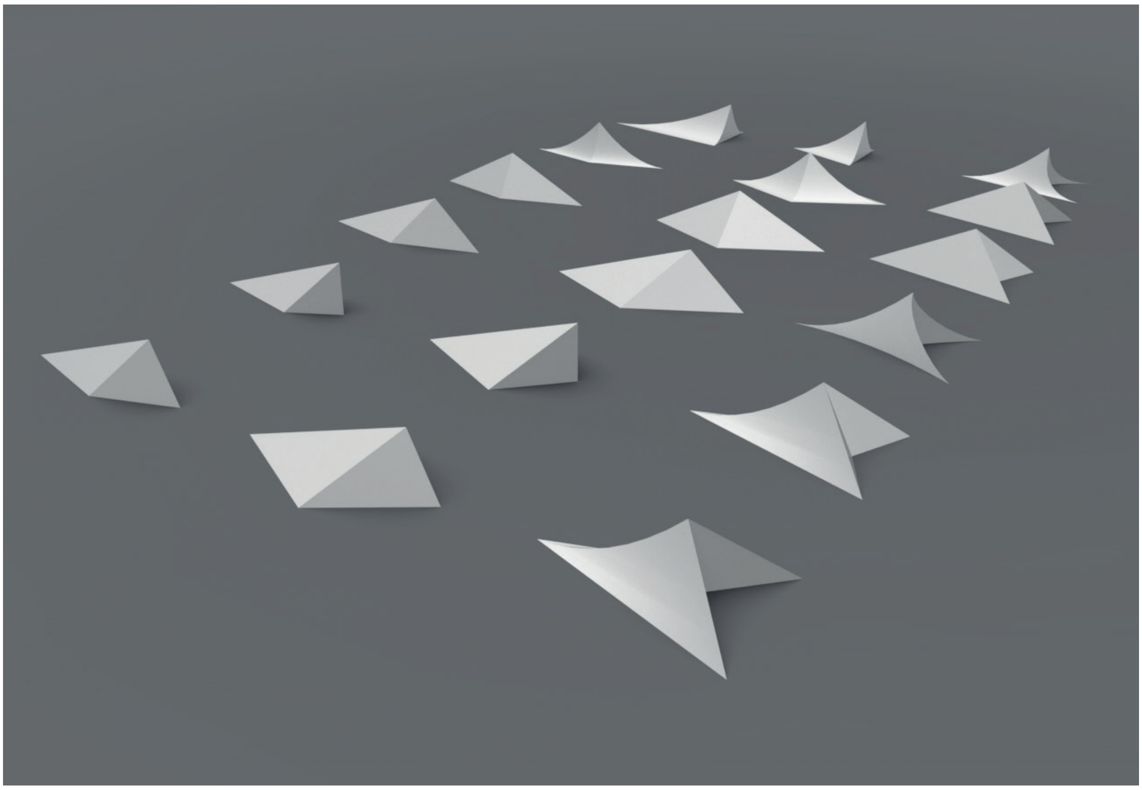


Figure 16.5 Examples of traction geometries from ideation.

The geometries are distributed across the front of the plate, evening out the load from the ground reaction forces across the plate. On the sides around the forefoot, the geometries are placed along the edge and cut in half along the outer edge of the shoe to create a distinct side profile of the plate. At the very front, a slightly compressed version of the geometry is placed as a row of teeth, emphasising the aggressive and instant grip the shoe provides.

16.3 Placement and number of spikes

As explored in detail in the chapter *Properties of track spikes,* the number of spikes is typically lower for long distance shoes, compared to middle distance and sprint shoes. This saves weight which is important in longer races that rely more on efficiency, and the forces are lower, creating less need for traction. The consistent surface of the track makes it possible to place spikes precisely where they are needed, typically at the first and fifth metatarsal heads, behind the big toe, and at the tip of the little toe. The outer spikes are important at touchdown, as the supinated position of the foot means they are planted first. As the load shifts to the entire ball of the foot during push off, the rest of the spikes are engaged as well. The two spikes at the back should not extend too far back of the metatarsal heads as the internal structures behind them in the beginning of the arch may become agitated from the load. Several of the interviewed runners still preferred more than four spikes, typically placing fifth somewhere along the outer edge of the shoe. We found little evidence that there is need for a spike advanced to the front of toe line, as most of the load is placed under the ball of the foot. An explanation for the seemingly intuitive request for a spike at the front could be explained by the fact that it feels like the toes are doing much of the work when pushing off. They experience forced dorsiflexion and are activated to stabilise the forefoot, which is apparent to the runner, and could be interpreted as the toes doing a more significant part of the pushing even though it is not necessarily the case. The joints in the toes are rather slow and weak, meaning that even if they feel like they are doing much work, relative to the loads being handled under the ball of the foot the amount of work is small.

The number of spikes was nonetheless decided at five. Apart from redundancy in case of one spike becoming inoperable, this makes the shoe more suitable to those running the steeplechase, for which four spikes is not optimal. The shoe may glide when placing the foot on the obstacle, made worse if the distance between spikes is too long. There is a higher likelihood of weird landings as they jump over high obstacles with other runners causing disorder, according to interviewed runners and the abundance of steeplechase fail videos available through a quick web search. You do not want to slip face first into the water after an obstacle, with a hoard of runners landing at the same spot with spikes first. The fifth spike also distribute the load more evenly along the outside of the foot, as one of the runners reported feeling pain that he suggested was caused by the load from the spike placed where touching down occurred.

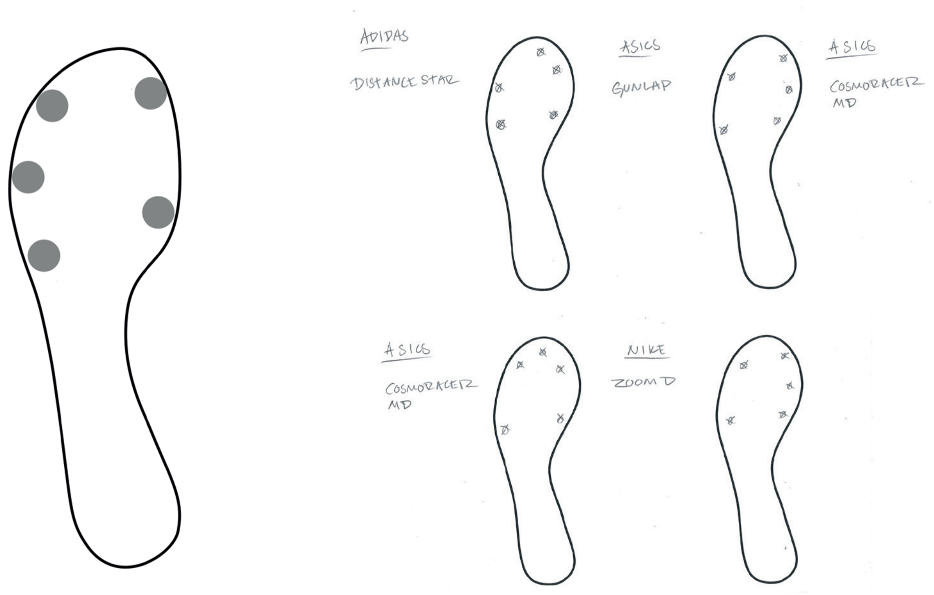


Figure 16.6 The final concept spike placement (left) in relation to other five-spike track spikes. Other placement mappings can be found in *Appendix F*.

Compared to what was found in the benchmark, this placement is not used by any of the major brands at the moment. None of the benchmarked shoes with five spikes had this placement, instead placing three spikes on the inside of the foot, seen in figure 16.6. To place three spikes on the outside is an advantage because it gives more control as the foot can be easily supinated, making that part of the foot easier to place with precision. This is also the side of the foot that strikes the ground first at initial contact.

The side profile of the plate reveals a substantial toe spring, which is decided by the taper of the shoe. The taper angle was chosen to be 20 degrees, as it was the preferred angle of the runners who tested the benchmarking shoes. It is commonly used in long distance track spikes, and allows adequate flexion in the foot prior to landing. Without a taper angle, the rigidity of the spike plate would inhibit toe dorsiflexion so that the windlass mechanism becomes harder to utilise upon landing. That would limit the elastic absorption of the impact. The toe spring also contributes to the elastic rebound of the shoe, as it wants to return to the bent shape after being forced flat in midstance. The taper angle of the Hoka One One was measured at about 30 degrees, which was too excessive according to the runners. It was chosen to be 20 degrees in the concept design.

"The toes would point up in the sky in these ones. There must be some sense to it."
- Long distance runner regarding toe spring of the Hoka One One Speed Evo R.

16.4 Heel plate

A heel plate was designed to match the front plate. The traction requirement for the heel was found to be much lower; it was omitted entirely in the Hoka One One model, which relied on the foam midsole to mediate track contact. While while one could argue that to be a reasonable concession to save weight, the reasoning only holds up for shorter distances. As mentioned in previous chapters, long distance runners rely much more on heel support, and an outsole element helps position the heel by establishing a horisontal platform, limiting excessive pronation. Without an outsole element under the heel, the midsole may collapse without applying any torsion which would level the heel, creating an unstable platform.

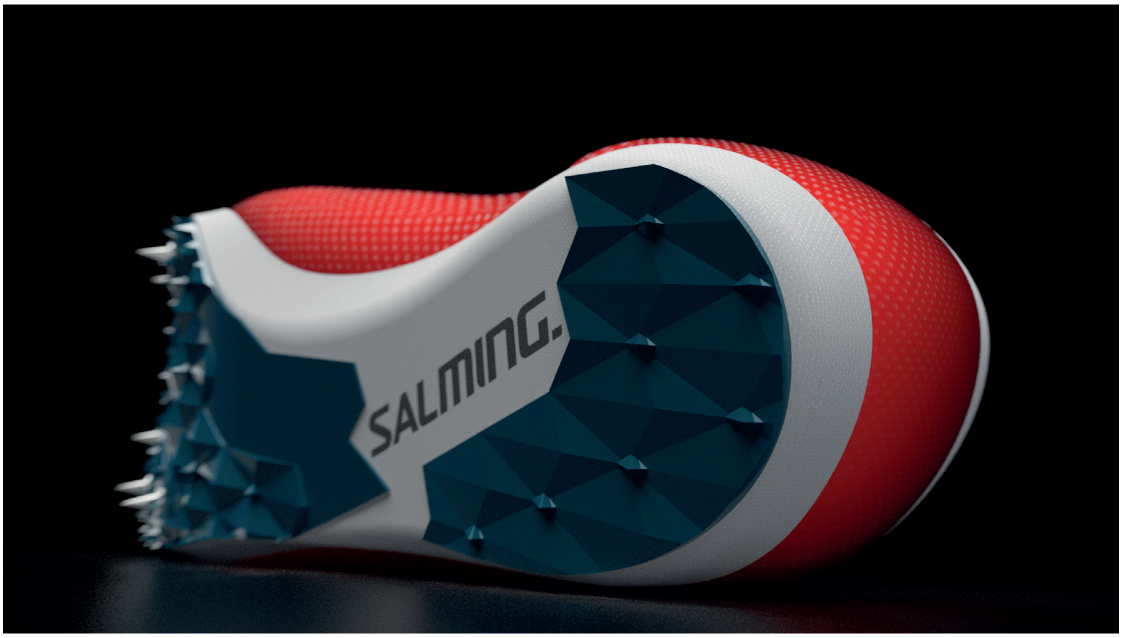


Figure 16.7 Close-up of heel plate.

Additional advantages include resistance to wear, as the EVA foam in the midsole is not sutiable to handle abraison, especially if the shoe is used in cross country conditions. While not considered the most common use case, 77 percent of the long distance runners taking part in the survey reported using track spike shoes in terrain conditions. This violation of intended use should due to its frequent occurrence have some influence of the design choices.

The heel plate is slightly extended on the outside of the foot due to the more pronounced ground contact the shoe experiences there. This plate can be made thinner than the front plate as it does not serve the same purpose. It does not need to hold spikes and it does not need to provide any elastic rebound. It is feasible to use a different grade of plastic to make it less noticeable to the runner. A heel plate design closer to a more conventional racing flat was also considered, using a more rubber-like material. However, the requirements of the steeplechase, where heel traction is essential at times, dictated a material which could have protruding geometries that would be strong enough and resist wear. It was determined to be beneficial to the overall expression of the shoe, whereas a softer heel section without protrusions could be percieved as incoherrent. The choice to make the heel in a more rigid material was made despite only a third of the survey responders preferring a material similar to that of the spike plate compared to the other alternatives, seen in figure 16.8. The interviews indicated that the material itself was not the most important aspect, but rather that there was something there at all.

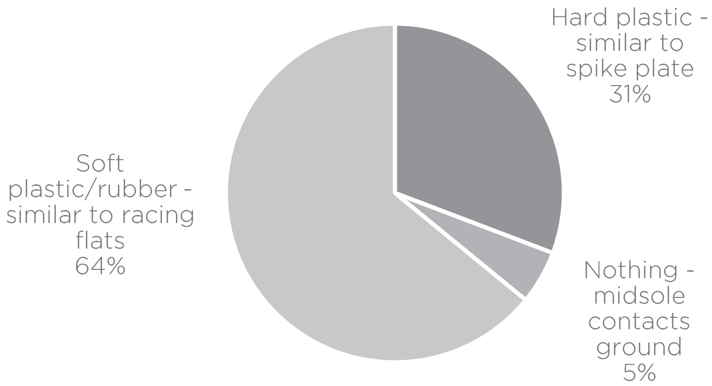


Figure 16.8 Preferred sole design option under heel in survey.

17 Spikes

For shoe models allowing spikes to be changed, there are several different types of spikes and lengths, prompting the question of what spikes should be shipped with a shoe for long distances. Several types were purchased and tested. The International Association of Athletics Federations' *Competition rules 2018-2019* (2017), dictates a maximum spike length of 9 mm for outdoor and 6 mm for indoor running, but track manufacturer and stadiums can impose lower limits. The maximum number of spikes permitted is 11, far more than needed for long distance running, and they need to fit through a 4 mm square gauge if they are replaceable, which matches the profile of the spike wrench.

Figure 17.1 Four spikes variants: pyramid, tartan, blank and compression tier. The rightmost two in steel and the latter two in ceramic material.

17.1 Common spike types

Runners showed little interest in the different types of spikes, and typically used what came with the shoe. That is almost always a 6 mm pyramid spike, which despite its name is not a pyramid, but a cone. On the track, this model and length provides perfectly adequate traction in all conditions. It is the go-to all-round spike, and there is a point to including spikes that runners are familiar with. As no other spike seemed to have any major performance advantage, this is the spike that should be included at the sale of a shoe.

Compression spikes are, as the name suggest, a spike meant to elastically compress the track rather than penetrate it, returning the energy as the track bounces back. However, how well this works seem to depend on the track material, as we noticed penetration rather than compression using it on a relatively soft track. Inconsistencies in its performance make this spike type less suitable to ship with the shoe, and using it should be decided by the runner depending on the track surface they will be running on. When it functions as intended, it returns more energy than other spikes (Bahamonde, 2014), however, the effect is small.

The third kind of spike is the needle spike. It is narrow and sharp, which may cause tears and stick to the track, which is unpleasant. This means that this spike returns little energy to the runner (Bahamonde, 2014).

Blanks are not common, but should be mentioned as they do not provide any traction, it protects the threads should the runner for any reason want to run without spikes at any or all spike positions.

17.2 Spike material

As low weight is highly premiered, the most common steel spikes may be replaced with ceramic spikes. The material was found to remove two thirds of the spike weight, a set of five 6 mm pyramid spikes weighing 2 g instead of 6 g. While this was noticeable holding just the spikes, it is likely not noticeable to the runner considering the relatively low difference when adding the weight of the entire shoe, as it falls well within the limits of Weber's law of perception. The benefit would be more psychological, which makes it a compelling argument considering the context of competitive running. The downside of the ceramic spikes is a slightly blunt point, which was noticeable as well. While perhaps not affecting performance directly, the feeling of instant grip and responsiveness - which was slightly lower - are important, and a potential psychological advantage. Steel spikes may corrode primarily due to moisture, and the spikes should therefore not be left in the shoes for longer periods of e.g. storage during off-season. A small amount of Vaseline on the threads may prevent them from corroding and getting stuck as a result.

17.3 Use of spikes

Most of the interviewed runners changed spikes between track and cross-country races, where many used track shoes occasionally. In cross country, longer spikes are needed, as made clear by the infamously muddy Swedish cross country national championship of 2017 frequently referred to by interviewed runners. It was basically a mud crawl. Such conditions may ruin a lesser shoe, especially considering the extreme torque long spikes apply to the spike mounts. A few of the runners mentioned that spikes were changed during the season as they wore down. The wear of spikes is increased by walking on other materials than the track surface, such as asphalt or concrete. Some runners admitted to such behaviour as putting on the shoes takes some time and they perhaps found themselves really needing to grab that water bottle they had forgotten on the wrong side of the concrete. Using the shoes at an indoor track was also mentioned as a reason to change spikes, but to shorter ones. Indoor tracks are sometimes thinner and/or softer, limiting the need or suitable length of spike.

Figure 17.2 The Swedish national cross country championships 2017, with author Johanna Larsson wearing track spikes in muddy conditions.

Figure 17.3 Pyramid spikes: 15, 12, 9, 6, and 4 mm.

17.4 Spikes included with shoe

As stated, a 6 mm pyramid spike should be included. We recommend the standard metal spike as the ceramic ones were found to be softer and could potentially wear out faster. Either option was found to be about equally good, with different advantages. The runners did not seem to have any preference one way or the other. The point should be sharp but not excessively so, definitely not blunt. The spikes included with the Hoka's were not finished to any degree of precision, leading to low perceived quality and being unnecessarily sharp to the point of damaging fabrics they ome into contact with. A spike should be sharp, but not so sharp as to ruin other equipment. A nicely finished spike with a polished surface can be seen in figure 17.4.

As runners sometimes loose spikes during races, we suggest including two extra spikes bringing the total to twelve. In addition to the pyramid spikes, a pair of blanks can be included. This will give the runner an opportunity to minimise loads in areas where they experience agitation from the spike placement. While the spike placement was chosen so that the risk of this is low, all feet are different, and individual differences may cause issues. The spikes should not be mounted upon delivery, as they may cause damage if stored or transported pre-mounted. Another reason for this would be to let the runner familiarise with mounting the spikes.

Figure 17.4 The 12 6 mm pyramid spikes that should be included with the shoes.

18 Accessories

When receiving a track spike, several accessories are often included. They enhance the user experience as well as reflect the context of track shoes, such as the often included storage- and transport bag that promotes the brand through its presence at competition events.

18.1 Spike wrench

As the spikes are removable, and not inserted when shoes are delivered, a tool for mounting them should be included. This tool is a 4 mm square wrench, the standard for spikes. The shape of the wrench mirrors the geometries and patterns in the shoe. The spike tool should be shaped so that it reaches the spikes, as some shapes may interfere with the traction geometries protruding from the spike plate. The edges are sharp and can be used to clean the shoes from pebbles or dirt after use, which is of particular importance should the shoe be brought to a cross country event.

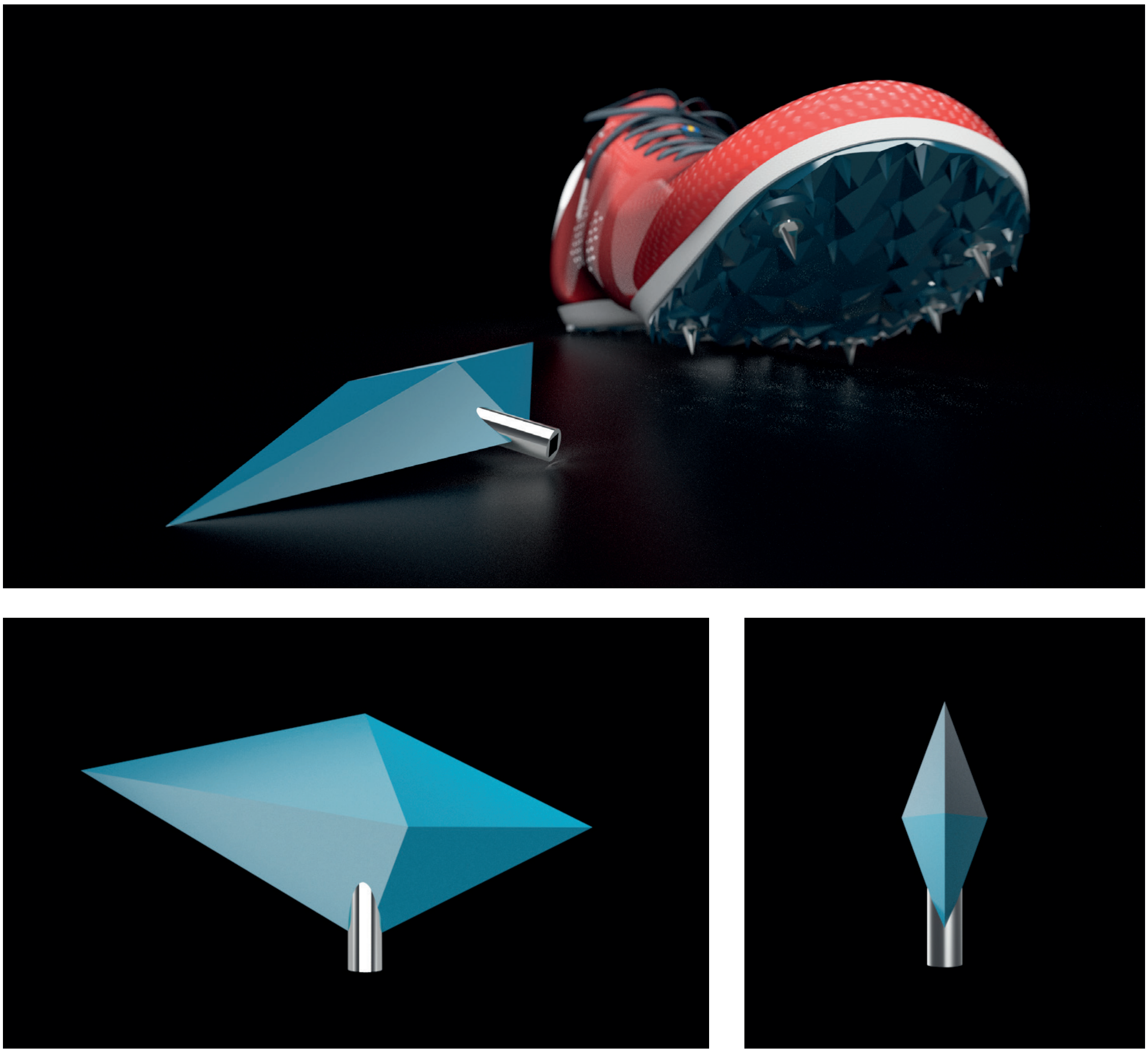


Figure 18.1. Collage showing a spike wrench included with shoes.

18.2 Drawstring bag

As the shoes should not be worn on hard surfaces, and are unsuitable for warming up, they are often carried around the stadiums. A dedicated bag, prominently displaying the brand should be provided with the new pair. The spikes may otherwise damage other equipment and clothes. The classic drawstring bag is suitable for this application, as runners expressed that they like being able to wear it on their back. Wearing the bag as a backpack around the stadium exposes brand clearly in a prestigious context. According to interviewed runners, an issue that occurred when using drawstring bags was that the spikes went through the fabric, poking at their backs. To avoid this problem, the bag should have a thicker fabric at the back. The infamous horrible odour of track spikes may be temporarily mitigated by placing them in a bag for transport to and from the track. However, permanent storage should be well-ventilated.

Figure 18.2 Drawstring bag for carrying shoes.

18.3 Care and fitting instructions

A sponsored runner who experiences issues with the fit of the shoe should be given maximal opportunity to mitigate the issue through adjusting the fit. There will likely not be any other alternatives, making this extra important in a Salming track spike. We recommend including instructions for how to adjust the fit and basic care of the shoe. The instructions could easily be included e.g. on a note in the box or printed on the inside box lid.

The instructions should inform the runner about different spike variants and how blanks can be used, such as if the placement of spikes causes discomfort. The necessity of clean threads should be noted, along with instructions to apply Vaseline to the threads before insertion to keep the spikes from getting stuck. Instructions for mounting the spikes so that they are not over- or under tightened, how they should be stored to limit odour, and how cleaning should be done should be included as well. To enable the best fit for all users a guide of different lacing techniques may be provided. It was seen during user tests that some runners already have certain lacing methods they use, but providing options would be helpful for those who do not already do it, and it could possibly make the difference between a shoe being usable or not for a sponsored athlete.

19 Discussion

The aim of the project was *to understand and translate the needs and preferences of runners who train and compete at tracks into requirements for a long distance running spike, and then develop a design concept for such a shoe.*

Through investigation into the context of track running and elite runners - their motivations, shoe preferences and use - we believe a highly valid and relevant view of the requirements was established. While some user needs and preferences were found to disagree, we believe they were explored and presented in the results in chapters seven through eighteen to the extent that an informed compromise can be made to form a great shoe. One of the possible solution combinations consists of the final design proposal. It is based on the targeted functionality and properties described in the chapter *Desired characteristics and design principles* and motivated in further detail in the chapters ten through eighteen treating the different elements of the proposed shoe.

As far as the aim of the project is concerned, we consider it to be reached in full. The objectives were also fulfilled to the extent intended as well as the deliverables which are all contained within the content of this report. That includes *a set of qualitatively described product requirements derived from user centred research* found throughout the results. The same applies to *a set of solution suggestions addressing important design variables*, and *a final design proposal combining a selection of solutions to form a concept track spike for long distance track running*.

The project resulted in a concept proposal of a track spike for long distance runners at elite level. The defining features reflected a shift in prioritisation of properties compared to the current convention in equivalent spike shoes, providing increased stability and extra traction at the cost of slightly higher weight. Support for such prioritisation was found in the preferences of runners, the studied literature, and interviews with a variety of experts in running dynamics and sports medicine. In addition to the functional aspects of the shoe, the final project included a suggestion for an aesthetical profile aimed to reflect the identity of Salming.

19.1 Limitations

Validation and evaluation of solutions was largely restricted to qualitative theoretical analysis and comparison to real world equivalents of the function or design element in question. To gain more knowledge, the concept would have to be realised and tested in practice, which for the most part was not possible within the boundaries of the project. Physical prototyping would in many cases need to be performed with refined resolution and at a high cost to accurately reproduce and evaluate the performance intended in the final design. This limitation means that the solution space presented is larger than if we had eliminated design alternatives through physical testing. The implications of this is touched upon in the section *Future work and prospects*. The relevance lies there as the final result reached the intended resolution. It was in the beginning assumed that a semi-functional physical prototype would not be feasible given the time frame of the project.

The availability of research on the specific conditions present when running in track spike shoes was limited. Instead, most research on running approaches the recreational runners or sprinters. The possibility to apply results and proposed ideas and conclusions from papers needed to be evaluated more rigorously than had the project revolved around, say, a shoe for recreational runners. This was, of course, an activity that strengthened the validity of the project conclusions, but ultimately, the lack of research explicitly treating the conditions of track running in spikes should be considered a disadvantage. An example is the large amount of research that was found to be based on heel striking, even in articles treating barefoot running, as participators were often conditioned to heel strike, disrupting their natural technique, or they simply did not include forefoot strikers. This deviation from the natural stride technique made much of that research inapplicable upon close examination of its methodology. A noticeable and positive effect of the rigorous effort to sift out papers with high relevance and validity among running literature was the wider and deeper knowledge it contributed to. This resulted in many papers being thrown out at later stages when intricate details became understood, and that that rendered them inadequate for the purposes of this project. This may indicate that some research with lesser applicability slipped through, but the number would have been higher had we not examined the details of them. With that said, no research paper is without imperfections.

The last design implications of the project could have been explored in much higher detail, if that component had been considered more thoroughly early in the project. While accurate to the extent of our knowledge, the last design implications only touch upon the principal aspects of its shape. A more detailed and validated last design would allow a faster realisation of the proposed design. The last is one of the few areas where, if we had the chance to go back, more efforts had been diverted to it. Instead, the last design resides at the top of the list in *Future work and prospects*.

19.2 Starting point and framing of the project

One purpose of a running spike is to create traction. Therefore, an approach to the project could have been to ask how better traction can be achieved, which does not presume that spikes are part of the solution. While the fundamentals behind traction when running certainly was important to the project, this was not how we choose to formulate the main problem. The specificity of the defined problem space should serve the project such that it aligns with the requirements of a master's thesis, and the external stakeholder's - here Salming's - intended purpose. A question not limiting the solution space to a spike-equipped shoe could have had interesting implications for innovation and the directions possible within the project. However, it would have been too wide to also serve Salming's requirements for the project. This was partly because of the intended context; Salming's position on the market as a smaller actor meant they had limited resources and incentive to carry the risk bringing an entirely new type of innovation to the market. So, while the question of how traction can be achieved still was relevant to the project in other ways, the main formulation of the problem space presumed a running spike. This, we believe, still provided a sufficiently open problem space regarding the requirements of the academically master's thesis framework.

19.3 Influencing the direction of the project

As with much design work, there was a large measure of subjectivity involved in making the decisions, especially those that relied on interpretations of less tangible aspects, such as the brand identity of the company or interpretation of runners expressing their perception of shoe properties and behaviour. While the different activities in the project included investigating factors that could be objectively determined, the direction of the project was certainly influenced by our biases. We believe that to be an inevitable consequence of such a wide-ranging project, focusing on many aspects of use and benefit. The idea of creating a shoe that fits all feet is perhaps an impossible task when also considering the high performance demands of a track spike, and ultimately it can be seen a balance of how specialised toward a certain activity or user group the shoe is and the resources available to find solutions that accommodate the variation present in that range. The choice to design a shoe aiming at a wide target group, including the entire long distance range and steeplechase was perhaps influenced by the nature of the project, as it needed to be challenging enough to function as a master's thesis. A difficult challenge with plenty of constraints can drive both creativity and innovation, which served the academic role of the project well. This had to be balanced with the requirements of Salming, who needed a solution with high prospects of being realistically implementable; not moving too far into unconventional territory. A project with a larger or already established track shoe maker might instead have focused on a much narrower product, such as a shoe directed only at the longer distances or for steeplechase alone. The presence of a range of products that together covers the needs of long distance runners would then lower the importance of width in the final solution. We believe there are many solutions that can be considered equally good, and given the same project executed by different people, such alternative solutions would emerge as well. The solution space presented in this report reflects that in a way, as many approaches were detailed together with those chosen for the final concept, making it possible to arrive at a different but still well-supported shoe design.

19.4 The process

The general process followed the iterative structure and nature detailed in chapter six. The overlapping of different activities and phases made the process feel adaptive and dynamic, hopefully reflecting its true nature and not just our perception of it. Much like solving a Sudoku puzzle - exploring several possible options for each choice with the aim of eliminating them to a single solution - the process would at times require a choice to be locked in to move forward. When the right option was not apparent, there was a risk of getting stuck, just as you may hesitate whether you should investigate deeper to find a definitive clue, or take a leap of faith by just picking a path and hope it pans out. We believe we found a good balance between the two approaches, as there were many such choices to make in this project.

Continuing along the Sudoku analogy, the process phases may also be seen in it. At first, the problem is established by exploring the board, finding the numbers with which you start and cannot change - framing the project. Then, you start filling in numbers of your own in the white boxes, the most apparent solutions, while also starting to explore the options for the less obvious ones. The exploratory phase starts to transition into the creative - designing the solution at the high level of abstraction. These two phases inform each other, each number that is chosen affects what is possible at other places on the board. The process felt very much like that, and when progressing fast, it is easy to see how the reasons for each choice could be forgotten in the haste. Therefore, in the process of developing a product in this way, we found a need to pause from time to time and document the progress and reasons for the choices propelling it. We believe we managed to adequately perform that task. Organising ideas and problems in accordance with the theoretical framework had the ability to create much confusion before significant mental weightlifting sorted out how things were related. These sessions are not easily forgotten.

Generally, the project managed to stick to its schedule, with the exception of the final visualisations which required an additional week of work as the concept resolution became slightly higher than initially presumed. The good adherence to the initial plan could be seen as a positive consequence of the process nature. Working with several tracks at the same time allowed us to identify issues and redistribute resources so that the most prominent challenges received the most attention. Working linearly, such compensation had not been possible to the same extent.

19.5 Methods and activities

The selection of activities for both the exploratory and creative phase worked well to achieve the goals set up in the beginning of the project. Naturally, some areas could not be explored fully due to the time available, detailed in *Limitations*.

The user tests did not involve any longer sessions of use, and instead we had to rely on testimonies from runners. Not seeing the effects of fatigue on the runners first hand could have deepened the understanding of the issues we were trying to solve. This applied not only to the understanding of the runners, but also the shoes themselves. The perception of the shoes might have been different if they had run longer distances in them as part of the benchmarking process. Fatigue and aging of the shoes would provide more performance information to the project with possible design implications.

19.6 Relative properties

The description of what a shoe should be contained tangible and quantifiable properties, such as proportions and amount of stretch in the fabric, but also properties that were harder to define through absolute and concrete measurements. One such example would be the elastic rebound of the shoe, which through rigorous investigation could have been proposed through more concretely defined material properties of the midsole and spike plate, e.g. specific values of bending stiffness at different points in the sole. Like with other aspects of the shoe design, this would have been more easily determined at a later stage, including testing the properties in a real-world setting using physical prototypes. However, theoretical approximation of several such aspects could have been proposed to make the results more concretely defined. Instead, many properties are described relative to other shoe types, or explained how they should be experienced by the runner. While that was the most important part of the result, the material properties and proportions are at some point necessary to make a physical shoe.

The abstraction level at which properties were implemented in the final design proposal varied, much depending on what was possible to achieve in the time available and with what level of certainty the attributes could be determined. At instances where such decision needed to be made, i.e. whether further investigation was worth the time and effort for the increased understanding it would provide, another team might had prioritised differently. It should be noted that explaining the attributes of the shoe as they relate to other shoes within the spike shoe segment, or other categories of shoes entirely, is a necessity to achieve the desired experience of the product. So, concluding that both relative and absolute descriptions of properties are of importance, their importance may change depending on the level of abstraction of the solution. The relative description was perceived to be effective at conveying desired properties to Salming, who are experienced in making other types of shoes to which a spike could be compared to emphasise both similarities and differences.

19.7 User representation

Considering the user group, long distance track runners, and their relatively low numbers in the general population, suitable participants for interviews, user tests, and the survey were surprisingly easily recruited. The variation within the six interviewed runners represented all the different events considered *long distance* in athletics, with at least three runners in every event. Together with the fifty-fifty representation of the sexes, this group were on paper a well-suited to achieve a both wide and deep understanding of the runners, their use, needs and preferences regarding track spikes. While it is possible some aspects of track running with relevance to the project did not appear as a result of the individuals taking part in the interviews, on paper, they were as close can be to a perfect selection of runners given there were six of them. Including additional runners in the interviews could have provided other insights, e.g. doing a selection representing certain on anatomical features or running styles. That was ultimately not possible due to time constraints, but additional knowledge of other runners, their preferences and perceived issues became apparent as some things are shared with others in the running community and therefore could be shared with us through those we had contact with.

The survey performed could thanks to the in-depth interviews with runners and other experts be reduced to the most relevant questions, and the response rate was satisfactory at 39 participators. They represented a wider selection than the interviewees, including middle distance runners for between-group comparison. While we had lower control of the participant profiles, relying on the responders to recuse themselves based on the information provided to them in the beginning of the survey, we see little reason the results would not accurately represent the track running population.

19.8 Personal experience and competence areas

An aspect that likely influenced the project was our relationships to running and the track running context. Both authors are frequent runners, and one also has experience with long distance track running and track spikes. Interest in running was favourable by Salming, and it is hard to deny that it was useful to understand both the runners and the theory related to running. Experience of different types of running shoes could also help reduce the amount of time spent on evaluating possible solutions, as their advantages and flaws might be more apparent. Overall, the project might have come along further than if there was no running experience between the authors. On the flip side, being on the inside of the running bubble might influence and limit the possible routes to a solution, as we are heavily influenced by convention. Therefore, effort had to be made to let go of preconceptions and approach the problems with an open mind. It is hard to determine to what level that was achieved. The fact that only one of us were familiar with track running may have been an advantage, as there were significant differences between the contexts of track running and more typical recreational running. That way, there was some distance to the main context, providing an outside perspective to complement the incredible useful perspective from within.

19.9 Influence from external experts

The final result was influenced by the input from several different people with perspectives on running created by their relationship to it. The selection of whom were included in the project should therefore be considered when interpreting the results. The long-term sustainability of using track spikes, influenced by such things as injury incidence, was perhaps emphasised in this project due to the several orthopaedists and other experts knowledgeable in sports medicine that were interviewed. While the merits of the argument for a certain prioritisation should be considered first hand, it may be affected by the number of voices raising it. In running, several conflicting views on fundamental concepts can be identified, and the science is at times inconclusive. These differing views may exist between groups defined through their area of expertise, and overrepresentation of one group in the selection of external sources may then skew the priorities of the project compared to another selection of people. This could be an explanation as to why we identified a higher need for injury prevention than what is present in many spike shoes available on the market.

19.10 Ethical and environmental considerations

Running shoes are as part of the wider product family of sport shoes and sneakers symbolically connected to controversial issues regarding how they are produced. Even though practices vary between different manufacturers, shoe manufacturing is an infamous example regarding working conditions factories, and that reflects badly on the industry as a whole. Production is typically done in third world countries due to the low cost, and this is associated with lower protection and poor conditions for workers. The relevance to this project comes in the need to acknowledge the impact of how the company chooses to produce the shoe, and what measures are taken to ensure production is done responsibly regarding social sustainability. When it comes to consumer oriented products such as running shoes, economical rationalisation, institutional dependency, and developmental realism are three concepts cited as the main reasons not enough consumer pressure is placed on companies responsible for producing and selling the products (Eckhardt, et al., 2010).

The societal impact potential of this project was assumed to be low; the niche character of the product it means that the commercial market space is narrow and production volumes of a potential product would therefore be relatively low. Relative impact, i.e. the effects of running spikes per unit produced, was estimated to be in the same range as other sport shoes. However, as an elite shoe designed for high performance, there are implications for the durability and lifespan of the shoe, trading the former in favour of the latter two. A shoe which is discarded after only a couple of races as the ultra-light construction cannot hold up to the repeated stresses, has a higher impact in terms of resource use. While such extreme is not the case in the final concept of this project, the durability of the product was not the highest priority. Due to the low production volumes of a potentially realised shoe, the profit of choosing more environmentally friendly materials and manufacturing techniques would in itself have little direct impact compared to a product produced in higher volumes. It could, however, contribute symbolically, should there be a wish to promote an environmentally sustainability initiative, perhaps including a range of such products. Then, the high profile nature of a high performance elite shoe could strengthen the message, but that is more of a marketing hypothetical well without the boundaries of the project.

19.11 Future work and prospects

Should this concept be developed further, much work would revolve around validating the concept ideas more thoroughly and designing the technical aspects of manufacturing. As our experience in shoe design is limited to this project, the fundamental principles developed for the proposal should be reviewed by someone with experience in translating such ideas to a physical prototype. While manufacturing principles have been considered to a great extent in the project, there are likely solutions that are only apparent to an experienced sports shoe designer. Part of this work would involve finalising the design of the last, which we lacked the resources to finish in detailed resolution. The mechanical elements of the shoe would require evaluation through what would likely be a series of runs of prototypes in which the function fit and feel is fine-tuned toward the design goals set in this thesis. As discussed in *Limitations*, physical evaluation of the shoe's different elements would be necessary to further the level of detail in properties of the different parts.

The aesthetical profile of the proposal exemplified how the functional qualities of the shoe could be married with an image that reflected both them and Salming. However, trends are always changing, and the explicit features of an aesthetical profile should be tailored to work well at the time of a hypothetical release of the product. This would include going through an internal design review at Salming to complement this thesis' external interpretation of their brand identity. The values or aesthetical profile they wish to convey may well shift within the time of both a potential decision and realisation of the proposed design.

The prospects of moving forward with further development of the concept relies entirely on the will of Salming to do so. The economic benefit from brand exposure from high profile runners and events would likely be the driving motivation if such a decision were to be made, as the specialised nature of the product and current reach of Salming would likely not make the shoe profitable from sale numbers alone. The findings of the project include exploration of ideas that can have implications for development of other running shoes as well, meaning the use of the project extends beyond the explicit aims detailed in the project scope.

19.12 Wider implications and importance of results

The findings of this project suggest that the current prioritisation of properties in long distance track spikes does not align perfectly with the needs of runners when it comes to sustainable running in training and competition. As this to some extent could be attributed to cultural elements in elite running, widening the available range of shoes to include more models that to a higher degree prioritise stability and support could contribute to shifting the norm in athletics running thereby making track running less harmful to the body and more sustainable. At the very least it would allow those who wish to make that prioritisation to train and compete in shoes that meet their needs and preferences.

Figure 19.1 Collage of the final concept.

20 Conclusion

The goals of the project were reached with the methods uses, identifying both the requirements of a long distance track spike and proposing a way to meet those requirements.
A discrepancy was found between the properties prioritised by runners and what the typical track spike offers. Both runners and experts were sceptical of the market fixation with low ultra-low weight, feeling that properties such as stability and durability suffered from the compromises that were made to shave off additional grams.

Focusing on speed, efficiency, and injury prevention, the design process lead to several solution sets, as well as a final design concept reflecting the functions and attributes prioritised by the runners. The final design proposal took the form of a shoe equipped with five spike and a spike plate covering forefoot, as well as extending back under the midfoot to provide torsional rigidity and elastic rebound. The spike plate was designed to stand out visually, conveying Salming's brand identity during elite competition events. The shoe design is apart from the plate minimalistic to keep the weight low while still prioritising some stability and support needed for the longest distances. By having five spikes instead of the conventional four, and ventilation holes allowing drainage, this shoe is also suitable for steeplechase where redundancy in traction is needed and water jumps exposes the shoe to large amounts of water.

We conceived what we believe is a no-nonsense shoe for long distance track running, but to verify such claim, the development process should continue with producing physical prototypes that can be evaluated toward the highly specific and demanding requirements of elite performance.

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Appendix A - Runner interview guide

Intervju om spikskor och dess användning
Introducera projektet och strukturen på intervjuerna. Fråga om de intervjuade personerna accepterar att intervjun spelas in. De intervjuade personerna kommer vara anonyma. Inköpta skor fungerade som ett diskussionsmaterial.

Om användaren
Vilka typer av löpning sysslar du med?
Hur ser löpning på bana ut? Träning, tävlingar, distanser, hur ofta?
Tempo vid banlöpning?
Olika träning/tävling?
Fotisättning, storlek, fottyp.
Erfarenhet av spikskor för banlöpning? Hur används de? Träning/tävling? Olika träningsmoment?
Finns det vissa pass du helst inte gör med spikskor? Varför?
Har du fått någon skada som du direkt kan koppla till spikskor?
Hur skiljer löpningen sig över året? Periodisering?

Nuvarande sko
Vad för spikskor springer du med idag? Modell? Antal spikar? Hur känns den?
Hur kommer det sig att du springer med just den skon? (Inköp, tips, funktion?)
Vad är det som gör den bra/dålig?
Alltid haft samma märke/modell? Varför har du bytt/inte bytt?
Om du hade fått ändra något på skon, vad hade det varit?
Gör du någon skillnad på medel- och långdistanssko?
Om du bara skulle ha en sko, ska den vara anpassad för längre eller för kortare? Vart görs kompromisser?

Generell om användning på bana
Hur är känns en spiksko jämfört med en vanlig sko? (känns spikarna? passform?)
Blir det annan känsla vid olika hastigheter? Snabbare/långsammare? Vad skiljer sig? Vad tror du det beror på?
Var går gränserna för när spikar börjar bli viktigt för grepp? Tempo och distans.
Får man en mental boost av att ha på sig spikskor?
Skiljer sig behovet av en spiksko mellan olika banor/banmaterial?

Passform
Hur bör passformen vara, vilka ställen ska sitta åt och vilka ska vara lösa? Varför? Hur skiljer sig passformen från en bansko utan spikar/andra löpskor?
Vad har de för typ av fot? Vilka krav sätter fottypen på skon?
Snörning? Gör de någon speciell snörning eller används de som de kommer från affären?
Använder du strumpor i skorna? Varför/varför inte?

Hälen
Vad är viktigt med häldelen av skon?
Hur uppnår man ett stabilt grepp?
Hård eller mjuk?
Passform, greppa om hälen.

Överdelen
Vad är viktigt att tänka på för överdelen?
Material i ovandelen av skon? Hur tunn? Andning? Sidoförstärkningar?
Hur mycket utrymme för tårna?

Sula
Dämpning?
Klack/häl
Behövs innersula i en spiksko?
Yttersulans egenskaper och struktur? Böjbar, vridbar.

Spikarna
Hur bör spikarna vara placerade? Varför? Antal spikar?
Fasta/avtagbara spikar?
Form/längd på spikar?
Går spikarna sönder? Infästningen till spikarna?
Tappar spikar?
Färre spikar blir lättare vikt på skon. Färre spikar och lättare sko? Eller fler spikar men lite tyngre vikt?

Spikplatta
Flexibilitet/styvhet?
Form?
Hur tänker de kring övergång mellan framdel med spikplatta?

Hållbarhet
Vart går skon oftast sönder?
Hur slits den?
På vilket sätt går den sönder, varför? (slits/spricker/torkar)
Hur länge håller spikskor?

Förbättringsmöjligheter med spikskor

Hokas sulor
Det finns skor med asymmetriska sulor i syfte att optimera för vänstervarv. Vad är tankarna kring det? Nackdelar?

Allmänt om praktiska grejer
Välja mellan vikt/passform?
Hur viktigt är vikten av skorna?
Vad är låg vikt?

Hur förvaras skorna när de inte används lika mycket?
Hur förvaras de under säsong?
Rengöring av skor?

Hur interagerar de med skorna, kastar i väskan, bär i påse?
Transport?
Spikar rispar?

Salming
Vad skulle du säga är typiskt Salming?
Vad har du för koppling/åsikter/uppfattning/relation till/om Salming?
Märket?
Produkterna?
Åsikter kring skorna?

Nya tankar som kommit under intervjun
Om du hade fått designa din ultimata sko, hur hade du gjort den sett ut?

De intervjuade får skissa egen spikplatta och placera ut fritt antal spikar på spikplattan

Sammanfattning
Vad är det sämsta med spikskor?
Vad är det bästa med spikskor?

Appendix B - Survey questions

Spikskor

*Obligatorisk

Din löpning

Vilka av följande grenar tävlar du i? *

- ☐ 800 m
- ☐ 1 500 m
- ☐ 3 000 m
- ☐ 3 000 m hinder
- ☐ 5 000 m
- ☐ 10 000 m
- ☐ Tävlar ej

Till vilka distanser händer det att du använder spikskor när du tävlar? *

- ☐ 800 m
- ☐ 1 500 m
- ☐ 3 000 m
- ☐ 3 000 m hinder
- ☐ 5 000 m
- ☐ 10 000 m
- ☐ Händer aldrig

De gånger du inte använder spikskor vid tävling, vilka är anledningarna? Det är möjligt att välja flera alternativ *

- ☐ Sliter på kroppen
- ☐ Förbättrar inte prestationen
- ☐ Behöver mer stöd
- ☐ Inte tillräcklig komfort
- ☐ Använder alltid spikskor
- ☐ Övrigt: ____________

Vilka av följande förhållanden har du upplevt under tävling? *

- ☐ Blöt bana, utomhus
- ☐ Torr bana, utomhus
- ☐ Inomhusbana
- ☐ Tävlar ej

För de alternativ du kryssade i ovan, i hur stor utsträckning använder du/har du använt spikskor?

Lämna tomt om situationen aldrig förekommit.

Blöt bana, utomhus

	1	2	3	4	5	
Använder aldrig	○	○	○	○	○	Använder nästan alltid

Torr bana, utomhus

	1	2	3	4	5	
Använder aldrig	○	○	○	○	○	Använder nästan alltid

Inomhusbana

	1	2	3	4	5	
Använder aldrig	○	○	○	○	○	Använder nästan alltid

Vilka av följande förhållanden har du upplevt under träning? *

- ☐ Blöt bana, utomhus
- ☐ Torr bana, utomhus
- ☐ Inomhusbana
- ☐ Tränar ej på bana

För de alternativ du kryssade i ovan, i hur stor utsträckning använder du/har du använt spikskor?

Lämna tomt om situationen aldrig förekommit.

Blöt bana, utomhus

	1	2	3	4	5	
Använder aldrig	○	○	○	○	○	Använder nästan alltid

Torr bana, utomhus

	1	2	3	4	5	
Använder aldrig	○	○	○	○	○	Använder nästan alltid

Inomhusbana

	1	2	3	4	5	
Använder aldrig	○	○	○	○	○	Använder nästan alltid

Använder du olika skor för olika distanser? *

- ○ Ja
- ○ Nej

Har du någon gång använt spikskor anpassade för banlöpning på terränglopp? *

- ○ Ja
- ○ Aldrig

Prioritering av egenskaper

Vilka 5 av nedanstående egenskaper tycker du är viktigast i en spiksko? Läs alla alternativ innan du väljer. *

- ☐ Dämpande
- ☐ Utstickande utseende
- ☐ Följsam
- ☐ Åtsittande
- ☐ Stabil
- ☐ Styv
- ☐ Stödjande
- ☐ Mjuk
- ☐ Låg vikt
- ☐ Stum
- ☐ Fjädrande
- ☐ Responsiv
- ☐ Stum
- ☐ Fjädrande
- ☐ Responsiv
- ☐ Hållbar
- ☐ Skonsam
- ☐ Hård
- ☐ Säker
- ☐ Förtroendeingivande
- ☐ Neutralt utseende
- ☐ Kännas lätt
- ☐ Anpassningsbar

Fördela totalt 10 poäng mellan nedanstående tre egenskaper hos en spiksko för långdistans. Fler poäng innebär viktigare egenskap. *

Dela ut en poäng per rad. Exemplet nedan visar hur poängen ska föras in i formuläret om man vill ge 3 poäng till låg vikt, 4 till hållbarhet och 3 till stabilitet.

	Låg vikt	Hållbarhet	Stabilitet
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○
1 poäng	○	○	○

Var på följande skalor tycker du att en spiksko anpassad för 3 000-10 000 m ska befinna sig? *

	1	2	3	4	5	
Neutralt utseende	○	○	○	○	○	Sticka ut

*

	1	2	3	4	5	
Styv	○	○	○	○	○	Flexibel

*

	1	2	3	4	5	
Hård	○	○	○	○	○	Mjuk

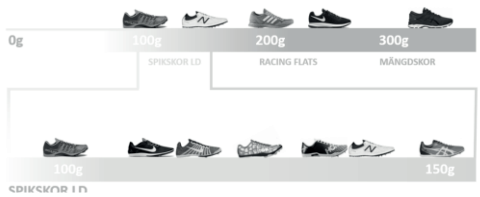
*

	1	2	3	4	5	
Neutral	○	○	○	○	○	Stödjande

Gramjakten

Spikskor för långdistanslöpning väger oftast mellan 100 och 150 gram. I vissa fall skulle den låga vikten kunna påverka andra aspekter av skons egenskaper, så som nivån av dämpning, stabilitet och hållbarhet. Låg vikt är också förknippat med lägre syreförbrukning.

Vikter för några löparskor (ovan) och för spikskor (nedan)



Vad beskriver bäst din inställning till vikten hos en spiksko? *

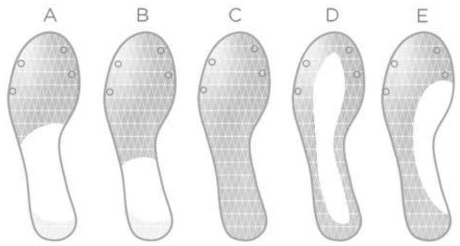
- ☐ Jag bryr mig inte alls om vad spikskon väger
- ☐ Vikten spelar inte så stor roll i jämförelse med andra egenskaper
- ☐ Låg vikt är en fördel
- ☐ Gärna så lätt som möjligt, men det är inte avgörande
- ☐ Varje gram räknas, låg vikt är av hösta prioritet

Utformning

Under hälen finns det ofta ett tunt skikt för att skydda mellansulan och ge lite grepp. Vilken typ av material vill du ha under hälen på en spiksko? *

- ◯ Hård plast (liknande spikplattan)
- ◯ Mjuk plast/gummi (som på konventionella racing flats)
- ◯ Ingenting (mellansulan kommer i kontakt med banan)

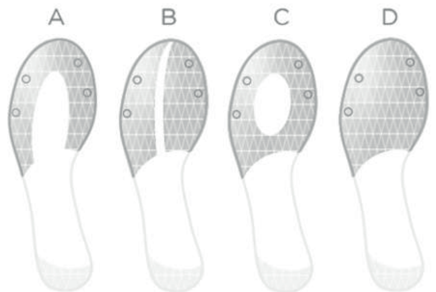
Nedan syns olika typer av spikplattor



Rangordna typerna utifrån hur du uppfattar dem *

	A. Framfot	B. Framfot och mellanfot	C. Heltäckande	D. Uttag i mitten	E. Följer ytterkanten
Bäst	◯	◯	◯	◯	◯
Näst bäst	◯	◯	◯	◯	◯
3:e bäst	◯	◯	◯	◯	◯
4:e bäst	◯	◯	◯	◯	◯
5:e bäst	◯	◯	◯	◯	◯

Nedan syns olika typer av spikplattor



Rangordna alternativen utifrån hur du uppfattar dem *

	A. Hästsko	B. Delad	C. Uttag i mitten	D. Hel framfot
Bäst	◯	◯	◯	◯
Näst bäst	◯	◯	◯	◯
3:e bäst	◯	◯	◯	◯
4:e bäst	◯	◯	◯	◯

Vilken av dessa två utformningsprinciper för föredrar du?

*

- ◯ A. Vanlig utformning - En tunga/plös under snörningen som kan justeras
- ◯ B. Strumpliknande, mono sock - Sitter ihop med resten av ovandelen på skon
- ◯ Det spelar inte någon roll

Fyll i det alternativ som stämmer bäst med ditt behov/användning av inlägg eller egen innersula, samt om du vill ha möjligheten att använda något av dem i en spiksko för långdistans. *

- ◯ Använder ej, men vill kunna använda i en spiksko vid behov.
- ◯ Använder ej, och ser inget behov av att kunna använda i en spiksko.
- ◯ Använder, men har inget behov av att kunna använda i en spiksko.
- ◯ Använder, och vill kunna använda i en spiksko vid behov.

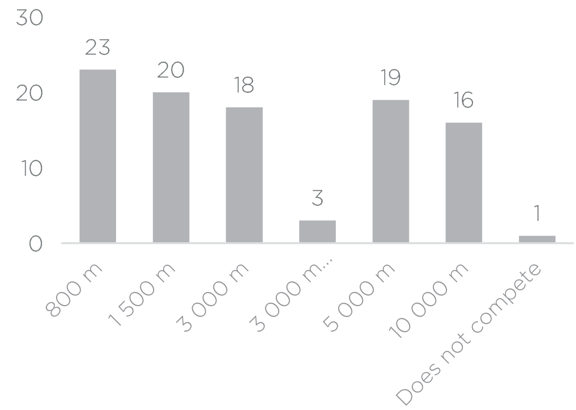
Intervjuer

Fyll gärna i din mejladress om du kan tänka dig att vara med på en kort intervju i Göteborgsområdet om spikskor och deras design.

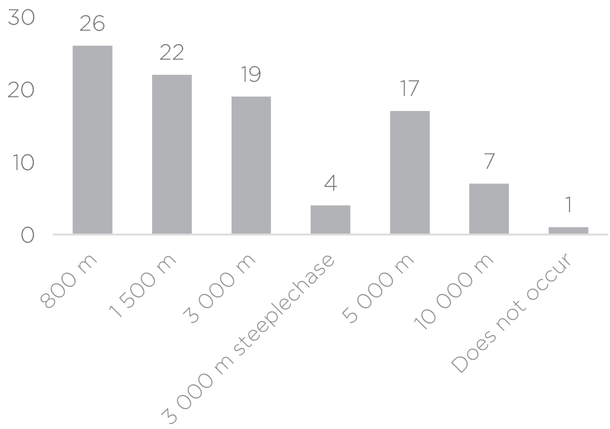
Ditt svar

Appendix C - Processed survey results

Processed results from online survey of 39 middle- and long distance runners with track spike experience. The survey was conducted in Swedish, and the results are presented in English.

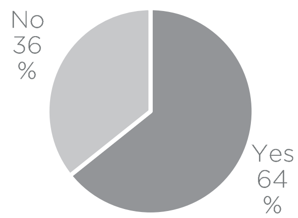


Distribution of competition distances.

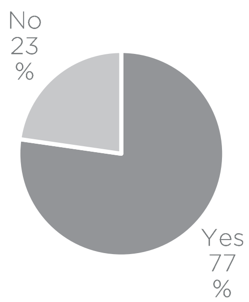


Use of spike shoes during competition.

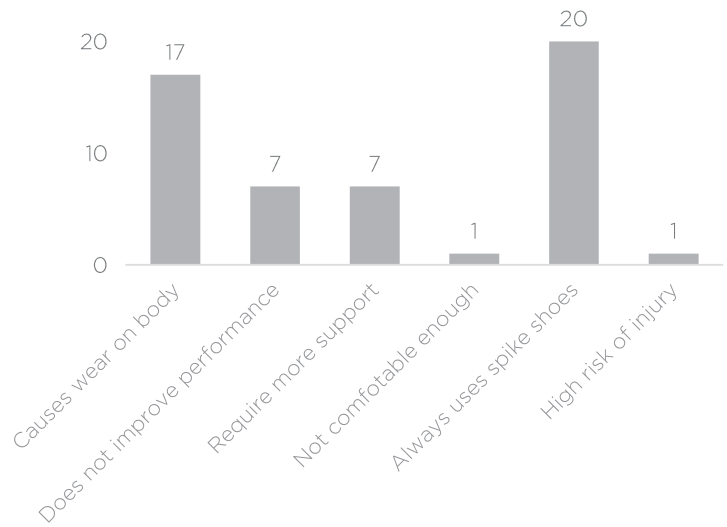
Use of different shoe models among multi-distance track runners.



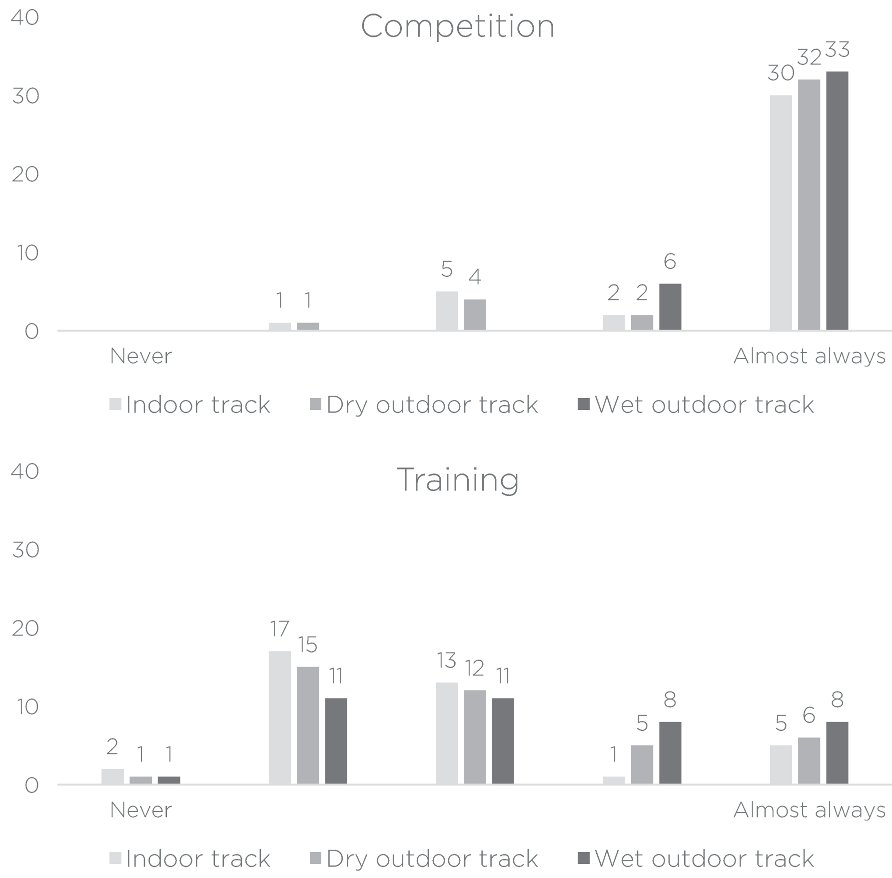
Long distance runners who at least once have used track spikes in terrain conditions.

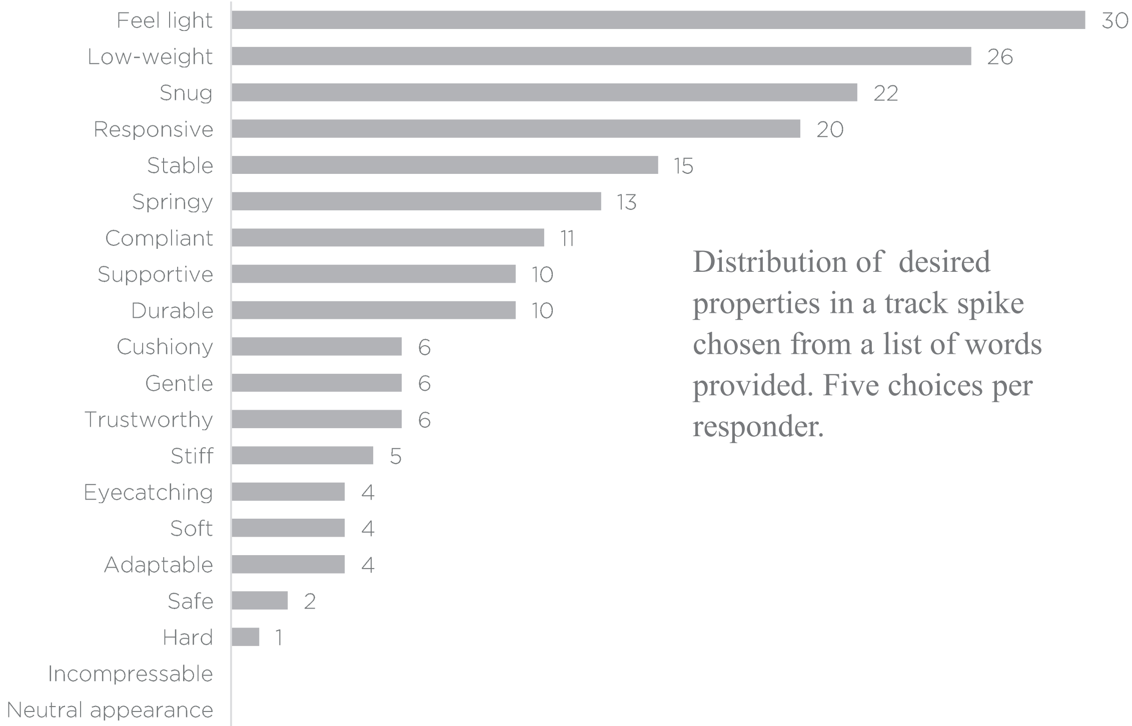


Experienced causes of not using track spikes during competition.



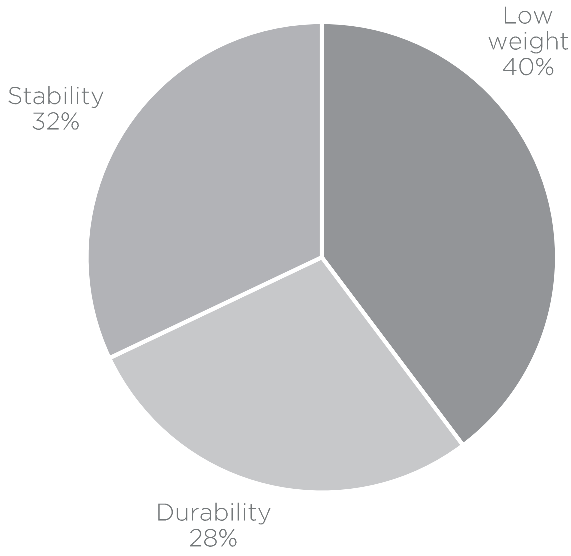
Reported frequency of track spike use in various conditions.



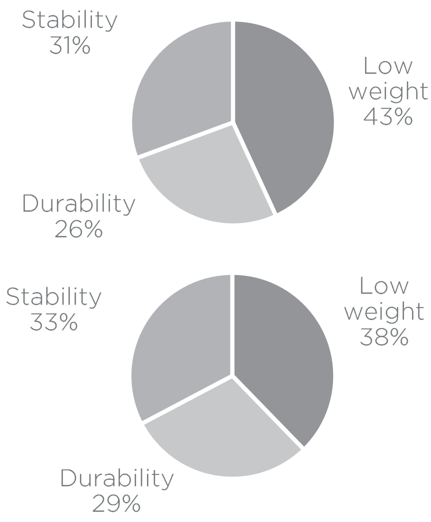


Distribution of desired properties in a track spike chosen from a list of words provided. Five choices per responder.

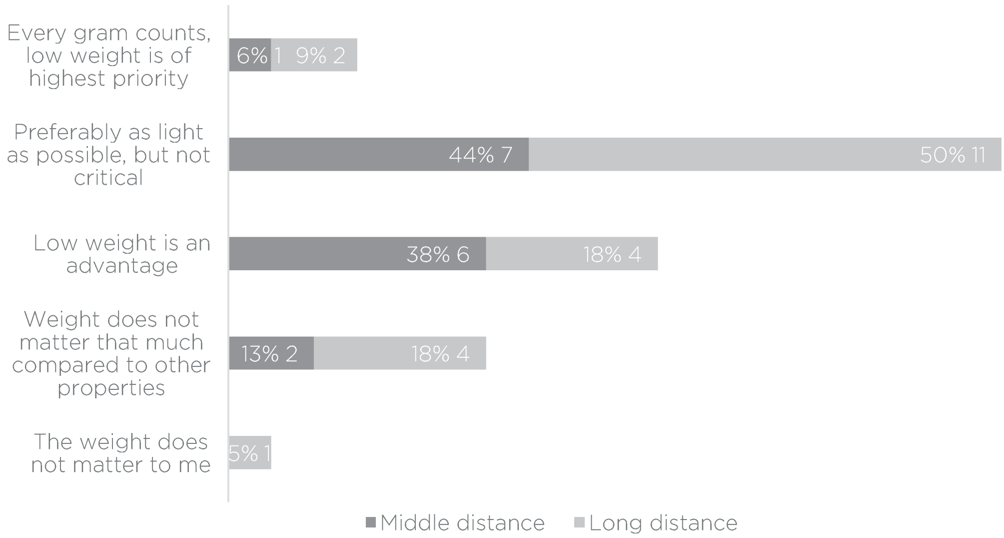
Distribution of points across three different properties. Each responder distributed ten points.



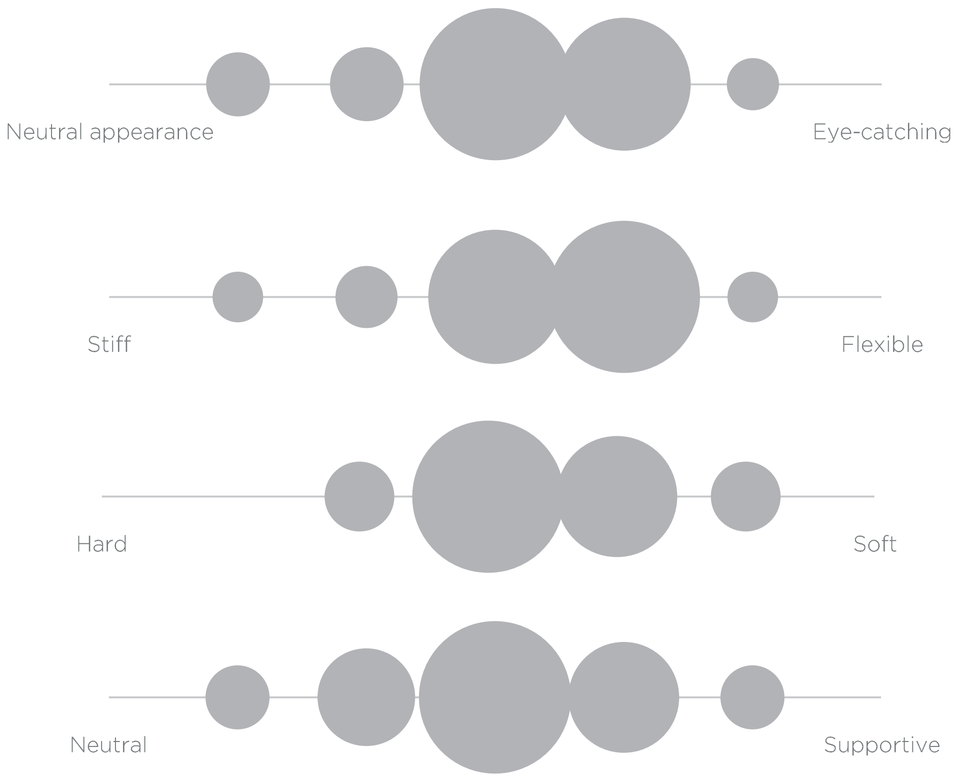
Distribution of points for middle- and long distance track runners respectively.



Attitude toward weight of track spike for middle- and short distance runners.

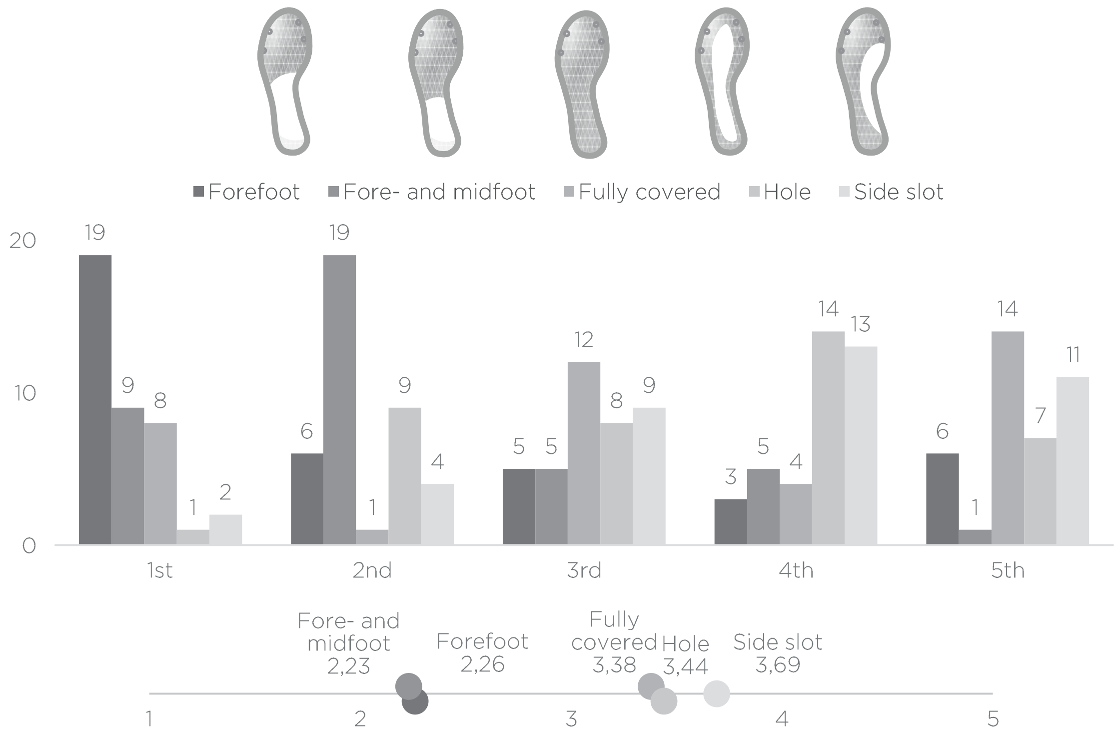


Distribution across five-increment spectrums of properties of long-distance track spikes.

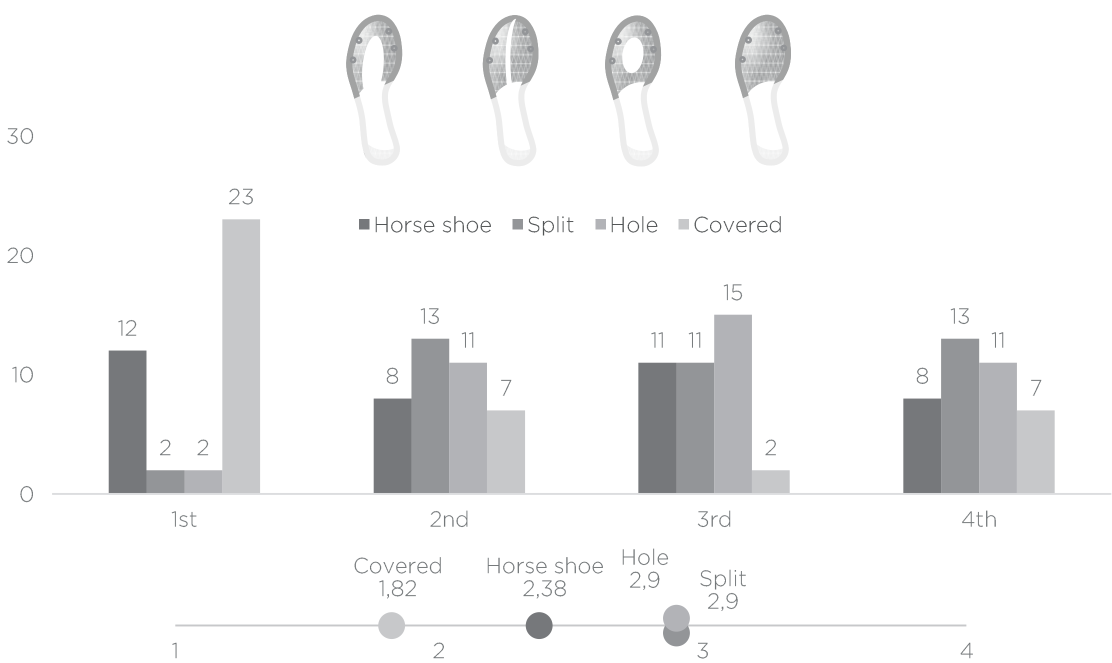


Appendix C

Ranking of options for principle design of spike plate shape, and average ranking

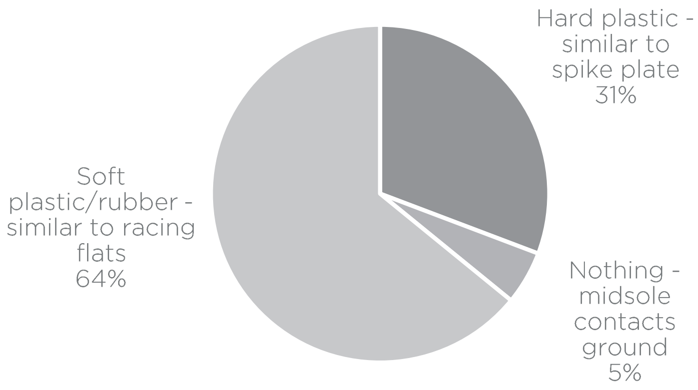


Ranking of options for principle design of spike plate shape, and average ranking.

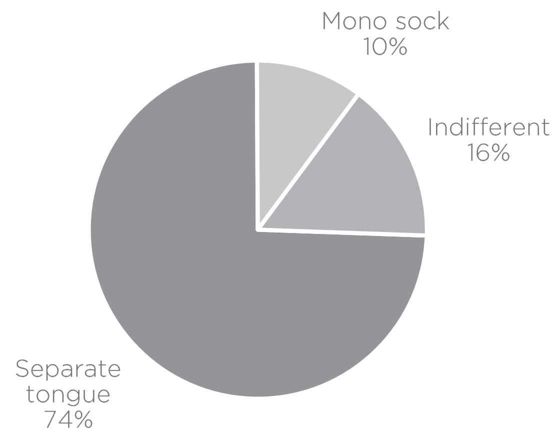


Appendix C

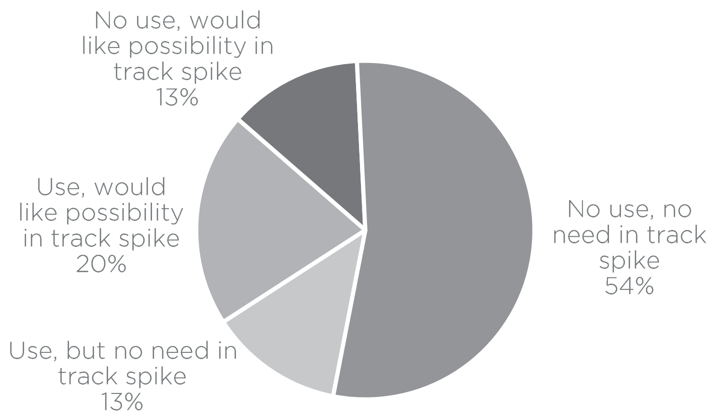
Preferred sole design option under heel.



Preferred design option dorsum cover.



Use of orthopaedic insert or custom footbed and attitude toward being able to use in track spike.



Appendix D - User test questionaire

New Balance:
Vad får du för intryck av skon innan du tagit på den?
Hur känns den när den är på?
Skiljer sig känslan från vad du förväntade dig utifrån första intrycket?
Hur känns löpningen i olika farter samt i kurva och på raksträcka?
Vad tycker du om passformen generellt?
Vad tycker du om utformning (form/material) och passform av:
Hälen?
Tårna?
Förstärkningar/stöd?
Ovandelen?
Tungan?
Mellan- och innersulan (Tjocklekar/Hårdhet/Dämpning)?
Spikplattan (formen/styvhet/hårdhet/studs)?
Placeringen av spikarna?
Vilka distanser hade du valt att springa med dessa skor?
Vad hade du ändrat på detta par för att de skulle bli ännu bättre?
Vad var det bästa med skon?

Nike:
Vad får du för intryck av skon innan du tagit på den?
Hur känns den när den är på?
Skiljer sig känslan från vad du förväntade dig utifrån första intrycket?
Hur känns löpningen i olika farter samt i kurva och på raksträcka?
Vad tycker du om passformen generellt?
Vad tycker du om utformning (form/material) och passform av:
Hälen?
Tårna?
Förstärkningar/stöd?
Ovandelen?
Tungan?
Mellan- och innersulan (Tjocklekar/Hårdhet/Dämpning)?
Spikplattan (formen/styvhet/hårdhet/studs)?
Placeringen av spikarna?
Vilka distanser hade du valt att springa med dessa skor?
Vad hade du ändrat på detta par för att de skulle bli ännu bättre?
Vad var det bästa med skon?

Hoka One One:
Vad får du för intryck av skon innan du tagit på den?
Hur känns den när den är på?
Skiljer sig känslan från vad du förväntade dig utifrån första intrycket?
Hur känns löpningen i olika farter samt i kurva och på raksträcka?
Vad tycker du om passformen generellt?
Vad tycker du om utformning (form/material) och passform av:
Hälen?
Tårna?
Förstärkningar/stöd?
Ovandelen?
Tungan?
Mellan- och innersulan (Tjocklekar/Hårdhet/Dämpning)?
Spikplattan (formen/styvhet/hårdhet/studs)?
Kändes de assymmetriska sulorna av något?
Raksträcka/kurva?
Fördel/nackdel?
Placeringen av spikarna?
Vilka distanser hade du valt att springa med dessa skor?
Vad hade du ändrat på detta par för att de skulle bli ännu bättre?
Vad var det bästa med skon?

Jämförelse mellan alla:
Vad kan du se för likheter och skillnader i skorna?
Likheter/skillnader på känsla? Passform?
Utformningen?
Är det någon som sticker ut?
På vilket sätt? Bra/dåligt?
Vilken av dessa skulle du välja bort först?
Varför?
Om du skulle köpa nya spikskor inför sommaren 2018, vilken av dessa tre skulle du köpt då?
Varför?

Appendix E - Requirements overview

Needs

Goals
Maximise athletic performance during long distance track running

Requirements
Adhere to IAAF regulations
Not cause damage to track
Not cause pain
Not cause injury
Convey Salming's brand identity

Guidelines
Energy input should propel runner forward
Endure one season of wear
Comparable performance to equivalent products

Use requirements

Goals
Efficient force transfer from foot to track
High rate of force transfer
Energy efficient stride
Provide mental boost

Requirements
No lateral movement of planted foot
Allow use with/without socks
Allow use of custom footbed
Allow heel planting
Tolerate water exposure
Tolerate ambient temperature interval -10 °C to 40 °C

Guidelines
Allow use of natural stride mechanisms
Tolerate dynamic forces of stride
Promote stable ankles during stride
Accommodate common foot types
Minimised weight
Minimised odour
Not interfere with athlete's routines
Perceived as a high-performance shoe

Product requirements

Requirements (functional)
Provide grip in transverse plane
Provide space for toe spreading
Allow use with industry standard spikes
Tolerate track contact abrasion
Transport moisture from foot
Transport heat from foot
Drainage of ingressed water
Room for footbed
Allow toes to spread during planting
Adjustable tension across dorsum of foot

Guidelines
Promote stable ankles during stride
Minimise water retention
Provide information about condition
Prevent high heel impact force
Minimise bacterial growth
Minimise abrasion against foot
Minimal cushioning
Tight fit
Adapt to shape of foot
Provide redundancy in traction
Feel light
Feel responsive
Feel springy

Sub-system requirements

Requirements (functional)

Midsole
Attach to upper
Hold spike plate
Support insole
Provide minimal elastic cushioning
Hold strobel
Attach heel counter
Support foot
Refuse water absorption
Transfer lateral force

Footbed
Distribute pressure
Transfer force
Support foot
Grip foot
Grip strobel
Divert moisture

Heel section
Hold footbed
Pull upper
Attach to midsole
Attach to strobel
Wrap heel
Guide heel

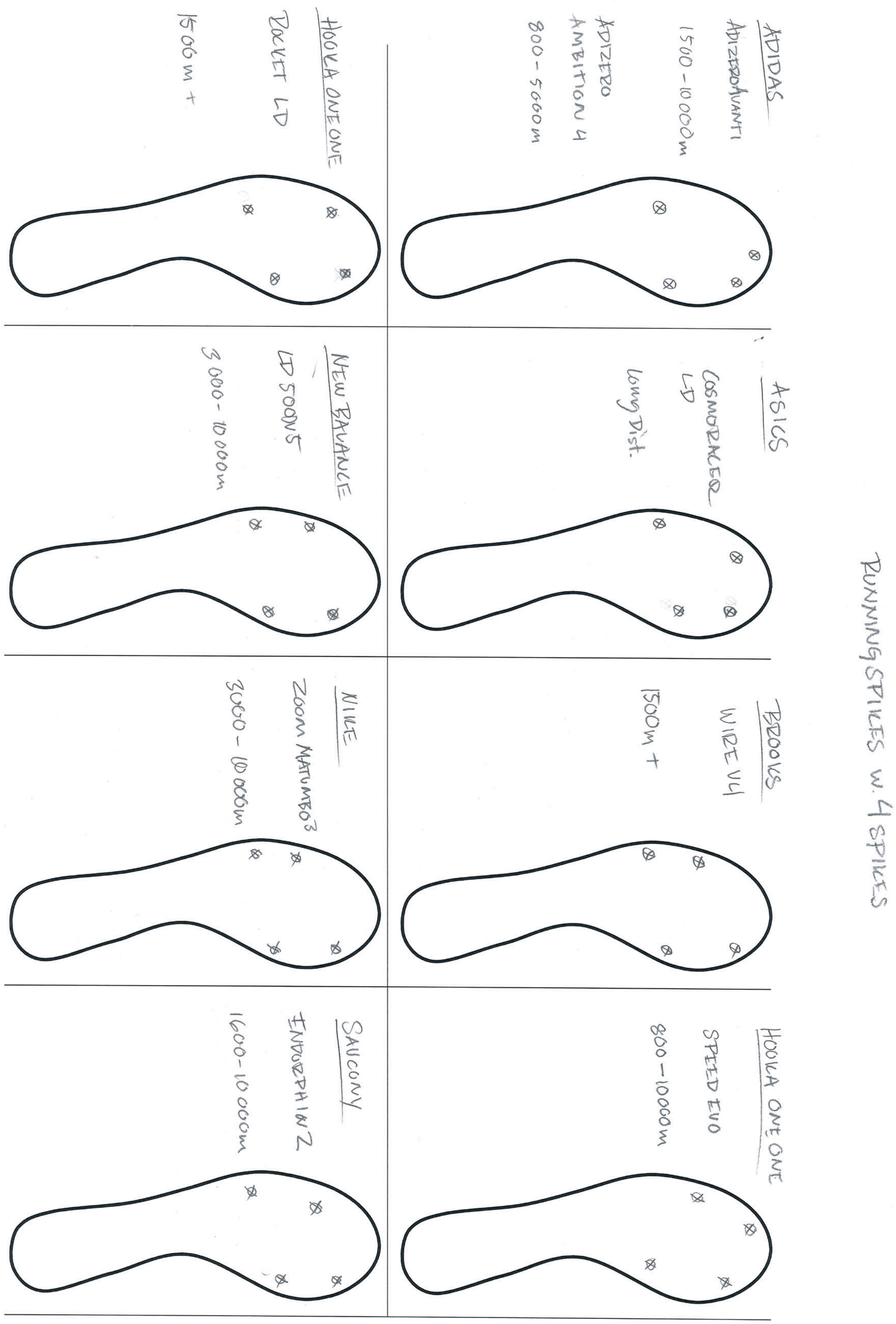
Upper
Allow different lacing techniques
Express brand identity
Provide stretch
Hold foot
Provide ventilation

Lace
Tighten upper
Apply pressure to dorsum cover
Distribute pressure
Allow access to hands
Allow grip

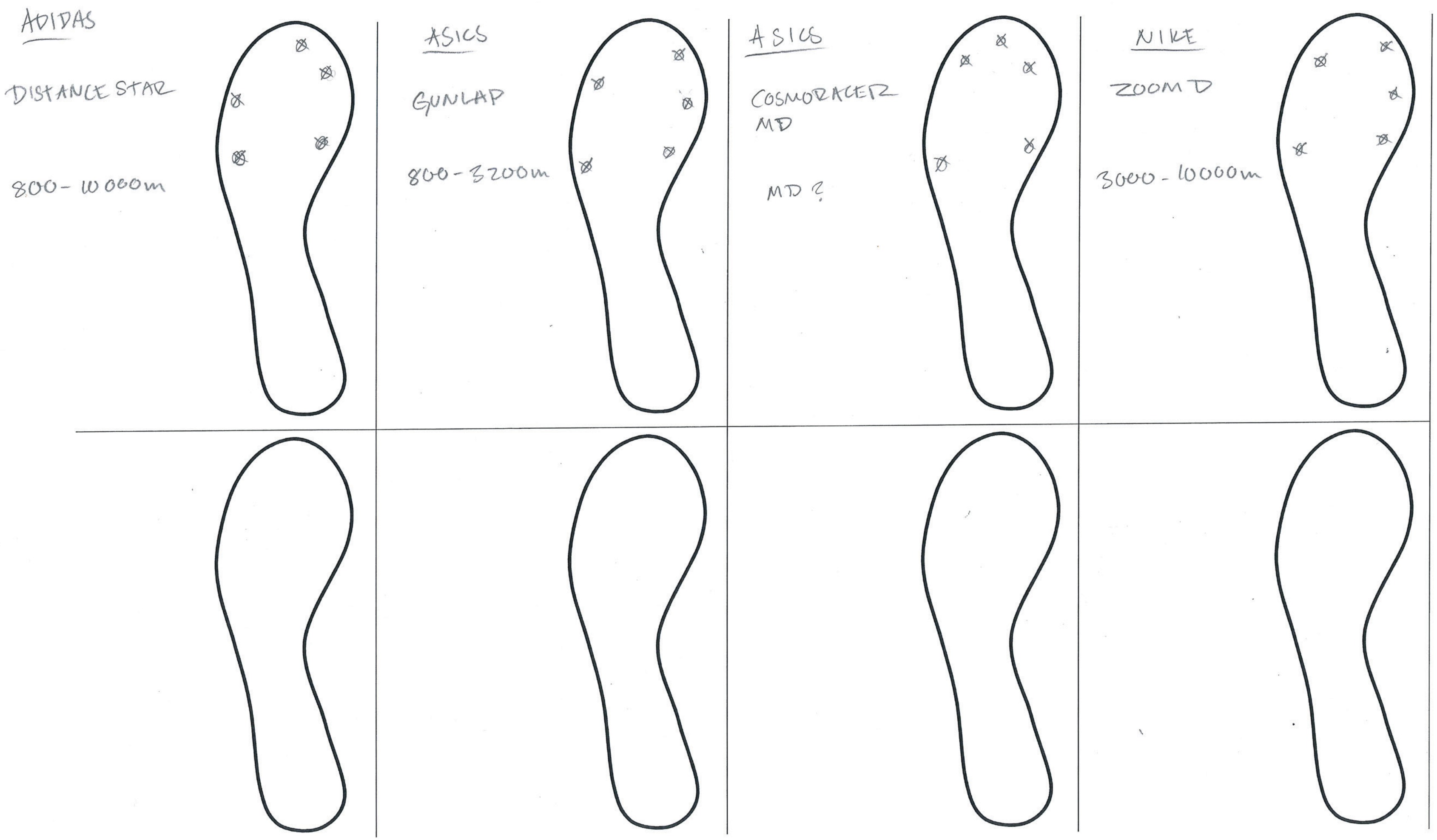
Spike plate
Hold thread inserts
Grip track surface
Transfer force
Distribute point pressure
Provide elastic rebound
Provide torsional rigidity
Allow tool access
Express brand identity

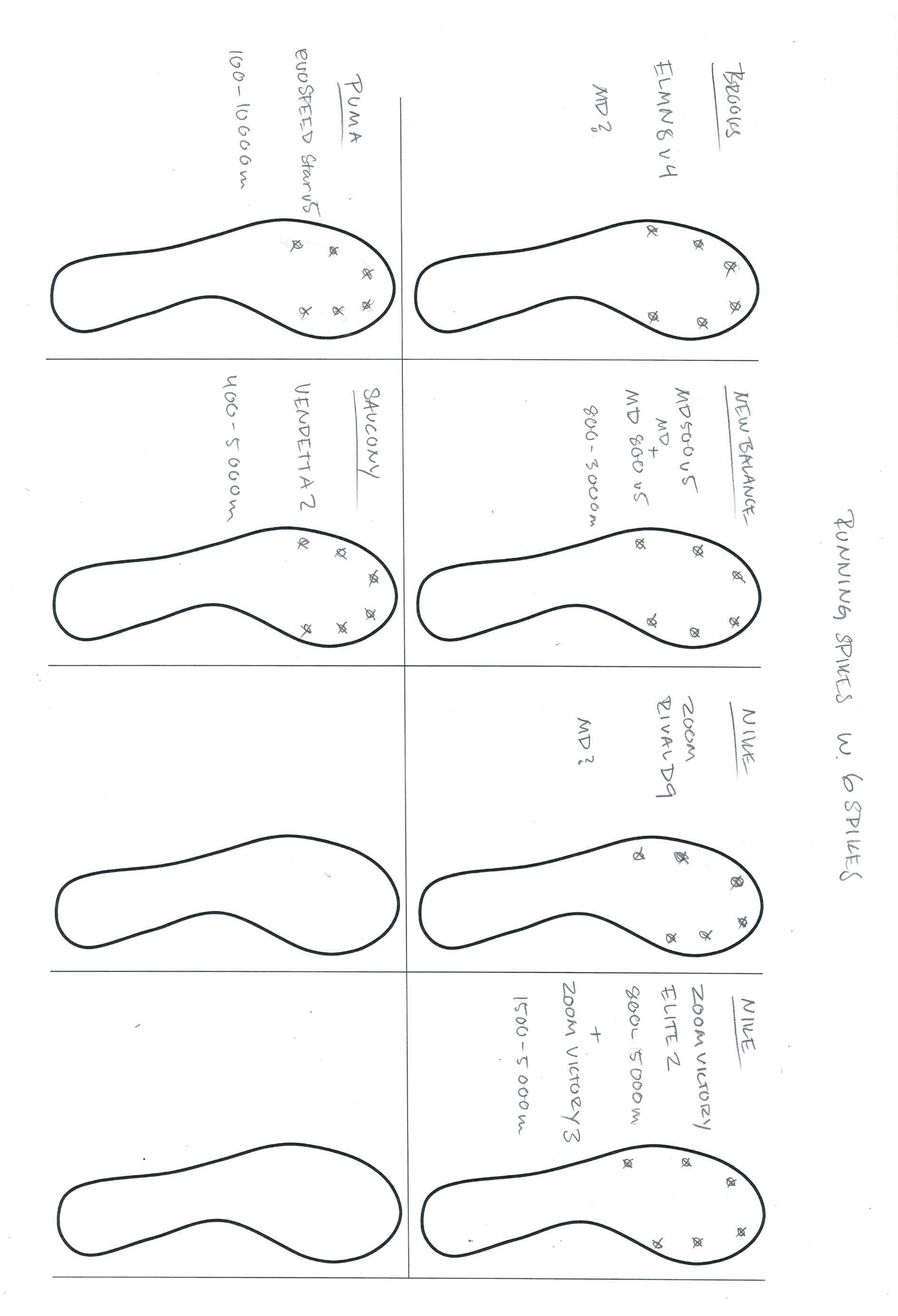
Spikes
Grip track surface
Attach to thread inserts
Detach from thread inserts
Accept tool

Appendix F - Spike placement mapping

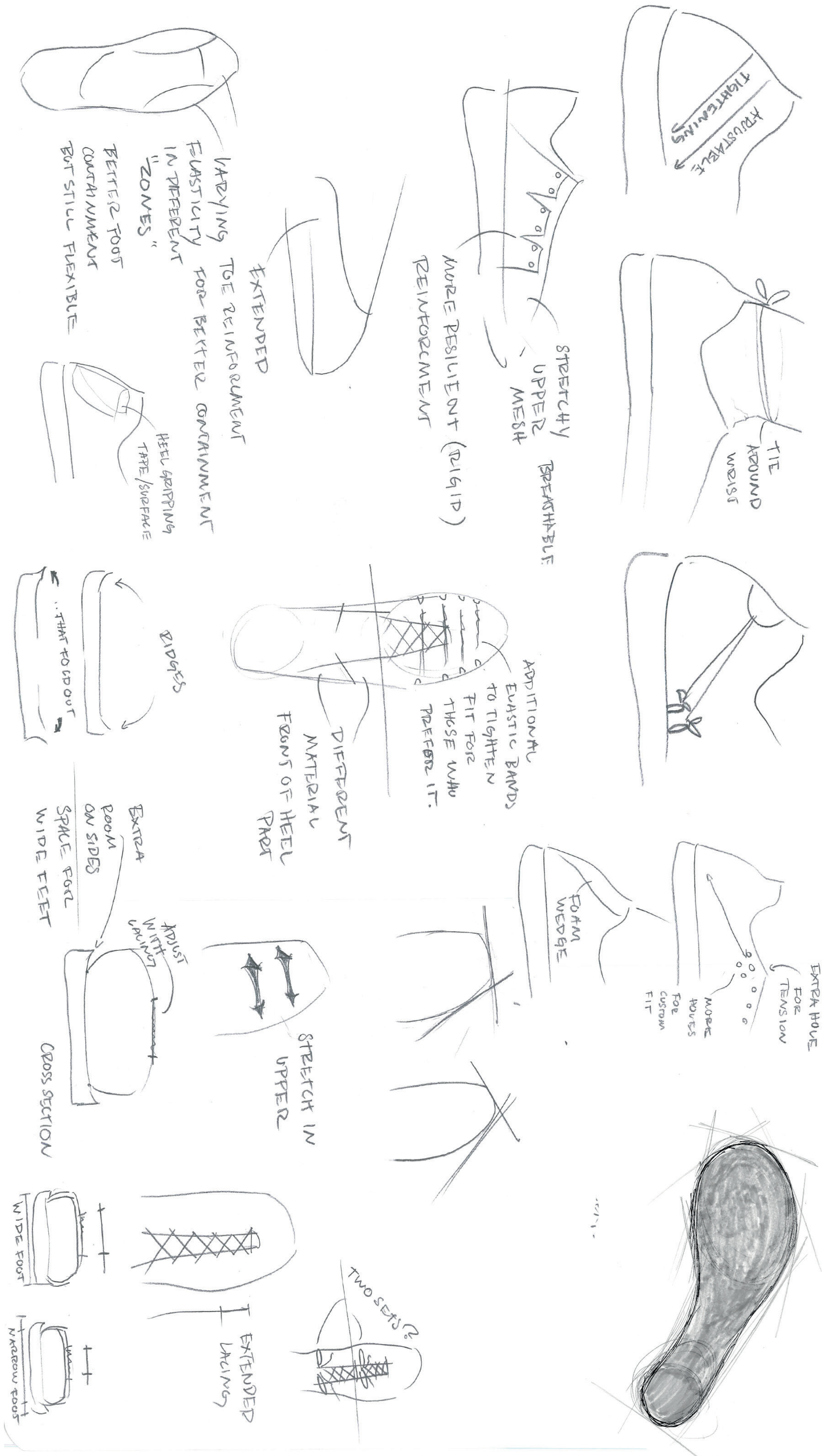


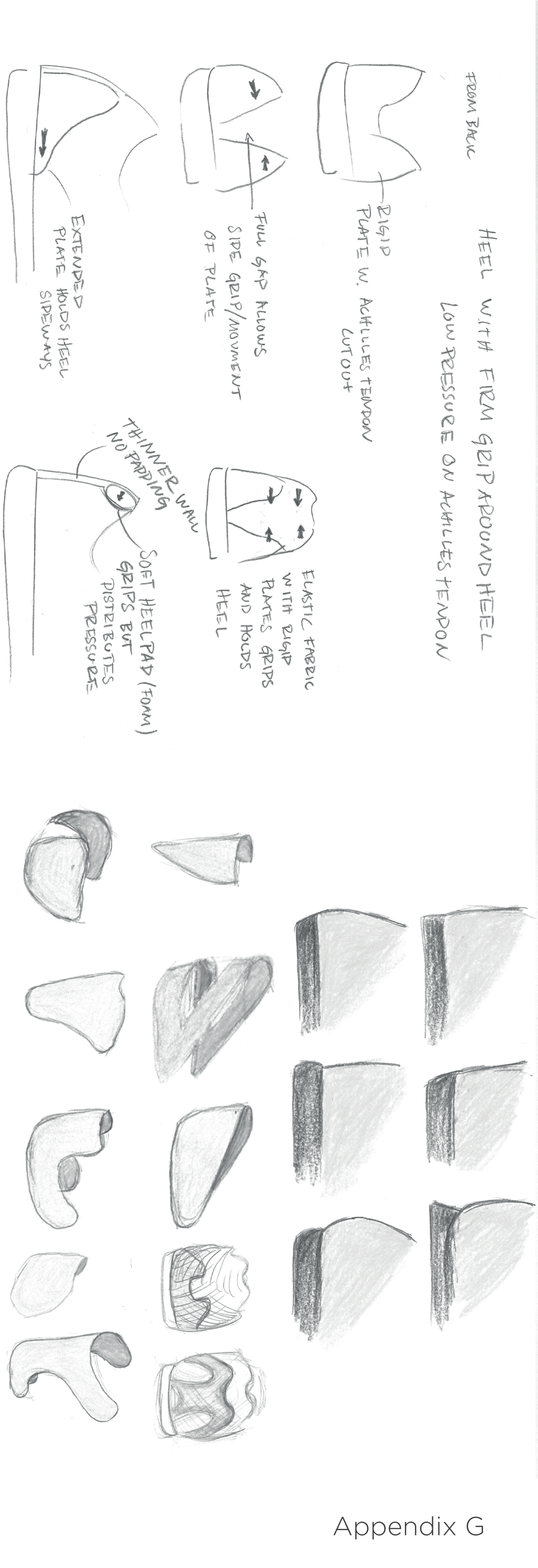
RUNNING SPIKES W. 5 SPIKES

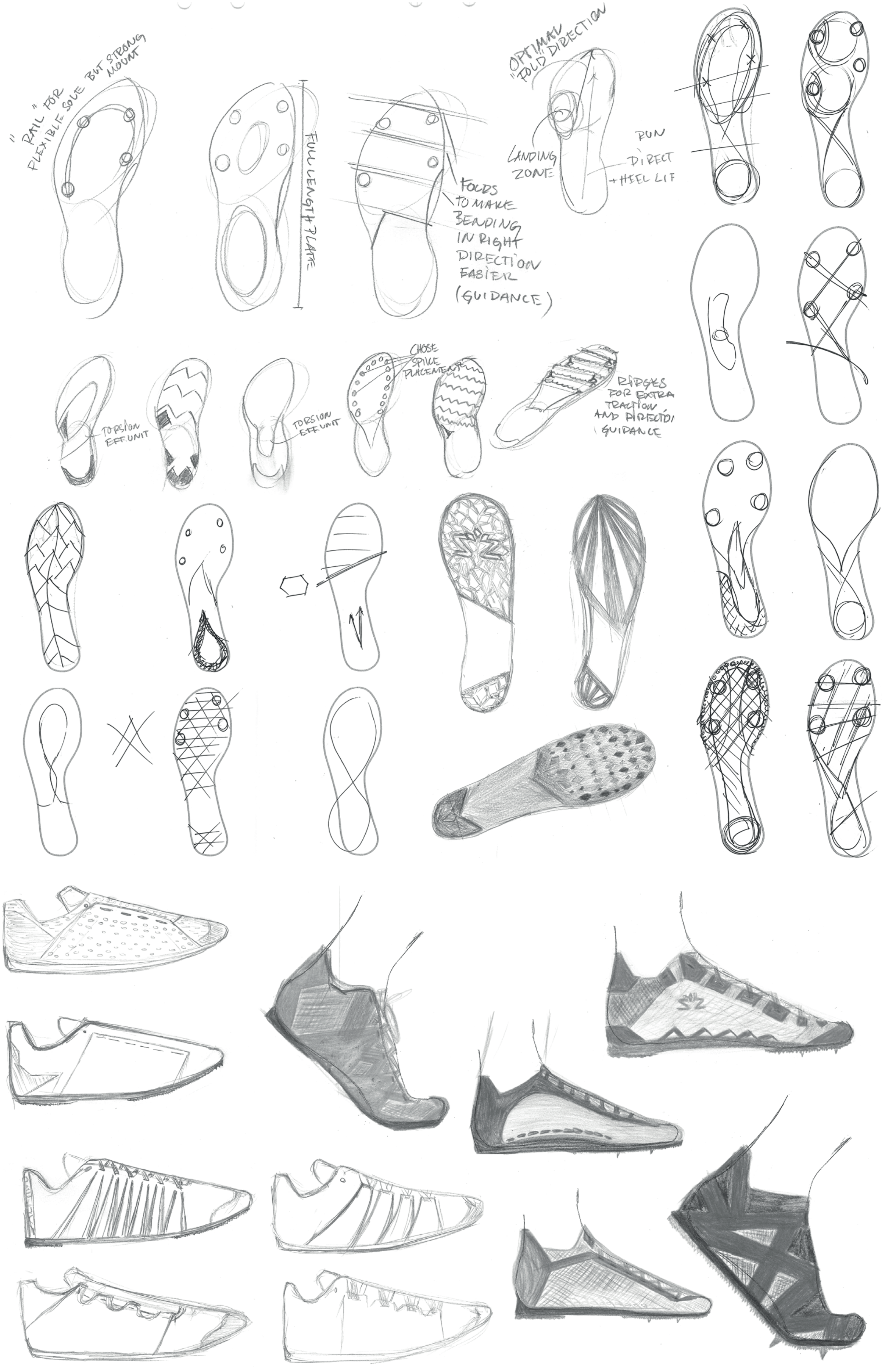



RUNNING SPIKES W. 6 SPIKES
BROOKS
ELMN8 v4
MD?
NEW BALANCE
MD500 v5
MD
+
MD 800 v5
800-3000m
NIKE
ZOOM
RIVAL D9
MD?
NIKE
ZOOM VICTORY
ELITE 2
800L 5000m
+
ZOOM VICTORY 3
1500-5000m
PUMA
evoSPEED Star v5
100-10000m
SAUCONY
VENDETTA 2
400-5000m

Appendix G - Ideation sketch samples




FROM BACK
HEEL WITH FIRM GRIP AROUND HEEL
LOW PRESSURE ON ACHILLES TENDON
RIGID
PLATE W. ACHILLES TENDON
CUTOUT
FULL GAP ALLOWS
SIDE GRIP/MOVMENT
OF PLATE
EXTENDED
PLATE HOLDS HEEL
SIDEWAYS
ELASTIC FABRIC
WITH RIGID
PLATES GRIPS
AND HOLDS
HEEL
THINNER WALL
NO PADDING
SOFT HEELPAD (FOAM)
GRIPS BUT
DISTRIBUTES
PRESSURE


"RAIL" FOR FLEXIBLE SOLE BUT STRONG MOUNT
FULL LENGTH PLATE
FOLDS TO MAKE BENDING IN RIGHT DIRECTION EASIER (GUIDANCE)
OPTIMAL "FOLD" DIRECTION
LANDING ZONE
RUN DIRECT
+HEEL LIF
TORSION EFF.UNIT
TORSION EFF.UNIT
CHOSE SPIKE PLACEMENT
RIDGES FOR EXTRA TRACTION AND DIRECTIO GUIDANCE

Appendix G