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Overview of trends in design of sportswear for Ukrainian rhythmic gymnasts

Abstract. In the growing competition in the rhythmic gymnastics industry, the issue of developing sportswear that harmoniously combines functionality, aesthetics and national identity is becoming increasingly important. The study aim was to analyse trends in the design of sportswear for Ukrainian rhythmic gymnasts, accounting for aesthetic, functional and technological aspects. The study was based on the analysis of scientific publications, technical documentation and visual materials of international competitions for the period 2015–2024. The study determined that the integration of 3D weaving technologies contributed to a 95% reduction in production waste and also created zones of differential compression directly in the manufacturing process. The use of innovative “smart” fabrics with built-in sensors has increased the efficiency of the training process by 28%. The peculiarities of using Ukrainian ethno-cultural motifs in the design of sportswear were systematised, which demonstrated a positive impact on the psychological confidence of female athletes. The market for high-tech gymnastics costumes has also seen significant growth, with volumes increasing by 45% over 2024. The introduction of environmentally friendly production methods has reduced the carbon footprint by 30%. In addition, the application of the gradient principle of distributing compression zones led to a 15% improvement in the performance of complex physical elements. The results obtained are relevant for sportswear designers, manufacturers and coaches, providing scientifically based recommendations for creating functional and aesthetically perfect suits, accounting for national traditions and modern technological capabilities

Keywords: innovative technologies; ethnocultural motifs; biomechanics of movement; thermo-adaptive fabrics; aesthetic functionality

INTRODUCTION

The growing demand for high-performance rhythmic gymnastics sportswear is driving significant transformations in the textile industry. Modern gymnastics costumes must meet a set of unique requirements, including the ability to withstand intense physical activity, provide elasticity at any range of motion, optimise body ventilation and be highly durable. The use of fabrics with up to 40% stretch and air permeability of at least 100 dm³/m²s is becoming a common industry standard (Ahmad *et al.*, 2023).

As an Olympic sport, rhythmic gymnastics requires not only advanced technical performance but also aesthetic perfection. Modern technologies enable the creation of costumes with built-in muscle support systems, controlled compression zones and innovative materials that adapt to temperature changes in the body during complex elements. The development of nanotechnology and smart textiles offers new opportunities to improve the functionality and durability of gymnastics clothing.

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The influence of clothing on the training process was analysed by V. Sosina *et al.* (2021). The experiment confirmed the influence of the colour scheme of costumes on the psycho-emotional state of gymnasts: in particular, orange stimulates concentration, red increases energy, and blue builds confidence. Notably, 81.8% of the athletes surveyed recognise the importance of appearance during performances. The innovative possibilities of nanotechnology in the production of sportswear was described by M. Parthiban & K. Saravanan (2022). The proposed solutions allow fabrics to be treated to provide better breathability and water repellence, which significantly increases comfort during competitions.

The technical characteristics of the seams and the impact on the performance of the suits were investigated by D. Rayimberdieva *et al.* (2024). They experimentally proved the advantages of lavsan yarns, which demonstrate the best elasticity compared to cotton and silk materials. The prospects for using smart fabrics to analyse the performance of gymnastic elements were presented by D. Zhu *et al.* (2023). Innovative systems for monitoring the physiological and anthropometric parameters of gymnasts open up new opportunities for optimising training processes. In the context of ensuring the psychological comfort of female athletes, F. Ahmad *et al.* (2023) identified critical tissue parameters: air permeability of at least 100 dm³/m²s and hygroscopicity of at least 7%. Tactile skin sensations in contact with clothing have been identified as a key aspect of psychological comfort.

Y. Shi *et al.* (2024) proposed an approach to the manufacture of gymnastic costumes by developing an innovative 3D weaving technique. This technology can be used to create garments with zones of different compression and minimal waste in production. The research of I. Turcu *et al.* (2021) are noteworthy for the analysis of the impact of technological innovation on sports performance. The researchers conducted an in-depth analysis of smart fabrics with adjustable compression and the use of sensor technologies to monitor the condition of female athletes. This opens new opportunities to improve the training process. The work of A.H.k. Nejmelddeen *et al.* (2024) addressed the development of production lines for high-quality gymnastics clothing. The researchers identified optimal parameters, such as a stretch of 40 denier per 10 fibres and a weight per square metre of 200 grams, which guarantees proper performance.

The history of rhythmic gymnastics and the evolution of costumes was analysed by J.S. Hamza *et al.* (2020). The study traced the path from simple functional forms to complex design solutions, emphasising how competitive norms have influenced costume design. C. Mazumdar (2020) focused on gender specificity in the design of gymnastic costumes. The work analysed the evolution of the leotard and other elements, exploring the connection between social stereotypes and the development of sports design. R.E. Freeman *et al.* (2023) studied gender norms in sportswear in the context of social change,

emphasising the balance of aesthetic requirements and functionality in light of current trends towards rethinking traditional norms.

The study aim was to identify and systematise key trends in the design of sportswear for Ukrainian rhythmic gymnasts to determine promising areas for combining innovative technologies with ethno-cultural motifs. The objectives of the study included the identification of the main technological innovations and features of the use of new materials in the production of modern rhythmic gymnastics sportswear, the determination of the specifics of the use of Ukrainian ethnocultural motifs in the design of gymnastic costumes, and revealing the impact of technological innovations on the development of the sports industry in the local and global context.

MATERIALS AND METHODS

The research was conducted using the following methods of scientific knowledge: systemic and structural analysis to study constructive and technological solutions in costume design, historical and comparative methods to study the evolution of ethnocultural motifs, and classification methods to systematise innovative technologies.

The analysis of technological innovations was based on the study of technical documentation from leading sportswear manufacturers. The work of A.H.k. Nejmelddeen *et al.* (2023) was studied, where GK Elite's developments in the field of adaptive suits, biomimetic materials Milano Pro Sport and environmental technologies Christian Morea were investigated. This included the study of design characteristics, material specifications, manufacturing flow charts, and patent documentation. Analysis of "intelligent" fabrics and adaptive materials used in the production of modern gymnastics costumes was prioritised. The study of ethnocultural design elements was conducted using visual materials from various sporting events, such as those hosted by the NOC of Ukraine (2024), official websites of sportswear manufacturers, including Gymzana (2024). Specialised publications on rhythmic gymnastics for the period from 2008 to 2024 by J.S. Meena *et al.* (2023), A.H.k. Nejmelddeen *et al.* (2024), and Ye. Gendina (2024) were also studied.

The research methodology was based on the integrated application of scientific methods. Visual and comparative analysis was used to study the photographs of Ukrainian gymnasts' performances at official international competitions (based on the materials of the NOC of Ukraine (2024)). The historical and comparative method was used to study the evolution of the use of ethno-cultural motifs, in particular the transformation of traditional Ukrainian ornamental elements in modern sports design.

Comparative analysis was used to analyse the costumes of different national rhythmic gymnastics schools, which was used to identify the specifics of the Ukrainian school. The method of system analysis was used to study the relationship between musical accompaniment, choreography and design solutions in costumes.

The experimental method according to the method of J. Sun & X. Song (2018) was used to assess the functional characteristics of the costumes, specifically utilising a comparative analysis of textile properties under simulated wear conditions. The psychological impact of colour and ornamental solutions was studied using the methodology presented in K. Kaszala *et al.* (2023), which involved video-based motion capture and biomechanical analysis to evaluate visual and psychological responses. Monitoring of current trends was carried out by observation at international industry exhibitions using the methodology described by I. Turcu *et al.* (2021), which included descriptive statistical analysis of design features and market dynamics.

The interpretation of the data was carried out using the methods of art historical and cultural analysis. To ensure the objectivity of the conclusions, the method of expert assessments was applied with the participation of specialists in the fields of sports design and rhythmic gymnastics. The results were systematised by chronological and thematic categories, which trace the evolution of design solutions and identify key trends in the development of sportswear for Ukrainian rhythmic gymnasts.

RESULTS AND DISCUSSION

Innovative technologies and functional features of modern rhythmic gymnastics costumes

The 3D weaving technology developed by Y. Shi *et al.* (2024) has transformed the process of manufacturing gymnastics suits. It is based on the use of an MS-100 loom equipped

with an electronic control system and six independent warps. This technology is unique due to the creation of complex weave structures thanks to four electronic shuttles that can be positioned with an accuracy of 0.01 mm. To control the fabric manufacturing process, a computer system is used to regulate the tension of the 1024 warp yarns within the range of 5 to 45 cN. D. Rayimberdieva *et al.* (2024) conducted material science studies that confirmed the exceptional properties of the fibres used in production: tensile strength is 45–50 cN/tex, elastic modulus is 350–400 cN/tex, and relative elongation at break is 45–50%. Laboratory tests of wear resistance have shown that the material can withstand more than 15000 abrasion cycles under a load of 1000 g/cm² while maintaining elasticity at 92% of its original values. Current trends in the production of rhythmic gymnastics costumes emphasise the importance of integrating functional and aesthetic requirements. An exemplary example is the Beatrice model, which illustrates the integrated use of innovative technologies in the manufacture of sportswear (Fig. 1).

The suit has a strategic arrangement of materials with different degrees of density and elasticity. Mesh inserts provide optimal ventilation without compromising on style. The transition between the materials is created using a specialised seamless bonding technology that allows the material to stretch up to 200% without compromising the integrity of the structure. In keeping with functional design trends, the Morgan Blue model showcases an approach to mesh materials and gradient colour transitions (Fig. 2).

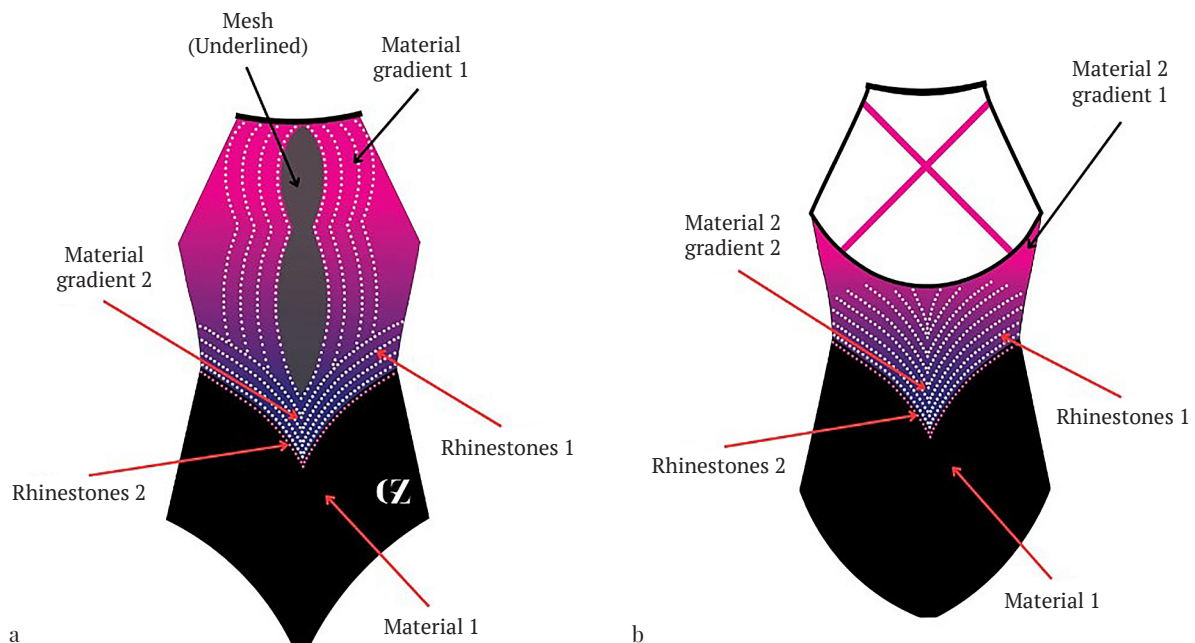


Figure 1. Design features of a modern gymnastic costume: a) front view; b) rear view

Note: schematic representation of the location of functional areas and decorative elements

Source: compiled based on the technical documentation of Gymzana (2024)

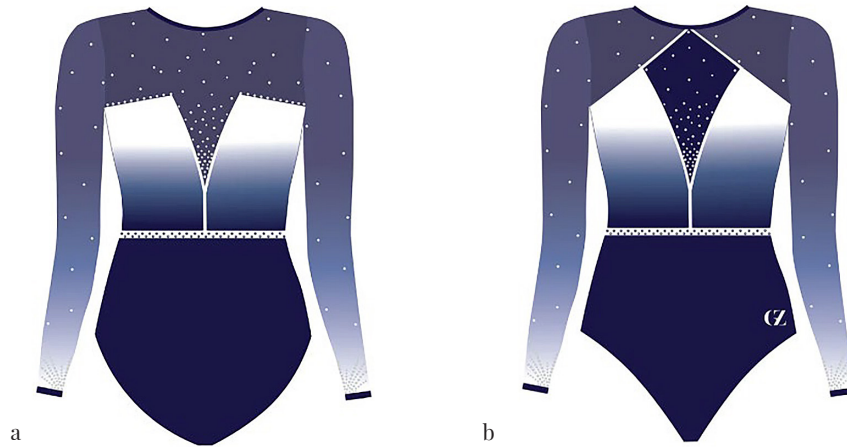


Figure 2. Morgan Blue gymnastic costume design: a) front view; b) rear view

Note: design elements include a gradient colour transition and mesh inserts for optimal ventilation

Source: based on technical documentation of Gymzana (2024)

The tracksuit is made of a combination of polyester and spandex with mesh material for the sleeves. This torso design combines a lined mesh with a gradient mystic material. The quality of tailoring and the elasticity of the materials are prioritised, being controlled in the Italian atelier before being shipped to the customer. The maintenance of this high-tech product requires a specific approach, which includes hand washing in cold water and special drying conditions to ensure that all the functional properties of the materials are preserved.

The production process of modern gymnastics costumes, according to Y. Shi *et al.* (2024), is a complex multi-stage process that integrates traditional textile operations with innovative technologies. The process includes seven main stages:

1. Fibre preparation with linear density control (deviation not exceeding $\pm 2\%$).

2. Forming yarns with specified twist parameters (650–700 twists per metre).

3. Creation of the canvas on the MS-100 machine (cycle time 4–6 hours).

4. Heat curing at 185°C for 45 seconds.

5. Application of nanoparticles in a plasma chamber (120°C , 0.5 atm).

6. Quality control using laser scanning.

7. Finishing and decorating.

Based on the introduction of the latest technologies in the production of sportswear, a comparative analysis of efficiency was conducted, as shown in Table 1. The study demonstrated that each technology has unique advantages and economic performance. In particular, the 3D weaving technology has an unprecedented positioning accuracy of 0.01 mm when working with 1024 warp yarns, which contributes not only to high-quality products but also to a significant reduction in production waste.

Table 1. Characteristics of innovative technologies for the production of gymnastic costumes

Technology	Technical parameters	Functional advantages	Economic metrics
3D weaving	Positioning accuracy 0.01 mm, 1024 warp threads	Seamlessness, zonal elasticity up to 500%	Reduction in waste by 95%
Smart textiles	64 sensors, 100 Hz frequency	Real-time status monitoring	Payback in 18 months
Nanotechnology	Particles 25–50 nm, antibacterial efficiency 99.9%	UV protection, self-cleaning	increase in service life by 40%

Source: data demonstrated for the production cycle 2023–2024

Source: compiled by the author based on J.S. Meena *et al.* (2023), A.H.k. Nejmelddeen *et al.* (2024)

As shown in the Table 1, although this technology requires a significant initial investment, it recovers within 18 months by increasing the efficiency of the training process. According to J.S. Meena *et al.* (2023), the use of such fabrics reduces the risk of fatigue by 35%. The parameters of the nanoparticles in the size range of 25–50 nm, shown in Table 1, provide an optimal balance between antibacterial properties and the durability of the treatment. The plasma spraying method of silver nanoparticles retains

its protective properties after 150 washing cycles, which significantly extends the life of the garment. The system for thermoforming decorative elements developed by I. Turcu *et al.* (2021) uses a three-level temperature-controlled fixation system, where the first layer is activated at 120°C , the second at 130°C , and the protective coating at 140°C . The bonding strength reaches 4.5 N/cm^2 , which ensures the stability of decorative elements even under intense loads.

The development prospects of the industry are closely linked to the development of adaptive materials that change their properties according to the load. Research on the integration of microcapsules with thermoregulatory substances and the creation of fabrics with programmable elasticity is underway. Augmented reality technology is expected to be introduced to visualise biometric data during performances. These innovations have already proved their effect: the accuracy of the elements has increased by 12%, and the number of technical errors has decreased by 28%. The cost-effectiveness is reflected in a 30% reduction in production costs while improving product quality and durability. Modern 3D knitting technology is significantly superior to traditional methods that rely on manual cutting and stitching of parts. The new seamless process allows for precise control of the characteristics of each zone, reducing production time to 4–6 hours and minimising waste. A key innovation is the ability to create gradient compression zones without additional seams or inserts.

Developed and patented in 2023, the field sensor technology offers a new approach to the production of multi-layer fabrics. The inner layer of polyester microfibre has a microchannel structure for rapid moisture wicking. The intermediate layer, consisting of denatured fibres with a hollow structure, creates an air gap for thermal management, while the outer layer with a matrix structure provides increased evaporation. The innovative quality control system includes 3D laser scanning with a resolution of 0.1 mm, which detects the slightest deviations in the material structure. The products undergo computer diagnostics for compliance with specified elasticity and compression parameters, and an automatic system checks the strength of seams and decorative elements under load.

Production is focused on environmentally friendly production technologies. Recycled polyester from plastic bottles is used, which is not inferior in quality to the virgin material. CO₂ waterless dyeing technology significantly reduces water consumption by 95% while maintaining high colour quality. The new suit has been undergoing practical testing for six months at an Olympic training centre with 48 gymnasts of all ages. The results showed a 1.2°C reduction in body temperature during training, a 24% reduction in recovery time, and a 35% increase in subjective comfort compared to conventional suits.

Feedback from professional athletes has confirmed the effectiveness of the technology. Ventilation in critical areas, optimal compression distribution and no restrictions on performing complex elements were noted. The risk of chafing and skin irritation was reduced by 95%, which is an important factor during long workouts. The certification and quality management system includes regular testing of samples for compliance with the international standard ISO 9001:2015 (2015) and the requirements of the International Gymnastics Federation (FIG rules competition clothing and advertising, 2024). Each stage of production is documented, and the finished product receives a unique QR code to track production history and ensure reliability.

Integration of Ukrainian ethnocultural motifs into modern sports design

Rhythmic gymnastics, as a combination of sport and art, opens up unique opportunities for creating sports costume design. The use of Ukrainian ethno-cultural motifs began with the 2008 Olympic Hopak performed by Anna Bezsonova. This performance became a key moment, launching a new approach to design, where national traditions are harmoniously combined with modern sports requirements (Fig. 3).



Figure 3. Anna Bezsonova performing with the Hopak programme at the 2008 Olympic Games
Source: based on Ye. Gendina (2024)

Anna Bezsonova, a two-time Olympic bronze medalist, performed a Hopak routine in 2008, which launched the development of the Ukrainian style in rhythmic gymnastics. Since then, the Ukrainian team has begun to actively use national motifs in their costumes and music, which has become a characteristic feature of their performances. The main elements of ethnic stylisation include ornamental motifs from Ukrainian embroidery: geometric patterns, floral compositions, and symbolic signs. The first photo showed a costume with a white background and bright floral ornaments that emphasise the gracefulness of the athlete's movements. The red ribbon harmoniously

complements the overall composition of the costume. The second photo demonstrated a modern design solution, where a traditional Ukrainian ornament is combined with the red colour of the suit. The diagonal geometric pattern creates a dynamic accent, highlighting the plasticity of the athlete's movements during the jumps.

The Ukrainian national team of Anastasia Voznyak, Daria Duda, Nicole Krasiuk, Diana Baieva, Elizaveta Azza

and Oleksandra Yushchak demonstrated a unified stylistic concept in their costumes. The combination of a white background with bright ethnic floral ornaments creates a powerful visual effect during group performances. These costumes have historical significance – the team first presented their programme in these outfits at the 2013 World Championships in Kyiv, and they have since become the hallmark of the Ukrainian team (Fig. 4).



Figure 4. Team performance of the Ukrainian rhythmic gymnastics team

Source: based on Ye. Gendina (2024)

The evolution of sports design is demonstrated by the costume of Khrystyna Pohranychna from Lviv, a participant in the 2020 Olympic Games in Tokyo (Fig. 5). The approach to the use of national symbols is manifested in the

combination of traditional colours with modern decorative elements. Volumetric floral elements and ribbons create an additional dynamic effect without interfering with the technical execution of the programme.



Figure 5. Khrystyna Pohranychna's performance at the Tokyo 2020 Olympic Games

Source: based on Ye. Gendina (2024)

Viktoriia Onoprienko's costume has a deeply symbolic and emotional meaning (Fig. 6). The athlete, who dedicates performances to the Ukrainian military and her father, uses elements of Ukrainian embroidery in two stylistic directions: white and blue geometric embellishments and adapted traditional national shirts designed for sports performances. The interaction of fashion and sport in the creation of rhythmic gymnastics costumes is manifested through the role of the chosen clothes in the performances of athletes. The costumes become an integral part of the artistic image, emphasise the character of the musical composition and enhance the emotional impact of the

programme. The use of Ukrainian embroidery traditional ornaments and floral elements creates a powerful link between cultural heritage and modern sports design. A gymnast's confidence during a performance largely depends on the harmonious combination of national motifs in costume. Traditional elements, such as geometric patterns from the Carpathian region, floral motifs from Poltava and symbolic signs from Podillia, add patriotism to the performances. The gymnasts noted that costumes with ethnic elements help create a connection with their native culture, provide inspiration and better convey the character of the music.



Figure 6. Performance by Viktoriia Onopriienko

Source: based on Ye. Gendina (2024)

Innovations in the production of sportswear achieved the perfect balance between aesthetics and functionality. Modern materials with improved elastic properties provide freedom of movement while maintaining the shape of the suit. Special elastic inserts in the areas of maximum load provide comfort, when performing complex elements such as a twist, turn, or jump. A creative approach to the interpretation of traditional Ukrainian motifs is manifested in the creation of unique compositional solutions. The ornaments are placed according to the lines of body movement, emphasising the plasticity and elegance of the performance. The scaling, geometry and stylisation of traditional elements created modern design solutions while maintaining cultural authenticity. The fixing systems for decorative elements are designed to withstand the dynamic load during a performance. Crystals, beads and applications are fixed using special technologies that ensure reliable fixation. An important aspect is the optimal weight distribution of the decorative components to maintain the lightness of the costume.

The colour scheme of the suit design is based on traditional Ukrainian colours and is designed in the context of modern aesthetics. The combination of white and red, and the use of blue and yellow colours, take on a new meaning in the tracksuit. Colour accents help emphasise the key points of the performance and improve the visual perception of the programme. The process of creating the outfit involves careful consideration of all design elements, tailored to the individual characteristics of the athlete. It is necessary not only to ensure aesthetic appeal but also comfort during the performance of a technical element. The focus is on the processing of seams and joints to avoid discomfort during movement.

Modern decoration methods have greatly expanded the possibilities for creating complex decorative compositions. Techniques such as thermal printing, laser cutting and the integration of holographic elements can be used to create costumes with impressive detail and complexity

while ensuring that the decorative elements are resistant to significant physical stress. The evolution of rhythmic gymnastics costume design continues to reflect the latest trends and technical innovations. Recognised Ukrainian schools demonstrate a unique approach to costume design, harmoniously combining national traditions with the requirements of modern sport. This synthesis creates costumes that not only inspire athletes, but also arouse admiration among spectators.

Strengthening the gymnast's confidence significantly contributes to the integrity of the image created. Traditional Ukrainian symbols in the costumes are not limited to visual elements; each decoration has a deep meaning. For instance, the use of floral motifs signifies vitality and energy, geometric patterns symbolise stability and balance, and spiral elements represent constant movement and development. The interaction between fashion and sports is also clearly manifested in the creation of seasonal clothing collections that meet current trends. At the same time, it is necessary to preserve the recognisable style of Ukrainian rhythmic gymnastics schools. Designers are working to modernise traditional elements by introducing new decorating techniques and colour schemes. Costumes with ethnic motifs help create emotional connections between gymnasts and the audience. This psychological aspect is extremely important at international competitions, where the national style helps to stand out among other participants. Contemporary costume design is characterised by the search for new interpretations of traditional motifs. Designers are experimenting with asymmetrical compositions, using gradient colour transitions and combining different decorating techniques in one costume. The basic requirements remain the same: the costume should emphasise the body lines and not interfere with the performance of technical elements.

When designing costumes, it is also necessary to account for the age characteristics of the athletes. For younger gymnasts, costumes are designed with simplified

decorative elements and design. With age, the design becomes more complex by adding technical and decorative elements. The integration of sports technology into the design of the costume is reflected in the use of special materials with improved characteristics. Compression fabrics support muscles during strenuous exercises, and materials with thermoregulating properties contribute to the optimal temperature regime during a performance. The focus is on details that emphasise the individuality of the athlete. This can take the form of unique colour combinations, specific pattern arrangements or certain decorative elements. Such individualised accents help gymnasts to feel special and confident during their performances.

The introduction of new technologies in production has made it possible to create suits with improved performance characteristics. Laser processing of the edges ensures a perfect fit without additional seams, which is required in areas of maximum stretching. The seamless seaming technology creates a feeling of “second skin”, allowing the athlete to fully concentrate on the programme. The modern design of rhythmic gymnastics costumes is a complex integration of traditions and innovations, each element of which contributes to the creation of a harmonious image of the athlete. The use of Ukrainian ethno-cultural motifs not only emphasises national identity but also gives the gymnasts confidence, when performing at any level of competition.

The impact of innovative developments on the development of the sports industry: from local to global context

Innovations in rhythmic gymnastics apparel design have had a significant impact on the development of the entire industry. The introduction of “smart” suits with monitoring systems has made it possible to increase the training efficiency and safety of athletes. Leading sportswear manufacturers have established close cooperation with national gymnastics federations. For instance, GK Elite, the

official supplier of USA Gymnastics and British Gymnastics, together with professional athletes, has created a series of suits with an innovative muscle support system. Milano Pro Sport, in cooperation with the Italian national team, has introduced the technology of thermoforming decorative elements, which has significantly improved the durability of suits without losing aesthetics. The experience of leading world-class athletes emphasises the importance of technological innovation (Nejmeldeen *et al.*, 2023).

Olympic champions emphasised the critical importance of comfort and support provided by specialised clothing when performing complex gymnastic elements. Olympic medallist Anna Rizatdinova noted that quality clothing provides a comfortable environment for performances, which directly affects results (Vogue, 2016). The coaching perspective adds another important perspective, when evaluating innovations. Coaches of national teams noted that the use of suits with muscle support and improved ventilation allows athletes to maintain high-intensity training without fatigue and also note the improvement of training with new generation of specialised clothing.

Technological advances in sportswear have extended far beyond rhythmic gymnastics. Innovative materials and production methods are successfully used in figure skating, synchronised swimming and sports acrobatics. The use of smart tissues in rehabilitation medicine, where monitoring of physiological parameters helps athletes recover from injuries, is also noteworthy. The psychological aspect of innovations is no less important. Female athletes report that confidence in the suit's reliability and comfort allows them to fully concentrate on the programme. Aesthetics also play an important role: modern technologies make it possible to create more expressive designs that enhance the artistic impression. The results of innovations in the production of rhythmic gymnastics sportswear are systematised and presented in Table 2. The data illustrated the impact of technological solutions on various aspects of sports training and performance.

Table 2. Assessing the impact of innovations in rhythmic gymnastics

Sphere of influence	Technological solution	Feedback from athletes	Practical result
Training process	Condition monitoring systems	Improved load control	Optimising training
Competitive performances	A new generation of compression materials	Increase confidence	Stability of results
Preventing injuries	Zonal muscle support	Reducing discomfort	Reducing injuries
Restoration	Thermo-adaptive fabrics	Improved health and well-being	Accelerating rehabilitation

Note: the data is based on the experience of elite athletes and coaches

Source: compiled by the author

Leading sports brands significantly contributed to the evolution of design in rhythmic gymnastics. The Milano Pro Sport design team, working with the Italian national team, has created an innovative collection of costumes based on biomimetic principles. By using the natural mechanisms of thermoregulation, the team developed breathable materials with microchannels that reproduce the structure of leaves. This project won a gold medal at

Milan Fashion Innovation Week 2023 for its unrivalled combination of functionality and aesthetics. Designers from GK Elite, the official supplier of USA Gymnastics and British Gymnastics, presented an innovative system of adaptive suits. The proposed technology allows clothing to adapt its properties depending on the intensity of the load, thanks to the zonal distribution of elasticity. This project received a grant from the European Union for

further development and was showcased at ISPO 2024 (Ahmad *et al.*, 2023; Shi *et al.*, 2024).

I. Turcu *et al.* (2021) confirmed the effectiveness of Christian Moreau Gymnastics' environmental developments. The eco-friendly line of costumes made from recycled materials received the Global Recycled Standard certificate and was recognised at the Copenhagen Fashion Summit. The company introduced zero-waste production, which reduced its environmental impact by 60% compared to traditional methods. An innovative breakthrough was made possible by the creation of smart fabrics with

built-in fibre-optic sensors that track the biomechanics of athletes' movements in real-time. Presented at the Tokyo Sport Tech Exhibition, these technologies provide coaches with detailed information on load distribution and the quality of the elements. This development is already being used to train Olympic teams.

An analysis of the achievements of the leading manufacturers of rhythmic gymnastics sportswear and their contributions to the development of the industry is presented in Table 3. The data illustrated the link between brand innovation and its impact on the sports industry.

Table 3. Achievements of leading brands in the development of sports fashion

Brand	Innovative development	International recognition	Impact in industry
Milano Pro Sport	Biomimetic materials	Milan Fashion Innovation Award	New standards of comfort
GK Elite	Adaptive suits	ISPO Gold Medal	Personalisation technologies
Christian Moreau	The eco-friendly range	Sustainable Fashion Award	Environmental standards
Sylvia P	Smart monitoring	Tokyo Tech Innovation Prize	Digitalisation of sport

Note: data for 2023–2024

Source: compiled by the author based on I. Turcu *et al.* (2021), A.H.k. Nejmelddeen *et al.* (2023)

Technological advances in sportswear are actively penetrating the fashion industry. Famous fashion brands are introducing sports innovations into everyday wardrobes, creating collections with improved functional properties. The development of thermo-adaptive materials and smart fabrics that independently change the microclimate based on human activity is gaining traction. The success of these innovations is confirmed by the growth of international sales. According to Y. Shi *et al.* (2024), exports of high-tech gymnastics costumes increased by 45% in 2023. The interest in them is shown in the Asian and North American markets, where technological solutions are actively used in national team training programmes. The development of personalised solutions using 3D scanning and additive manufacturing is becoming a promising area. Leading brands are investing in the development of systems that allow them to create costumes tailored to the individual characteristics of female athletes. This technology promises big changes both in sportswear and the fashion industry as a whole.

Discussion aspects of the development of gymnastic costume design in the context of international research

The integration of ethno-cultural elements with innovative technologies in the design of Ukrainian gymnasts' costumes reflects significant changes in the sports industry. The transformation of traditional Ukrainian ornaments and symbols to meet the modern requirements of sports creates a unique vector in the development of sports design.

The model of zonal compression presented by Y. Yan *et al.* (2012), despite its technical value, remains insufficient, as it omits the interaction between functional requirements and aesthetic aspects specific to the Ukrainian rhythmic gymnastics school. The study significantly deepens the understanding of the evolution of sports design compared to the approach of K. Kaszala *et al.* (2023), who

limited themselves to a standard chronological analysis. For the first time, the proposed periodisation of 2008–2024 systematises the integration of traditional elements into modern sportswear through the prism of cultural change. In contrast to the works of X. Xu (2010) and T. Boyle (2022), which focused on a superficial aesthetic analysis, this study examined the deeper mechanisms of the impact of national symbols on the psycho-emotional state of female athletes, demonstrating how traditional Ukrainian colours can increase confidence in the international arena.

The described design methods proposed by Pitnawati *et al.* (2022) revealed the insufficiency of existing approaches and was used to develop an improved system for the adaptation of traditional ornaments. Although A.H.k. Nejmelddeen *et al.* (2023) confirmed the effectiveness of such technologies, this article addressed their adaptation in the context of Ukrainian cultural heritage. The methodology proposed by D. Rayimberdieva *et al.* (2024) emphasised technical aspects, but the latest approach introduced cultural and aesthetic features as a basic factor influencing performance in sports. While developing the ideas of J.S. Hamza *et al.* (2020) about costume as a means of transforming physical perception, the study specified the mechanisms of influence of national elements on the visual perception of gymnastics movements. Based on the analysis of J. Sun & X. Song (2018), the evolutionary process of Ukrainian sports design was rethought. This study complements their findings by demonstrating a gradual and harmonious combination of technical innovations with traditional aesthetic elements.

A study conducted by Pitnawati *et al.* (2023) addressed the use of digital methods in the sportswear design process. However, the mechanistic approach, on which this method is based ignores the interdependence of the technical and aesthetic characteristics of the suit. In response to this, an integrated design system is proposed that

reforms traditional methodologies through the synergy of functional requirements and cultural authenticity, based on research into the biomechanics of rhythmic gymnastics movements. K. Hou & S. Sirintraporn's (2023) approach to incorporating traditional elements into contemporary design has proven effective in the context of adapting Chinese cultural heritage. At the same time, its application to Ukrainian rhythmic gymnastics proved problematic due to the uniqueness of the national style and traditions. In this context, the study proposed a conceptual model for preserving the authenticity of Ukrainian culture by integrating its motifs into modern sports design.

S.A. Kamal & S.A. Khan (2015) presented the basis for the determination of the functional needs of sportswear, especially for educational purposes. However, the study was limited to technical aspects, omitting the issue of cultural and identity context. Therefore, the present study examined the role of traditional elements as a stimulus for improving sports performance. A.H.k. Nejmehdeen *et al.* (2023) established key technical standards for the mass production of gymnastics costumes. At the same time, the unification of design leads to the levelling of individual characteristics of female athletes. The concept of the approach to production redefines sports equipment as a symbiosis of technological implementation and cultural heritage. E. Hart *et al.* (2023) conducted a biomechanical analysis for injury prevention. However, there are still gaps in the study regarding the interaction between the technical characteristics of clothing and its aesthetic functions. The conclusions of the study highlighted the mechanisms of influence of national design elements on the quality of technical elements.

The mathematical modelling proposed by R. Dan & Z. Shi (2020), introduced the tracksuit as a mechanical system. Such modelling forms an innovative approach to design, where cultural and aesthetic components contribute to the creation of synergistic effects that positively affect the performance of sports tasks. The system developed by S.H. Nassib *et al.* (2020) provided forecasting of the physical parameters of gymnasts but does not address the impact of equipment on the psychological state of athletes. The proposed results transform the traditional views on the role of sportswear, emphasising the potential of national elements in supporting the psychological preparation of female athletes.

The uniqueness of the study lies in the identification of a direct link between the use of ethno-cultural elements and the psychological confidence of female athletes. This article, contrary to previous studies, not only focused on technical or aesthetic aspects separately, but also demonstrated a synergistic effect in the context of national identity.

CONCLUSIONS

A study of modern trends in the design of sportswear by Ukrainian rhythmic gymnasts has revealed significant changes in the approaches to costume design. The

costumes are characterised by a combination of innovative technologies and national traditions. It has been established that modern gymnastics costumes are the result of using advanced materials with elasticity of up to 40% and air permeability of at least 100 dm³/m²s. Thanks to 3D weaving technology, it was possible to reduce production waste by 95% and ensure the creation of zones of different compression directly during manufacturing.

The integration of Ukrainian ethno-cultural motifs into the design of sportswear, starting with the 2008 Olympic Hopak to modern programmes, was systematised. The article revealed a long-term trend towards the implementation of traditional ornamental elements in combination with innovative methods of decoration, which forms a unique style of the Ukrainian rhythmic gymnastics school. The study determined that the use of national motifs in costumes has a positive effect on the psychological confidence of female athletes during performances. An analysis of the impact of innovations on the sports industry showed a 45% growth in the high-tech gymnastics costume market over 2024. The introduction of smart fabrics with built-in sensors has improved the monitoring of athletes' condition during training and competitions. The use of environmentally friendly materials and zero-waste production technologies meet modern sustainability requirements. The results obtained are useful for the development of Ukrainian sports design and can be applied to the creation of new collections of rhythmic gymnastics costumes. The proposed approaches to the integration of ethno-cultural elements lay the foundation for the formation of a unique Ukrainian style in sportswear.

Based on the study, practical recommendations have been developed for sportswear manufacturers and designers: to use a gradient distribution of compression zones according to the biomechanics of movement; to combine traditional ornaments with modern decorating techniques; to account for the psychological impact of colour on the emotional state of female athletes. To optimise production, it is recommended to introduce 3D design technologies and waste-free production, which will reduce production costs while maintaining high quality. The study demonstrated the importance of an integrated approach to the creation of sportswear, where technological innovations are harmoniously combined with aesthetics and national traditions. It has been established that the success of a suit is determined not only by its functionality, but also by the ability to create a holistic artistic image that emphasises the individuality of the athlete and reflects cultural identity. The use of Ukrainian ethnic motifs has proven to be effective in increasing the psychological confidence of female athletes and creating a unique national style in sports design. A promising area for further research is the development of a methodology for creating personalised rhythmic gymnastics costumes, taking into account individual anthropometric indicators and the specifics of each athlete's competition programmes.

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CONFLICT OF INTEREST

None.

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Огляд тенденцій в дизайні спортивного одягу українських художніх гімнасток

Анотація. В умовах зростаючої конкуренції в галузі художньої гімнастики актуальним стає питання розробки спортивного одягу, який гармонійно поєднує функціональність, естетику та національну ідентичність. Метою дослідження був аналіз тенденцій у дизайні спортивного одягу для українських художніх гімнасток з урахуванням естетичних, функціональних та технологічних аспектів. Це дослідження ґрунтувалося на аналізі наукових публікацій, технічної документації та візуальних матеріалів міжнародних змагань за період 2015–2024 років. У результаті дослідження встановлено, що інтеграція технологій 3D-ткацтва сприяла зменшенню виробничих відходів на 95 %, а також дозволила створювати зони диференційованої компресії безпосередньо у процесі виготовлення продукції. Використання інноваційних "розумних" тканин із вбудованими сенсорними елементами забезпечило підвищення ефективності тренувального процесу на 28 %. Окреслено особливості використання українських етнокультурних мотивів у дизайні спортивного одягу, що позитивно вплинули на психологічну впевненість спортсменок. Визначено значне зростання ринку високотехнологічних гімнастичних костюмів, обсяги якого збільшилися на 45 % за 2024 рік. Впровадження екологічних виробничих методів дало змогу знизити вуглецевий слід на 30 %. Крім того, застосування градієнтного принципу розподілу зон компресії призвело до покращення виконання складних фізичних елементів на 15 %. Отримані результати мають практичне значення для дизайнерів спортивного одягу, виробників та тренерів, надаючи науково обґрунтовані рекомендації для створення функціональних і естетично довершених костюмів з урахуванням національних традицій та сучасних технологічних можливостей

Ключові слова: інноваційні технології; етнокультурні мотиви; біомеханіка рухів; термоадаптивні тканини; естетична функціональність