

Virtual Prototyping of Spacer Fabric Shoe Uppers for Racket Sports

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Abstract:

This article thoroughly explores the virtual prototype development of an asymmetrical shoe upper designed specifically for amateur athletes engaged in racquet sports such as badminton and tennis. The study targets athletes aged 12-16, focusing on enhancing comfort, performance, and aesthetics. Utilizing Spacer fabric, known for its superior breathability, cushioning, and flexibility, the research aims to address the unique biomechanical demands of lateral movements in racquet sports. The article highlights the design attributes derived from comprehensive surveys and data analysis, emphasizing the significance of vibrant colors and ergonomic features. The methodology encompasses material selection, design parameter analysis, and prototype development, culminating in a discussion on the implications for amateur athletes' performance and psychological well-being.

Keywords: Asymmetrical upper, amateur athletes, racquet sports, Spacer fabric, virtual prototype

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1. Introduction

The complex interplay between psychological perceptions, preferences, and design components is crucial when it comes to athletic footwear, especially for amateur athletes who participate in racquet sports like tennis and badminton [1]. These sports require quick lateral movements, which put a lot of strain on the lower limbs [2, 3]. To reduce the risk of injury and improve performance, specialist footwear is required. This article explores the development of a virtual prototype for a shoe upper specifically designed to meet the demands of amateur athletes between the ages of 12 to 16, a group distinguished by developing and sensitive feet [4]. The study highlights how an asymmetrical shoe upper that satisfies the biomechanical needs of lateral mobility may be made using Spacer fabric, which is renowned for its breathability, moisture management, cushioning, and flexibility [5, 6]. This study fills a gap in understanding amateur players' athletic shoe needs, especially in underdeveloped nations like India where anthropometric considerations are frequently disregarded [7, 8].

2. Methodology

The research's approach, which includes multiple crucial stages, begins with a thorough survey analysis to learn more about amateur players' demands and preferences for athletic footwear. Athletes playing racquet sports between the ages of 12-16 were the target audience for the survey, which focused on factors including comfort, aesthetics, and functionality. Three hypotheses about the influence of design elements on respondents' gender and the connection between weight, pressure points, and arch kinds were developed based on the data collected.

2.1 Survey Insights and Design Implications

The survey revealed significant insights into the preferences of amateur athletes. Key findings indicated that unattractive design, dated models, lack of new features, and non-branded options were the most undesirable factors in athletic shoes. Respondents favored avant-garde designs, retro looks, and minimalism, highlighting the importance of modern, aesthetically appealing designs with innovative features. The study also emphasized the importance of color vibrancy, with athletes expressing a preference for vibrant and attractive colors that can influence their performance and mood positively. However, the study did find a significant impact of design

parameters on respondents' gender, highlighting the role of aesthetics in influencing the psychology of amateur athletes as shown in Figure 1.

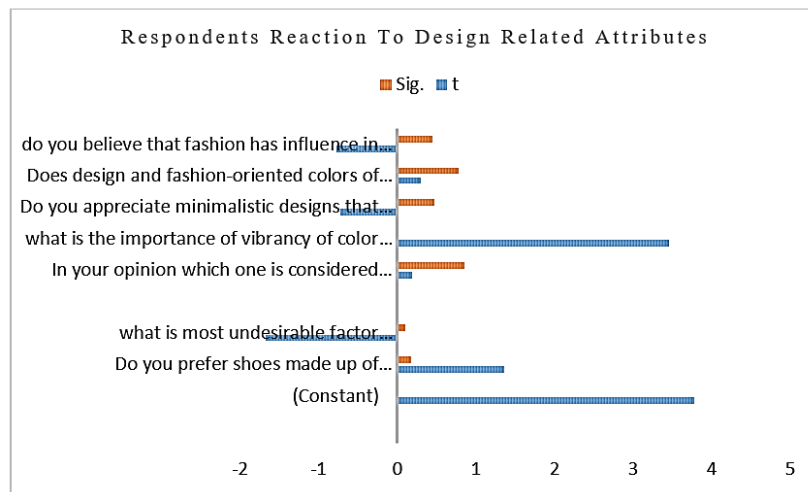


Figure 1 - Respondents' reaction to design-related attributes

F-statistic: The F-value of 2.530 indicates that the model is statistically significant.

p-value (Sig.): A p-value of 0.020 suggests that there is a significant impact of the design attributes on the gender of respondents. In other words, the design parameters significantly affect the gender classification.

Dependent Variable: Gender of the respondent (binary coded as 0 and 1).

Independent Variables: Various design attributes and opinions

Table 1- Preferences and opinions of amateur athletes regarding various design features in shoe

Preferences and opinions of amateur athletes regarding various design features of athletic shoes		Mean	Std. Deviation	N	Discussion
1.	The most undesirable factor that makes respondents reject a particular athletic shoe (Unattractive Design, No new features)	2.42	1.02671	100	The main score indicates that certain factors are considered desirable by respondents when choosing athletic shoes. The relatively high standard deviation suggests a wide range of design factors influencing rejection decisions.
2	Desirable future of aesthetics according to respondent's	2.36	1.18509	100	This suggests that respondents have a somewhat positive outlook on the future of athletics shoe design. The standard deviation indicates variability in the perceptions among respondents.
3.	Importance of vibrancy of color of upper in shoe selections	2.24	0.81798	100	Respondents moderately consider the vibrancy of color in the upper when selecting athletic shoes. The standard deviations indicate some variable tea in the importance place in this factor.
4.	Appreciation of minimalistic designs that allow color to play	1.72	0.85375	100	Respondents tend to appreciate minimalistic designs that provide opportunities for color to stand out. The standard deviation suggests variability in the degree of appreciation among respondents.
5.	Influence of design and fashion-oriented colors on psychological performance.	2.18	0.89194	100	Respondents moderately believe that design and fashion-oriented colors of shoes can positively influence psychological performance the standard deviation indicates variability in this belief among respondents
6.	Belief in the influence of fashion in court.	1.60	0.82878	100	Respondents tend to believe that fashion has some influence in courts. The standard deviation suggests variability in this belief among respondents

The study successfully identified specific design elements essential for sports shoes tailored to the preferences of amateur athletes. Vibrant colors, and aesthetically pleasing designs were highlighted as key elements. These findings guide the prototype development, ensuring that the design incorporates these elements to resonate with the target demographic.

2.2 Material Selection

The selection of materials for the shoe upper was guided by the distinctive physical characteristics of Spacer fabrics, which include breathability, moisture management, cushioning, and durability.

The fabric samples were evaluated across various properties using a scale of 1 to 5, as depicted in Figure 3. Sample 5, despite being thicker yet lighter and containing elastane, demonstrated superior performance and comfort compared to others.

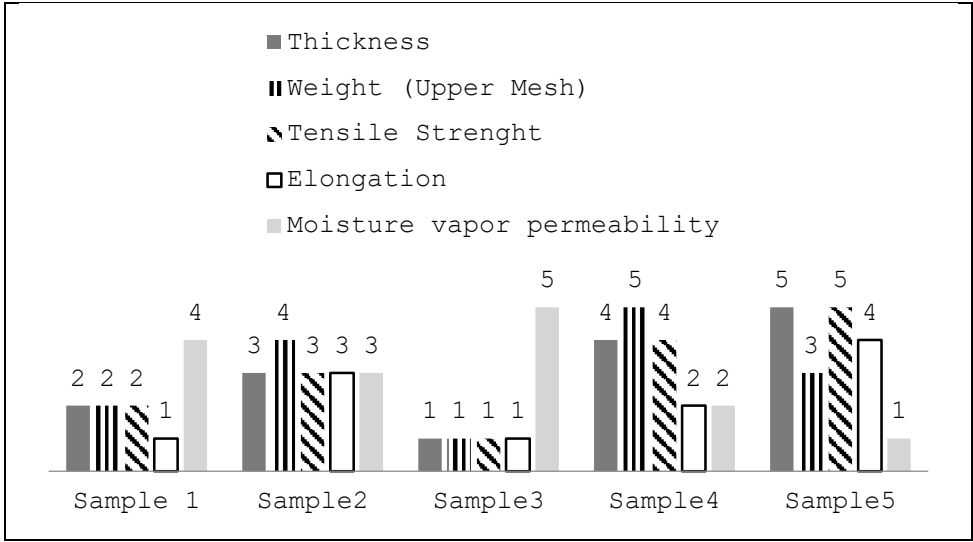


Figure 2 - The fabric samples were evaluated across various properties

Table 2 – Fabric parameters

	Fabric Properties	Test Standards	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
1	Fabric Thickness	GE 05	4	3	5	2	1
2	Fabric Weight	GE 07	4	2	5	1	3
3	Fabric Tensile Strength	ST 03	4	3	5	2	1
4	Fabric Elongation	ST 03	5	3	4	2	1
5	Fabric moisture vapour permeability	IS 15298, part 2: 2016	4	3	5	2	1

The Spacer fabrics used in the prototype construction comprised 98% PES and 2% EA, with a 3D warp knit hexagon structure. These materials exhibited superior tear strength, tensile strength, elongation, and water vapor permeability, making them ideal for athletic footwear designed for high-impact sports with rapid lateral movements.

2.3 Prototype Development Process

The prototype development process involved several iterative stages, incorporating feedback from amateur athletes and trainers to refine the design. A design process framework adapted from J.F. Boles was employed, comprising four fundamental steps: problem generation, needs assessment, prototype development, and evaluation. The prototypes were constructed using technical Spacer fabrics, ensuring they met international standards and aligned with global trends in athletic shoe manufacturing.

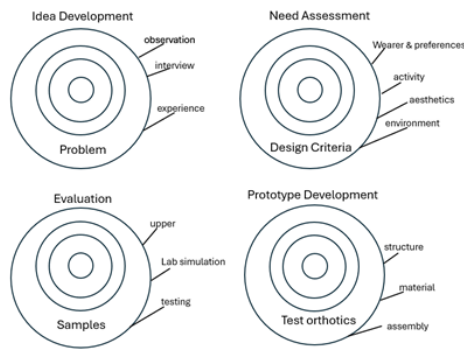


Figure 3 - Adopted from Boyles Design process framework [9]

A few Aesthetic descriptors from Table 1 were taken into consideration while designing a prototype

Table 3 - Aesthetic Descriptors [10]

Product Aesthetic Descriptors	
1.	Curvaceous
2.	Empowered
3.	Fun
4.	Rhythmical
5.	Edgy
6.	Geometric
7.	Retro

Table 2 shows the list of core themes and subthemes. The five core themes were taken into consideration: fit, function, aesthetics, color, and personal style. These core themes were then divided into various subthemes. These themes helped in identifying what the participants needed and desired from their athletic shoes.

Table 4- The list of core themes and subthemes

Core Themes	Fit	Function	Aesthetics	Colors	Personal Style
Sub Themes	Arch Support	Performance Features	Pattern	Hues/Shade	Minimalism
	Comfort	Flexibility	Fabric	Matching Schemes	Retro
	Mobility	Cushioning	Surface Ornamentation	Demographic (Age/Gender)	Uniqueness
		Shock Absorption	Rhythm		
			Balance		

The proposed asymmetrical upper made of 3D spacer fabrics is scientifically designed to meet the specific needs of racquet sports, offering targeted cushioning, specialized support for lateral movement, and a lightweight design for enhanced performance.

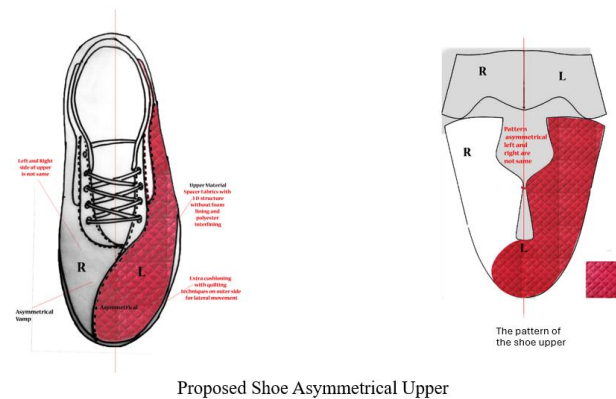


Figure 4 - Proposed asymmetrical athletic shoe prototype

3. Results and Discussion

The results of the study highlight how important design features are in determining amateur athletes' preferences and psychological health. The investigation showed no evidence of a significant relationship between pressure points and arch types or weight and pressure points, indicating that other factors may be more important in determining how comfortable a pair of shoes is. Nonetheless, a noteworthy effect of the design parameters on the gender of the respondents was noted, underscoring the significance of aesthetics in shaping athletes' psychological states. Prototypes were built with the specific demands of amateur athletes in mind. They included innovative materials, ergonomic features, and brilliant colors. The asymmetrical top shape accommodated the lateral movements common to racquet sports by adding extra cushioning to the shoe's exterior. This design improved performance and comfort at the same time. This design decreased the chance of injuries, especially ankle problems, while simultaneously improving comfort and performance.

The psychological effects of color on athletes were emphasized in the study, with vivid colors like orange, yellow, and red being very useful for generating strong feelings and improving performance. High emotional intensity colors like red and yellow can increase enthusiasm and adrenaline levels, as well as attentiveness and focus. Orange is a color that can generate sentiments of wholesomeness and vigor, which makes it a good option for sports footwear that aims to increase endurance and energy.

To improve comfort and offer a customized fit, the prototypes included asymmetrical designs, elastics, and adjustable drawstrings, among other design aspects. Surface decoration methods, such as quilting and embellishments, enhanced comfort and aesthetics by offering targeted cushioning and visual appeal. According to color psychology theory, vivid color schemes and patterns attract attention and produce pleasant emotional reactions. Ergonomics played a crucial role throughout the design process, emphasizing shock absorption, arch support, and general fit. To offer comfort and stability, the prototypes included arch supports, heel counters, and footbeds with anatomical shapes. While preserving functional integrity, the combination of tessellated designs, geometric overlays, and hexagonal meshes guaranteed a contemporary, minimalistic appearance.

4. Conclusion

The in-depth analysis provides insights into fabric composition, 3D structures, thickness, weight, and mechanical properties of spacer fabrics used in athletic shoe orthotics. This work examined the permeability and conductivity characteristics of polyester filament-based warp-knitted spacer textiles. When applying shoe orthotics, the spacer fabric is thought to produce a cozy material that normalizes heat transfer during physical activities. The study establishes significant relationships between fabric thickness and various properties. These relationships, analyzed through P-values and regression, reveal correlations between thickness and tear strength, tensile strength, weight, and water vapor permeability. The findings showed that the permeability of water vapor and air is dependent on the thickness.

This study contributes valuable knowledge for the selection of materials in the construction of sports shoe orthotics, guiding manufacturers towards optimal fabric choices for enhanced athletic performance and comfort.

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