

EXPLORING ERGONOMIC FEATURES AND INNOVATIVE TECHNOLOGIES IN MODERN FOOTWEAR DESIGN

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Abstract. *In addition to considering basic practicality, fashionable and popular attributes, and social attributes of consumers, the design of modern footwear products has begun to appear to focus on the combination of design and ergonomics in order to seek high-level innovation. This study uses methods such as case studies, analogies, and literature reviews to explore the intersection of design and ergonomics in footwear. Based on the analysis of shoe design and functional attributes, the latest achievements in product development and scientific research are analyzed, and innovative approaches in this field are summarized.*

Keywords: *ergonomics, design, shoes, functionality*

Introduction

While pursuing fashionable aesthetics and displaying individual expression, modern shoes design pays more and more attention to achieving a high degree of unity between artistry and functionality. Consumers not only expect shoes as accessories to show their unique aesthetic style in terms of shape, structure, colour, etc., but also require comfort, health and sports performance to meet the needs of daily wear, special occasions or specific sports scenarios. From the fusion of morphological aesthetics and human anatomy, to the interaction between colour, material and ergonomics; from the combination of technological innovation and ergonomics, to the expression of individuality and biomechanical considerations in customised services; to the communion of sustainable design concepts and human comfort [1]. These elements are intertwined with each other, and this paper will conduct research in these aspects to explore how to realise the perfect combination of artistry and functionality in modern footwear products.

1. Types of specialized shoes that are closely integrated with ergonomics

In sports, we often come across footwear that incorporates ergonomic design ideas, such as many types of professional sports shoes, including Basketball shoes with cushioning (as shown in Fig. 1), Soccer shoes with stopping function, running shoes with energy recovery [2] and so on. Special footwear is often used in orthopedic and rehabilitation treatments for lower limb and foot surgery, and the design of these medical footwear has in-depth experimental information and results incorporated in ergonomics [3]. For example, Fig. 2 shows a shoe used to assist in the treatment of foot bone fractures.

In the military field, soldiers often encounter different environmental conditions such as extreme cold, heat, humidity, water bodies, deserts, among others, while performing various tasks (as shown in Fig. 3). Shoes for the Air Force, Navy, and other specialized services have more specific needs, so the design of combat boots needs to incorporate more ergonomics into the design. Along with the worldwide economic development and the improvement of living standards, activities such as professional fitness, outdoor adventures, high-end medical

rehabilitation, orthopedic interventions and others are included in the everyday life of common people. The specialized design required for these activities becomes a necessary standard for the design of common footwear.



Figure 1. Basketball shoes with cushioning



Figure 2. Fracture rehabilitation shoes



Figure 3. U.S. Army boots

2. Ergonomic features and innovative technologies of sports shoes

Accompanied by the rapid development of competitive sports and countries' investment in sports for all, athletic shoes have also stepped into the fashion world and people's lives from the athletic stadium, and become an artistic treasure integrating the elements of athleticism, ergonomics and fashion. Athletic shoes, a footwear product in the professional sense, have also risen in demand. In the manufacturing sector, the design of athletic shoes has become even more diverse.

The combination of classification, specialization and ergonomics in the design of athletic shoes provides athletes with maximum efficiency in the process of sports, and is a powerful aid for athletes to achieve the goal of "higher, faster, stronger", which has become an important symbol of modern athletic shoe innovation and design. In the process of the development of competitive sports, athletes are specialized in their own abilities, so the important sports equipment used in the training and events of the athletic shoes also shows the characteristics of specialization, and even the phenomenon of separating the same athletic shoes from the training shoes for the field of competition [4].

The bones of the foot are connected to each other in an arch-like structure called the arch of the foot. Those arranged in the transverse direction are called transverse arches and those arranged in the longitudinal direction are called longitudinal arches. The lateral one is called the external longitudinal arch and consists of the heel bone, the dice bone, and the fourth and fifth metatarsals. There are also two transverse arches of the foot; the anterior transverse arch consists of the metatarsophalangeal joints, and the posterior transverse arch consists of the three cuneiform bones and the dice bone. There are two longitudinal arches: the medial longitudinal arch and the lateral longitudinal arch; the medial one is called the medial longitudinal arch and consists of the talus, navicular bone, three cuneiform bones, and the first, second, and third metatarsals [5] (as shown in Fig.4).

The foot relies on the structure of the arch and the attached ligaments to produce elasticity. When a person stands or walks, the internal and external longitudinal arches and the posterior transverse arch always maintain a bowed structure. When standing still, the anterior transverse arch maintains a bowed shape. However, during walking, as a person's center of gravity moves to the metatarsophalangeal joints, the bowed shape of the anterior transverse arch disappears at the same instant. When the center of gravity continues to move forward, the anterior transverse arch returns to its bowed shape, completing the mechanical work. When bouncing or gravity presses down, the internal and external longitudinal arches press down, dispersing the force to the anterior transverse arch and the heel bone. The anterior transverse arch presses down, completing the dispersal of the force, and then the arch springs back, completing the cushioning effect [6].

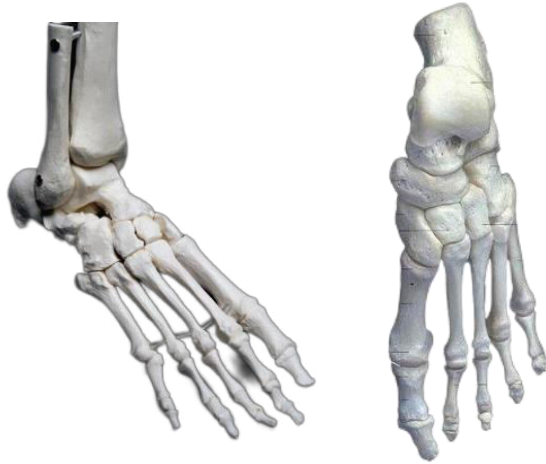


Figure 4. Foot bones



Figure 5. Honeycomb structure of the sole



Figure 6. Inflatable air cushion structure of the sole

Therefore, when designing footwear, it is crucial for designers to not only incorporate formal beauty elements and artistic principles but also consider and support the movement characteristics of the human body. Integrating ergonomic elements into the design process can assist designers in enhancing the quality of products comprehensively. This, in turn, can increase market acceptance and elevate the added value of the products [7].

In terms of shock-absorbing footwear design, designers often use a number of biomimetic design solutions, such as curved, honeycomb structure (as shown in Fig. 5), winding form, inflatable air cushion structure (as shown in Fig. 6) and so on.

Here we adopt a case study approach to analyze the "Li-Ning Bow" (as shown in Fig. 7) shock absorption technology designed by the famous Chinese sports brand "Li-Ning". The "Li-Ning Bow" shock absorbing technology is developed by utilizing the principle of relieving pressure by imitating the deformation of the arches of the human foot bones under pressure. The arch is the core component of the shock absorption function and has a very large deformation capacity. It is able to cushion the impact of the ground through appropriate deformation when the heel hits the ground. The core of the middle front part has superb toughness, the outer structure has superb elasticity, all of which provide perfect stretching ability for shock absorption deformation, and at the same time ensure the normal contraction of the Tensile, which plays a role in maintaining the durability of the overall structure. The PU component maximizes stability while ensuring shock absorption. The asymmetrical PU detailing on the heel is designed to maximize the stability of the heel when landing on the ground. The lateral extensions of the PU post and Arch on both sides play a key role in stabilizing the heel after landing. The perfect combination of the three components not only ensures the functional requirements of running, shock absorption and stability, but also realizes the technology that can be seen, touched and felt, and realizes the organic integration of ergonomics into the product design.

There is also a typical case of ergonomics being integrated into footwear design in soccer. The design of soccer shoes is aesthetically pleasing and requires spikes on the sole to enhance grip, an aspect that is well known to the general public. However, effective stopping power of the upper surface of the forefoot is also important for soccer players, which requires special attention to the design of the "toe box" of the shoe. This area should be reinforced with multiple layers or false stitching to break the ball's momentum upon contact with the shoe surface, aiding in quicker deceleration (as shown in Fig. 8). Since it is important for athletes to minimize the support during sports activities, designers should pay attention to the entire upper plate during the development of sprinting sports shoes.



Figure 7. The "Li-Ning Bow" structure Figure 8. Design of soccer shoes for stopping the ball

Conclusions

With the improvement of people's living standards and the development of science and technology, more and more ergonomic demands are introduced in product production. In footwear product design, more and more ergonomics issues such as comfort performance, hygiene performance, medical rehabilitation function, safety performance, etc. are integrated with art design and formal aesthetics. Modern designers should summarize the changes and requirements of the corresponding design rules in order to make design works to enhance the added-value. By combining art, science, and technology, designers can create footwear that enhances value and resonates with consumers' evolving needs and preferences.

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