

THEORETICAL FOUNDATIONS OF DESIGNING MEN'S SPORTSWEAR BASED ON BIONIC DESIGN



Tashkent Institute of Textile and Light Industry
Prof. **Aziza Kasimova**, Master's Student
Dildora Shomullaeva

Abstract. *This paper examines the theoretical foundations of designing men's sportswear based on bionic design. Modern approaches to using natural forms, structures, and functional mechanisms in creating high-tech garments aimed at improving ergonomics, functionality, and adaptability of sports equipment are analyzed. Special attention is paid to the properties and advantages of elastic knitted and membrane materials that ensure optimal thermoregulation, moisture management, and freedom of movement.*

Keywords: *bionic design; sportswear; men's equipment; elastic knitwear; membrane materials; ergonomics; adaptive constructions; parametric modeling; 3D scanning; high-performance materials.*

Bionic design is an approach based on studying natural forms, structures, and functional mechanisms, which are adapted in the clothing industry to improve ergonomics, functionality, and energy efficiency [1]. Modern sportswear incorporates natural analogues — muscle structure, skin texture, aerodynamic shapes of animals, and the distribution of loads in biological systems. The main principles of the bionic approach include natural integrity, functional adaptability, minimization of movement resistance, and the use of the body's natural geometry [2].

One of the key tasks of bionic design is creating garments capable of supporting the dynamic work of the muscular system and optimizing the athlete's heat and mass exchange. Unlike traditional design, the bionic approach relies not only on aesthetics

but also on functional patterns of living nature, making it particularly promising in the high-tech sports industry [3].

Designing men's sportswear involves considering biomechanical features of the male body, such as greater muscle mass, pronounced kinematic amplitudes, and increased heat output [4]. Ergonomic requirements include precise fit, optimized freedom of movement, controlled distribution of pressure across muscle groups, joint protection, and air circulation support. Functional requirements include moisture management, material strength, durability, adaptability to intense physical activity, and resistance to deformation under stretching [5]. Bio-analogous elements such as "muscle lines," "rigidity ribs," mesh zones, and directed ventilation areas enhance comfort and athlete performance.

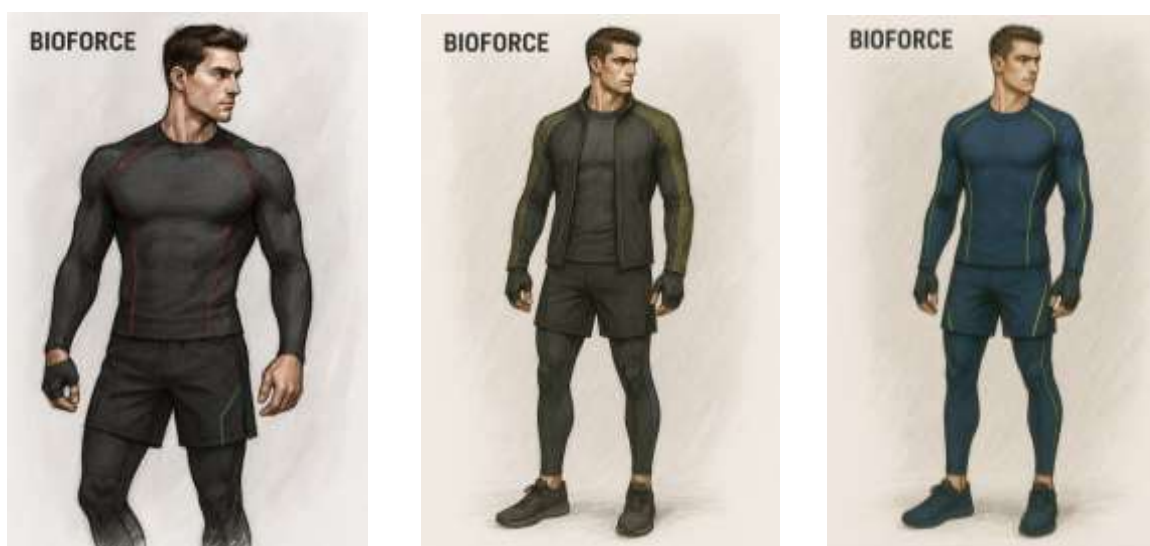


Figure 1. Bionic design of a men's training suit

Furthermore, men's sportswear must consider the specifics of various sports: aerodynamics for running and cycling, impact resistance for team sports, and high thermoregulation for fitness activities (Fig. 1).

Membrane materials are used in sportswear due to their ability to provide both waterproofness and breathability. According to modern classifications, membranes

are divided into microporous, hydrophilic, and combined types, each with specific properties [6].

Microporous membranes (e.g., PTFE, eVent) effectively release vapor while maintaining waterproofness, making them ideal for high-intensity sports. Hydrophilic membranes (PU, PES) are highly wind-resistant, lightweight, and durable. Combined membranes integrate the advantages of both technologies, providing improved ventilation and protection against external factors [7].



Figure 2. Microclimate between the body and clothing

In modern bionic sports products, membrane materials are used as analogues of human skin, providing dynamic “breathing” and regulating the microclimate between the body and the garment (Fig. 2). An important direction is the integration of membranes with smart fabrics capable of adapting to environmental changes. Bionic design technologies actively use 3D scanning, additive modeling, parametric construction, and digital CAD systems (CLO 3D, Browzwear, Assyst). These tools ensure accurate reproduction of anatomical lines and natural structures, such as “mesh” air channels inspired by honeycomb structures or laminate patterns mimicking plant leaves [8].

Bionic aerodynamic forms are widely used in running, swimming, and cycling apparel. For example, textures inspired by shark skin reduce air resistance; structures

resembling dragonfly wings increase flexibility and lightness. The introduction of elastic knitted materials with directional stretch enables the creation of adaptive garments that support muscles according to the “second skin” principle. Compression knit technologies and modular zonal construction enhance athletic performance, providing graduated pressure and support to key body zones [9].

Theoretical analysis demonstrates that integrating bionic principles into the design of men’s sportswear is a promising and scientifically grounded direction. The use of elastic knit fabrics, membrane structures, and digital technologies enables the creation of next-generation products that combine functionality, adaptability, and ergonomics. Bio-analogous forms and natural mechanisms can significantly enhance the performance characteristics of sportswear, making it more comfortable, efficient, and technologically advanced.

Material selection is a key stage in designing sports equipment, as fabrics determine 70–80% of the garment’s performance characteristics. Materials must ensure a balance between elasticity, thermoregulation, protection, and durability.

Special attention in designing men’s sportswear based on bionic design is given to high-performance materials capable of maintaining optimal microclimate and supporting intense movement. Among the most promising materials is the three-layer membrane fabric **ACTIVE**, consisting of two outer polyester layers and an inner thin membrane. This layered architecture protects the membrane from contamination, abrasion, and mechanical damage, significantly extending product lifespan. Additional advantages include soft tactility, high breathability, and the ability to create a comfortable microclimate by efficiently removing moisture and maintaining stable body temperature.

High elasticity is achieved through interlock weaving, characterized by a double-sided symmetrical loop structure. This provides stability, density, and resilience, making garments comfortable even during intense movements. The three-layer

structure — interlock + membrane + interlock — allows for a combination of elasticity, thermal insulation, wind and water protection.

Physical and Mechanical Properties of Materials for Sportswear

Table 1.

№	Fabric	Denist y, g/m ²	Elongation at break, %	Brea king stren gth, H	Air permeability, mm/c	Vapor permeability , g/m ² /24 h	Waterproof, mm	Cycle abrasion resistance
1	Elastic knitwear (PES + Elastane)	150- 220	120–180	180 – 250	150–250	2000–3000	-	8 000–12 000
2	Interlock (double knit)	180– 260	80–120	250 – 320	80–120	1500–2200	-	10 000– 18 000
3	Mesh / Air- Mesh	90– 140	60–90	100 – 160	250–350	3000–4500	-	6 000–10 000
4	Compressio n knitwear	200– 280	60–100	300 – 400	50–90	1500–2000	-	15 000– 20 000
5	ACTIVE (multilayer membrane)	260– 330	40–60	350 – 500	≤ 5 (wind protction)	5000	10000	> 20 000
6	Softshell (PES + membrane+ fleece)	280– 360	50–70	300 – 450	5–20	3000–5000	8000– 12000	15 000– 25 000
7	Nylon(PA)	80– 140	20–40	400 – 600	20–50	800–1500	-	25 000+

Materials used in sportswear differ significantly in structure, elasticity, breathability, thermal insulation, and compression properties. Elastic knit fabrics ensure freedom of movement and high moisture wicking, while mesh materials such as Air-Mesh provide intense ventilation in heat-generation zones. ACTIVE membrane fabric stands out with its three-layer construction, combining waterproofness (10,000 mm) and breathability (5000 g/m²/24 h), allowing the microclimate between the body and clothing to remain optimal. Compression fabrics produce bionically justified graduated pressure, increasing muscle efficiency. Thus,

a zonal combination of materials allows for next-generation sportswear with high functionality and adaptability.(tab1)

Comparative analysis shows that each material group has a unique set of physical and mechanical characteristics determining its functional purpose.

Elastic knitwear (PES + Elastane) is distinguished by maximum stretch — up to 180%, high breathability, and low density, making it ideal for dynamic areas requiring full freedom of movement. Its structure imitates the “second skin” principle.

Interlock materials have higher density and resistance to stretching, providing shape stability and durability, making them suitable for structural zones requiring support and close fit.

Mesh structures such as Mesh and Air-Mesh have the highest breathability (up to 350 mm/s), making them ideal for high heat-output zones.

Compression knitwear provides controlled stretch and abrasion resistance, creating graduated pressure based on bionic principles of tendon and fascia support.

ACTIVE membrane fabric demonstrates high functionality, combining waterproofness, breathability, and wind protection.

Softshell and nylon are designed for heavy loads, outdoor activities, and extreme conditions due to their durability and thermal retention.

Overall, combining materials with different physical and mechanical properties is a key principle of modern sports design aligned with the zonal and adaptive principles of bionic design.

Conclusion

The results of the comparative analysis show that optimal sportswear based on bionic design should be created using a multi-component combination of materials, each performing a specific functional task. Elastic knitwear ensures mobility, interlock provides structure, mesh materials offer ventilation, compression fabrics

enhance biomechanical support, and ACTIVE membrane provides protection while maintaining breathability.

Such a combination imitates natural principles — load distribution, environmental adaptability, directed support, and dynamic ventilation — confirming the effectiveness of the bionic approach in creating high-tech garments that enhance heat exchange, endurance, and overall garment performance.

Thus, integrating different textile structures with their unique physical and mechanical properties forms a scientifically grounded basis for developing next-generation sportswear distinguished by functionality, adaptability, and ergonomics.

References

1. Benyus J. *Biomimicry: Innovation Inspired by Nature*. New York: Harper, 2002.
2. Vincent J.F.V., Mann D. “Systematic technology transfer from biology to engineering.” *Philosophical Transactions of the Royal Society*, 2002.
3. Bar-Cohen Y. *Biologically Inspired Intelligent Robots*. SPIE Press, 2011.
4. Kukhta M. *Ergonomics of Sports Clothing*. Moscow, 2020.
5. Tao X. *Wearable Electronics and Smart Textiles*. Woodhead Publishing, 2019.
6. Gore-Tex Technical Manual. 2021.
7. Rossi R. “Moisture transport in textile clothing.” *Journal of Applied Physiology*, 2012.
8. Gibson L. “Cellular materials and structures.” *Materials Science and Engineering*, 2010.
9. Brown P. *High-Performance Apparel*. Elsevier, 2018.