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COMPREHENSIVE ANALYSIS OF SPACER FABRICS USED IN ATHLETIC SHOE ORTHOTICS

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Abstract

Recentadvancements in thefield of sports shoe fabrics haveseen significant progress in achieving high functionality and optimal comfort. This articleexplorestheevolvinglandscape of active sports shoe fabrics, with a focus on technicaltextiles and orthotic applications. Theintegration of advancedknowledge and textilescience in sports shoe manufacturing is essential for meetingthediverserequirements of differentathleticactivities. This paperemphasizestheimportance of fabric materials and construction methods, particularly for theupper parts of sports shoes, and highlights thetransformativeeffects of smart fabrics, polyurethane (PU), and knittedmesh, especiallyspacer fabrics. Theselection of materials plays a pivotal role in ensuringthebestproperties of comfort, flexibility, breathability, strength, fit, and overallperformance.

Keywords: Sports shoe, Technical textiles, Orthotics, Spacer Fabrics

1.Introduction

The ubiquity of sports shoes today extendsbeyondprofessionalathletes, encompassingfitnessenthusiasts and individuals engaging in outdoor activities for leisure and well-being. Thedemand for sports shoes with specific fabric properties has increased, necessitatingadvancements in materials to meetconsumerexpectations. This paperdelves into theessentialpropertiesrequired for sports shoe orthotics, emphasizingtherole of spacer fabrics in achievingsuperior fit, comfort, and performance.

The traditional materialsused in sports shoe orthotics, such as Polyamide, Polyester, Nylon, PU, and PVC, weredurable but lackedessentialfeatureslikebreathability, comfort, and lightweight construction. Spacer fabrics have emerged as a revolutionaryalternative, providing thenecessarystrength, breathability, and grip for sports shoe construction [5]. The growing market for sports shoes, driven by health-conscious consumersengaging in various outdoor activities, has spurredresearch into functional fabrics, with producers focusing on enhancingtheperformance and durability of sports shoes [5].

Spacer fabrics havegarneredattention for theirunique three-dimensional structure and exceptionalproperties, making them an idealchoice for sports shoe orthotics [2] [4]. Thekeyadvantagesincludeeffectivemoisturemanagement, breathability, cushioning, shock absorption, pressuredispersion, durability, and reducedbacterial growth [2]. Thesefeaturescontribute to enhancedathleteperformance, comfort, and overall satisfaction, fostering brand loyalty and marketability [2] [4].

Spacer fabrics aredistinctivelycharacterized by theiropen 3D structure, promoting efficient airflow, moisture-wicking, and heat dissipation during physical activity. Theinherent shock-absorbing capabilities of spacertextiles play a crucial role in reducingstress on joints during high-impact exercises [2]. Additionally, thematerial's durability and resistance to wearensuresustainedperformanceovertime [4].

The adoption of spacer fabrics in sports shoe orthotics brings severalbenefits to both athletes and manufacturers. Improvedcustomer satisfaction, reduced injury risks, and alignment with environmentalconsciousnesscontribute to theoverallsuccess of sports footwear in themarket [2] [4].

Figure 1 Materials used in constructing Athletic and Sports Shoes orthotics

https://www.linkedin.com/pulse/materials-athletic-sports-shoes-upper-midsoles-outsoles-miguel-silva

Figure 2Components of a Sports shoes https://www.nytimes.com/wirecutter/reviews/best-running-shoes

Contemporarymaterialsused in sports shoe orthotics, including theuppers and insoles, exhibitsuperiorpropertiescompared to traditional materials. Knittedmaterials, nylon, Lycra, smart fabrics, and PU insolescontribute to breathability, lightweight construction, and effectivemoisturemanagement, enhancingoverall comfort and performance [6] [8] [9].

Thesignificance of theshoe'suppermaterials is highlighted, emphasizingthe impact on stability, comfort, and athleteperformance. Nylon mesh, known for its breathability, lightweightcharacteristics, and rapid drying, plays a crucial role in promoting air circulation and reducingmoisture buildup insidetheshoe [7].

Insolesmade from modernmaterialslike PU, knittedmesh, and smart textilesfurtherenhance foot support, stability, and overall comfort during sporting activities [4]. Knittedmeshmaterialsofferimproved liquid transport capabilities, flexibility, and breathability, contributing to comfortable foot movement and reduced friction [6].

1.1 Production Process of Spacer Fabrics

The production of spacer fabrics involves specialized knitting or weaving techniques, incorporating warp and weft yarns and spacer yarns to create a resilient three-dimensional textile. Finishing processes, such as heat setting or bonding, enhance the stability and durability of spacer fabrics [11] [12].

The unique construction of spacer fabrics imparts various beneficial characteristics, such as breathability, moisture control, cushioning, shock absorption, pressure distribution, and resistance to repeated usage [13]. The adaptability of spacer materials allows for design flexibility, enabling the creation of sports shoes with diverse patterns, hues, and textures while maintaining practical advantages [8].

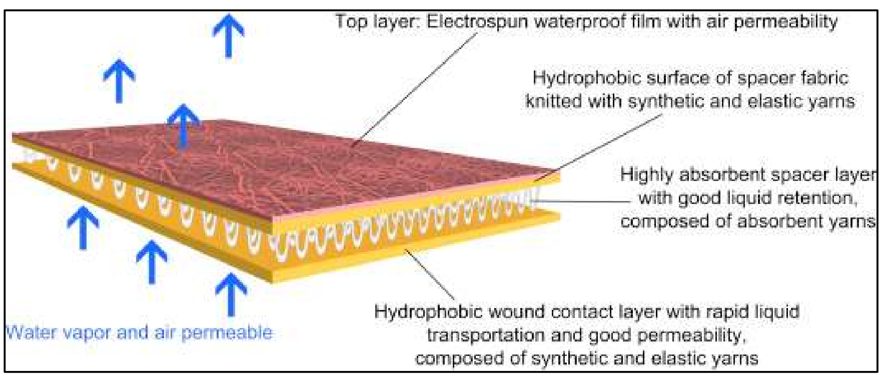

Figure 3 structure of spacer fabric[10]

Spacer fabric characteristics, in contrast to conventional materials, spacer textiles have several distinctive qualities that make them ideal for sports shoe orthotics. [13]

2.Methodology

2.1 Material

This scientific study investigates the properties of five spacer fabrics (coded as S1, S2, S3, S4, and S5) provided by three international athletic shoe manufacturers. The focus is on the utilization of spacer fabrics in the manufacturing of upper and insole components of athletic shoes. The study involves rigorous physiological testing to assess the physical and mechanical

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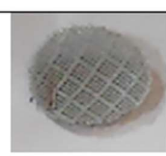
features of thesespacer fabrics. The methodology encompasses various tests, including fabric weight and thickness, tensile strength, tear strength, extension, and abrasion resistance. The findings contribute to a deeper understanding of the material characteristics crucial for sports shoe orthotics.

Table 1 Yarn composition of spacer fabric samples used in testing

Sample Code		S1	S2	S3	S4	S5
Layer 1	Composition	100%PES	100%PES	100%PES	100%PES	98%PES+2%EA
	Structure	3D warp Knit	3D warp Knit	3D warp Knit	3D warp Knit	3D warp Knit
Layer 2	Composition	100%PES	100%PES	100%PES	100%PES	98%PES+2%EA
	Structure	3D warp Knit	3D warp Knit	3D warp Knit	3D warp Knit	3D warp Knit
Layer 3	Composition	100%PES	100%PES	100%PES	100%PES	100%PES
	Structure	3D warp Knit (lock knit structure)	3D warp Knit (lock knit structure)	3D warp Knit (lock knit structure)	3D warp Knit (lock knit structure)	3D warp Knit (Hexagon structure)

Table 2Sample spacer Fabrics utilized in testing (Front and Back)

	S1		
1.	S2		
2.	S3		
3.	S4		
4.	S5		

The study concentrates on a detailed examination of the materials used in the construction of sports shoe orthotics, employing a systematic methodology to test the physical and mechanical

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attributes of the collected spacer fabrics.

Table 3: Physical and Mechanical Test of Spacer

Physical and Mechanical test of Spacer fabrics	
S,No	
1	**Weight and thickness**
2	**Tensile strength**
3	**Tear-strength**
4	**Absorbency**
5	**Colour Fastness**
6	**Abrasion resistance**
7	**Cushioning**
8	**Tractability**
9	**Compression**

Thickness and weight of the sample fabric.

Fabric weight and thicknessarefundamentalparameters for testingdifferent groups of fabrics. Standardizedresultsare crucial, consideringthedirectrelationshipsbetweenweight, stiffness, and heat with thickness. The study adheres to standardizedtestingmethods, including specimendimensions, mass/areaconsiderations, and controlledenvironments for precision in results.

Fig 3.3.1 Instruments used in measuring weight and thickness of Fabrics used in the construction of shoe orthotics.

Fabric Strength

Tensile and tearstrengths are vital in athletic shoes, influencingbreaking and elongationproperties. Tensile Strength, dependent on axial stretching load, is determined by fabric structure andfiber composition. Tearstrength evaluates the fabric's ability to withstand tearing along a line, especiallyrelevant in non-leatherathleticshoe components.

The standards used for the weight test include[1]

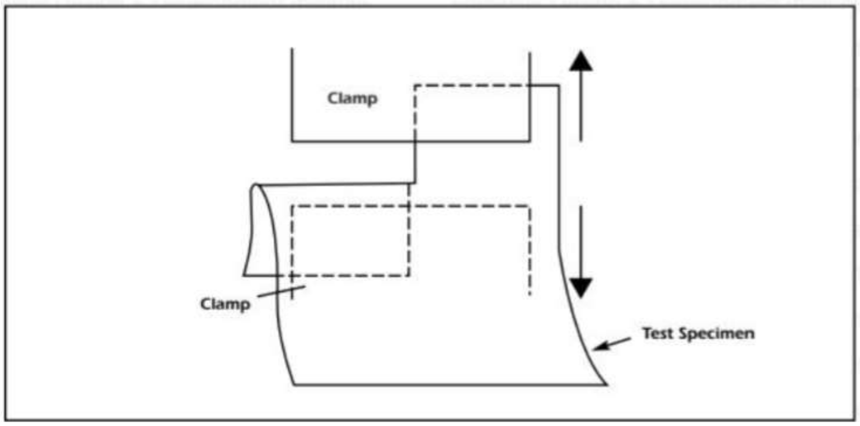

Fig 3.3.2 shows the clamping arrangement of fabrics[1]

Fig:3.3.3 shows mechanical operation during the tear strength test.

Extension

Extension, represented by the ratio of stretching to actual length, is crucial in assessing fabric stability. Young's modulus measures the stretch due to small stress, with soft materials exhibiting lower modulus compared to stiffer fabrics.

Fabric Abrasion Resistance

Abrasion resistance is critical in evaluating fabric performance and longevity. The study exploresdifferent types of machines, methods, and testingenvironments to assessthe impact of abrasion on fabric structure and properties.

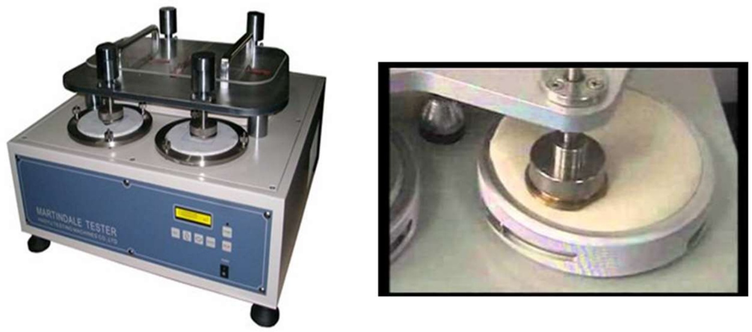

Fig 3.3.4 Martindale tester machine used in testing abrasion resistance.

3. Results and Discussions

These two manuals are used in testing the physical characteristics of Spacer samples.

- [2]
- [1]

Table 4: Minimum requirements of Spacer Fabrics/ Mesh Fabrics with Standard methods of testing.

Material:SPACER FABRICS USED IN CONSTRUCTION OF SHOE ORTHOTICS (UPPER)			
S.No.	**Test Name**	**Test Method**	**Requirement**
1)	Thickness of Fabrics	GE 05	-
2)	Spacer Fabric Weight	GE 07	-
3)	Spacer Fabric Tear Strength A	ST 02	0.03 kN (min)
4)	Spacer Fabric Tear Strength B	ST 02	0.03 kN (min)
5)	Spacer Fabric Tensile Strength A	ST 03	0.600 kN/0.05m (min)
6)	Spacer Fabric Tensile Strength B	ST 03	0.400 kN/0.05m (min)
7)	Spacer Fabric Elongation A	ST 03	40 percent (min)
8)	Spacer Fabric Elongation B	ST 03	60 percent (min)
9)	Spacer Fabric Water Vapour Permeability	IS 15298 (part 2) 2016	0.0008 g/cm^2h (min)
10)	Spacer Fabric Water Vapour Coefficient	IS 15298 (part 2) 2016	0.150 g/cm^2
11)	Spacer Fabric Colour Fastness to crocking	SATRA TM 167 2001	Dry three (min) Wet three (min)

12)	Martindale abrasionfor Spacerfabric	SATRA TM31:2017	DRY: After competition of 25600 cycles no deformity is observed. WET: After competition of 12800 cycles no deformity is observed.

Material: MESH FABRICS (UPPER)

Serial Number	Name of the Test	Test Method	Value					Requirement
			S1	S2	S3	S4	S5	
1) 01	Thickness of SpacerFabrics	GE 05	0.254 cm	0.282 cm	0.252 cm	0.285 cm	0.3 cm	-
2) 02	Spacer Fabric Weight	GE 07	0.274 kg/m^2	0.284 kg/m^2	0.272 kg/m^2	0.285 kg/m^2	0.282 kg/m^2	-
3) 03	Spacer Fabric Tear Strength A	ST 02	0.0843 kN	0.0823 kN	0.0802 kN	0.0846 kN	0.0828 kN	0.03 kN(min)
4) 04	Spacer Fabric Tear Strength B	ST 02	0.0693 kN	0.0683 kN	0.0673 kN	0.0696 kN	0.0682 kN	0.03 kN (min)
5) 05	Spacer Fabric Tensile Strength A	ST 03	1.105 kN/0.05 m	1.102 kN/0.05 m	1.1 kN/0.05 m	1.108 kN/0.05 m	1.104 kN/0.05 m	0.6 kN/0.05m (min)
6) 06	Spacer Fabric	ST 03	0.418	0.42	0.412	0.421	0.423	0.4

	Tensile Strength B		kN/0.05 m	kN/0.05 m	kN/0.05 m	kN/0.05 m	kN/0.05 m	kN/0.05m (min)
7) 07	Spacer Fabric Elongation A	ST 03	61 percent	63 percent	61 percent	62 percent	64 percent	40 percent (min)
8) 08	Spacer Fabric Elongation B	ST 03	85 percent	83 percent	82 percent	84 percent	83 percent	60 percent (min)
9) 09	Spacer Fabric Water Vapour Permeability	IS 15298 (part2) 2016	0.0755 g/cm^2h	0.0782 g/cm^2h	0.0659 g/cm^2h	0.0842 g/cm^2h	0.0891 g/cm^2h	0.0008 g/cm^2h (min)
10) 10	Spacer Fabric Water Vapour Coefficient	IS 15298 (part2) 2016	0.6615 g/cm^2	0.4437 g/cm^2	0.5276 g/cm^2	0.9474 g/cm^2	0.6843 g/cm^2	0.15 g/cm^2
11) 11	Spacer Fabric Colour stability during crocking	SATRA TM 167 2001	Dry 4 Wet 4	Dry 4 Wet 4	Dry 4 Wet 4	Dry 4 Wet 4	Dry 4 Wet 4	Dry three (min) Wet three (min)

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12) 12	Martindale abrasion for Spacer fabric	SATRA TM31:2017	No deformity No deformity	No deformity No deformity	No deformity No deformity	No deformity No deformity	No deformity o deformity	DRY: After competition of 25600 cycles no deformity is observed. WET: After competition of 12800 cycles no deformity is observed.

Table 6: One-way ANOVA of Spacer Fabrics' physical characteristics

Sample (S1, S2,S3,S4,S5) of Spacer Fabrics Used in construction of sports shoe Upper and insoles	Fabric physical properties	R^2 Value of Spacer fabric	P-value of Spacer Fabrics
	Relationship between Spacer’s Fabric Tear Strength and Thickness	0.084	0.009
	The correlation between a Spacer fabric's thickness and tensile strength	0.771	0.001
	The correlation between a Spacer fabric's thickness and weight	0.764	0.002
	The correlation between water Vapour Permeability and Thickness of Spacer Fabrics	0.830	0.395

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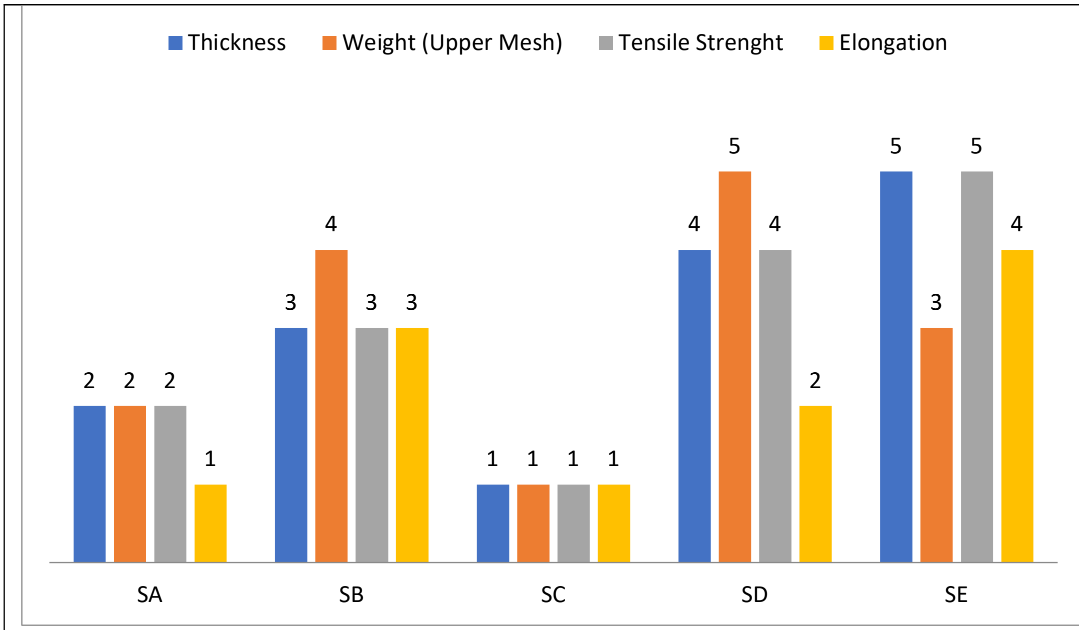
	The correlation between Water Vapour Coefficient and Thickness of Spacer Fabrics	0.096	0.931
	The correlation between Elongation and Thickness of Spacer Fabrics	0.867	0.001
	Abrasion Test Result	No deformity	

Table 7 3: Samples are rated according to test outcomes.

			S1	**S2**	**S3**	**S4**	**S5**
1.	**Spacer Fabric's Thickness**	GE 05	D	C	E	B	A
2.	**Spacer Fabric's Weight**	GE 07	D	B	E	A	C
3.	**Spacer Fabric's Tensile Strength**	ST 03	D	C	E	B	A
4.	**Spacer Fabric's Elongation**	ST 03	E	C	E	D	B
5.	**Spacer Fabric's Color Fastness (Dry and Wet)**	SATRA TM 167 2001	Satisfactory	Satisfactory	Satisfactory	Satisfactory	Satisfactory
6.	**Spacer Fabric's Martindale abrasion**	SATRA TM31: 2017	No deformity	No deformity	No deformity	No deformity	No deformity

In this case, "A" denotes the highest value (most thick, heaviest, most tensile, most elongation) while "E" denotes the lowest value (most thin, least weight, least tensile, least elongation).

Table 8: Rate of Samples based on Test results.



			S1	S2	S3	S4	S5
1	**Spacer Fabric's Thickness**	GE 05	D	C	E	B	A
2	**Spacer Fabric's Weight**	GE 07	D	B	E	A	C
3	**Spacer Fabric's Tensile Strength**	ST 03	D	C	E	B	A
4	**Spacer Fabric's Elongation**	ST 03	E	C	E	D	B

In this case, "A" denotes the highest value (thickest, heaviest, most tensile, most elongated.) while "E" denotes the lowest value (most thin, least weight, least tensile, least elongation).

The investigation involves testing five spacer fabrics (S1, S2, S3, S4, and S5) for thickness, tearstrength, tensile strength, elongation, water vapor permeability, and water vapor coefficient. The Spacer fabrics S1, S2, S3, and S4have Similar composition (100 %PES) and structure (3D and Warp knit) with a lock stitch. Whereas spacer fabric S5 had composition (98% PES +2%EA) and (3D and Warp knit) with hexagon structure. The spacer fabric S5 shows relatively greater Tear strength (82.8N), Tensile strength (1104 N/5 cm), Elongation (64%), and water vapor permeability (89.1 mg/cm2 h).Notably, spacer fabric S5, with a hexagon structure and unique composition (98% PES + 2% EA), exhibitedsuperiortearstrength, tensilestrength, elongation, and water vapor permeability.

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, tensilestrength, weight, and water vapor permeability.

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4.Conclusion

The in-depth analysis provides insights into fabric composition, 3D structures, thickness, weight, and mechanical properties of spacer fabrics used in athleticshoe 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 findings showed that the permeability of water vapor and air is dependent on the thickness and porosity of the spacer fabrics. The essential component of spacer fabrics' permeability and conductivity is their porosity.

The findings highlight the influence of tensile and elongationproperties on physiological comfort and recommend thicker 3D warp-knitted spacer fabrics with specific compositions for high-performance sports shoes. 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.

Spacer fabrics have emerged as a groundbreaking material for sports shoe orthotics, addressing the evolving demands of athletes and consumers alike. The distinctive features of spacer textiles, including breathability, moisture management, cushioning, and durability, contribute to improved athlete performance, comfort, and overall satisfaction. The integration of spacer fabrics aligns with the industry's focus on sustainability, environmental consciousness, and the pursuit of innovative solutions in sports footwear. Ongoing research and development in thefieldare crucial for advancing orthotic material technologies and furtherenhancingthewell-being of athletes.

References:

[1] M. Benno M Nigg, “Sports Inserts and Orthotics for sports and physical activities,” Human Performance Laboratory, 1999.

[2] M. L. Gross, “Effectiveness of orthotic shoe inserts in the long-distance runner,” SAGE, 1991.

[3] M. B. M. Razeghi, “Biomechanical Analysis of the Effect of Orthotic Shoe Inserts,” Sports Medicine, 2012.

[4] A. Subramanium, “The effects of shoe upper construction on mechanical ankle joint work during lateral shuffle movements,” Journal of Sports Sciences, 2021.

[5] “Sports and recreation textiles,” [Online].

[6] E. W. C. Frederick, “Textile use in sport shoes,” sciencedirect, pp. 339-351, 2005.

[7] Bruno Bazuelo-Ruiz, “Effect of the upper material of running shoes on muscle mechanical power transfer on lower limbs,” SAGE, 2022.

[8] D. M. M. sweta kumari, “Performance Characteristics of Textile and Pu Used In Amateur Athletic Shoes,” INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT, 2022.

[9] J. Cordero-Sánchez, “Effect of the upper material of running shoes on muscle mechanical power transfer on lower limbs,” Sage, 2022.

[10] E. Ramazan, “Advanced Textiles for Wound Care,” in Advanced Textiles for Wound Care, Woodhead Publishing, 2019.

[11] H. Hu, “Spacer fabric-based exuding wound dressing – Part I: Structural design, fabrication and property evaluation of spacer fabrics,” Textile Research Journal, 2016.

[12] D. D. Uttam, “Active Sportswear Fabrics,” International Journal of IT, Engineering and Applied Sciences Research (IJIEASR), 2013.

[13] “Active Sportswear Fabrics, High Functions and comfort,” The Int. Text. Magazine, Jan. 2001.

[14] “http://www.madehow.com/Volume-1/Running-Shoe.html#google_vignette,” [Online].

[15] I. H. Gulas SB, “The use of High Performance Textile Surfaces in Sport Shoe Designs,” J Fashion Technol Textile Eng Vol: 8 Issue: 4, 2020.

[16] S. M. P. B. S. C. IC Sharma, “Influence of Yarn and Fabric Properties on Tearning Strength of Woven Fabrics,” IJTR, 1983.

[17] T. Rajan, “The influence of fabric parameter on low-stress mechanical properties of polyester warp-knitted spacer fabric,” International Journal of Fashion Design, Technology and Education, 2017.

[18] S. Rahman, “Investigate the Relation among Thickness, Relative Porosity and Air permeability of different types of knitted fabrics,” INPRESSCO, 2015.

[19] M. Q. S. Lloyd Ndlovu, “Physical properties of plain single jersey-knitted fabrics made from blended and core-spun polysulfonamide/cotton yarns,” Textile Research Journal 85(3):262-271, January 2014.

[20] X. Ye, “Development of the Warp Knitted Spacer Fabrics for Cushion Applications,” Journal of Industrial Textile, 2008.

[21] L. M. C. a. A. B. Flatau1, “Smart fabric sensors and e-textile technologies: a review,” Smart Materials and Structures, 2014.