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Compression Clothes for Sports-Critical Review

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ABSTRACT: Compression knitted fabrics can differ from each other in the type of polyurethane fibers used with different characteristics of properties, their percentage, structure of elastomeric yarns, methods of fabric production, its weaving and other structural parameters, i.e. have a rather complicated internal organization, which determines the differences between their properties and the properties of traditional knitwear. The clothes from them, including sports, densely fit a figure, providing thus sufficient freedom of movement and, simultaneously, supporting a necessary muscular tone that is especially important for sportsmen at achievement of good results. In article the analysis compression knitted fabrics for playing sports is carried out.

KEYWORDS: sportswear, active sport, heat protection, stretch ability, elastic fibers and threads, heat transfer

I.INTRODUCTION

Today, the sportswear market, as an important component of the global textile industry, is actively growing every year. The development of the textile industry, the emergence of new textile fibers and innovative technologies in the production of knitted materials contributes to the active development of the sportswear market. Over the past 20 years there has been a huge growth in the global market for sportswear - by 7.5% and amounted to 244 billion dollars. Today, the largest segments of the global sportswear market are occupied by the following countries: the United States occupies 35% of the market, China 10%, Japan 7%, Brazil 5%, Germany, Great Britain and France 4% each, Russia and Italy 3% each, Spain 2 %, and the remaining 23% of the aggregate falls on all other countries [1].

Sport today occupies an important place in the life of every modern person. Thanks to this, sportswear has ceased to be clothing exclusively for sports and has firmly entered the everyday wardrobe of people of different ages. The growing interest of consumers in sports knitwear stimulates the emergence of new functional materials that meet the highest demands of the modern market. In this regard, science and industry are studying the characteristics of various sports, identify requirements for materials and design of clothing, offers new developments in this area. A steady tendency here is the creation of innovative materials, lightened in their weight, but possessing such qualities as hygroscopicity, thermal insulation, elongation, resistance to wear, and having a compression and biomimetic effect.

All sportswear can be conditionally positioned into four groups: special clothing for active sports, basic sportswear, sportswear for leisure, and sportswear (see the original text in English). Special clothing for active sports (1st group) is a high-tech clothing that has high functionality. It is produced in the smallest volume and maximum price range, whereas basic sportswear (2nd gr.) Is cheaper and more stylish, while retaining as many material attributes as possible. Sportswear for rest (3rd gr.) Is a sporty-style clothing for passive rest and at home, it is produced and sold in a larger volume at a much lower price [2]. Sportswear materials used for active sports are specially designed in terms of geometry, packing density and the structure of the composite fibers in the yarn, as well as their design to achieve the necessary comfort in the bottom layer and high athletic performance.

Compression is called elastic clothing, which due to tight fit provides compression of individual parts of the body and their support. This type of clothing may vary in the degree of compression. To date, the assortment of compression clothing, covering areas of the figure with different plastics, includes over 30 items. Design methods for such products are different and are influenced by many factors. Consider the types, the main characteristics of the properties, the design features of functional sportswear with a compression effect.

All compression clothing, depending on the destination, is divided into several types of products:

- Compression T-shirts - rashgards;
- Tops and T-shirts with a slimming effect;
- Pants with a slimming effect - leggings;
- Compression shorts - boxers;

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• One-piece compression overalls;
• Slimming sleeves;
• Products for legs - compression socks, socks, gaiters, supporting products - knee pads, elbow pads, shoulder pads, etc.

Sports compression clothing is designed to affect muscle tissue and can be combined (with or without sleeves, to the level of the ankles, to the level of the knees, to the upper thigh, or as a closed swimsuit); separate (leggings, shorts, swimming trunks, jumper, T-shirt, short fitted bodice). All products are used in different sports, depending on the season and the specifics of training.

This article analyzes the scientific work carried out in the field of tight-fitting compression sportswear.

II. REQUIREMENTS FOR SPORTS COMPRESSION CLOTHING

The functional requirements for sports compression clothing depend on the sport, wear season, climatic conditions and the amount of physical activity [3]. High active sports are classified as a game that is played for a short period of time with maximum physical activity, such as tennis, football, running, jumping, etc. Sports performance compression clothing can affect a player's performance and therefore become one of its most important quality criteria.

With amplitude movements, local stretching of the skin in the particular areas of the elbow and knee reaches 50% along the arm, 28% in cross section, while bending forward, the increase in the half-grip of the hips is 35% in the vertical direction and 21% in the cross section [3]. tilting and stretching the arms forward, an increase in the width of the backrest occurs by 20% [4].

Background information for the use of compression sportswear are: compression effects; body performance related to sports activities; achieved sports results [4]. Recommended pressure values of compression sportswear are 667-3332 Pa, recovery clothing is up to 3999 Pa. [five]

Sports compression clothing should maintain the optimal thermal balance of the body during exercise and sports, to ensure effective sports activities, protection from injury and mechanical damage. It should be light, comfortable, not hamper movements, fit in height and fullness, fit to the body, without allowances for freedom of fit, which is associated with the best aerodynamic properties of tight-fitting elastic clothing.

In the course of this study, more than 100 sports compression products of various brands (Nike, 2XU, Puma, Reebok, Adidas, etc.), presented in a trading network and Internet resources, were studied, analyzed and evaluated. Each product was analyzed by the following criteria: sport; type and purpose of the product assortment group; raw material composition; model-constructive solution. Analysis of the results of numerous studies of a large number of athletes from various sports, who were experimenting with the use of compression clothing, made it possible to determine useful properties and features of compression clothing. The analysis showed that sports compression clothing is used: 1) during training and physical exertion to increase the physiological parameters of muscle tissue: power, strength, endurance; improvement of the circulatory system; correction of body shape to reduce the resistance of the environment (air, water) in high-speed sports; thermoregulation; protection of ligaments and tendons from injuries and sprains; 2) during exercise and during the rest period - to accelerate the recovery of physical indicators and reduce pain in the muscles; compression clothing stimulates sweating due to a slight increase in body temperature: the muscles are constantly warm, which allows not only to avoid injuries, but also to put them into work more quickly. Together, these advantages allow you to qualitatively improve the effectiveness of training.

In sports compression clothing, selective compression and fixation ("support") effects are applied to individual groups of muscles and ligaments [5, 6, 7], taking into account various increases in muscle tissue during physical activity, which can reach 5%.

As a result of the carried out analytical studies, a classification of the range of sports compression products from tensile materials was proposed, grouped according to the anthropomorphic location in the figure (Fig. 1).

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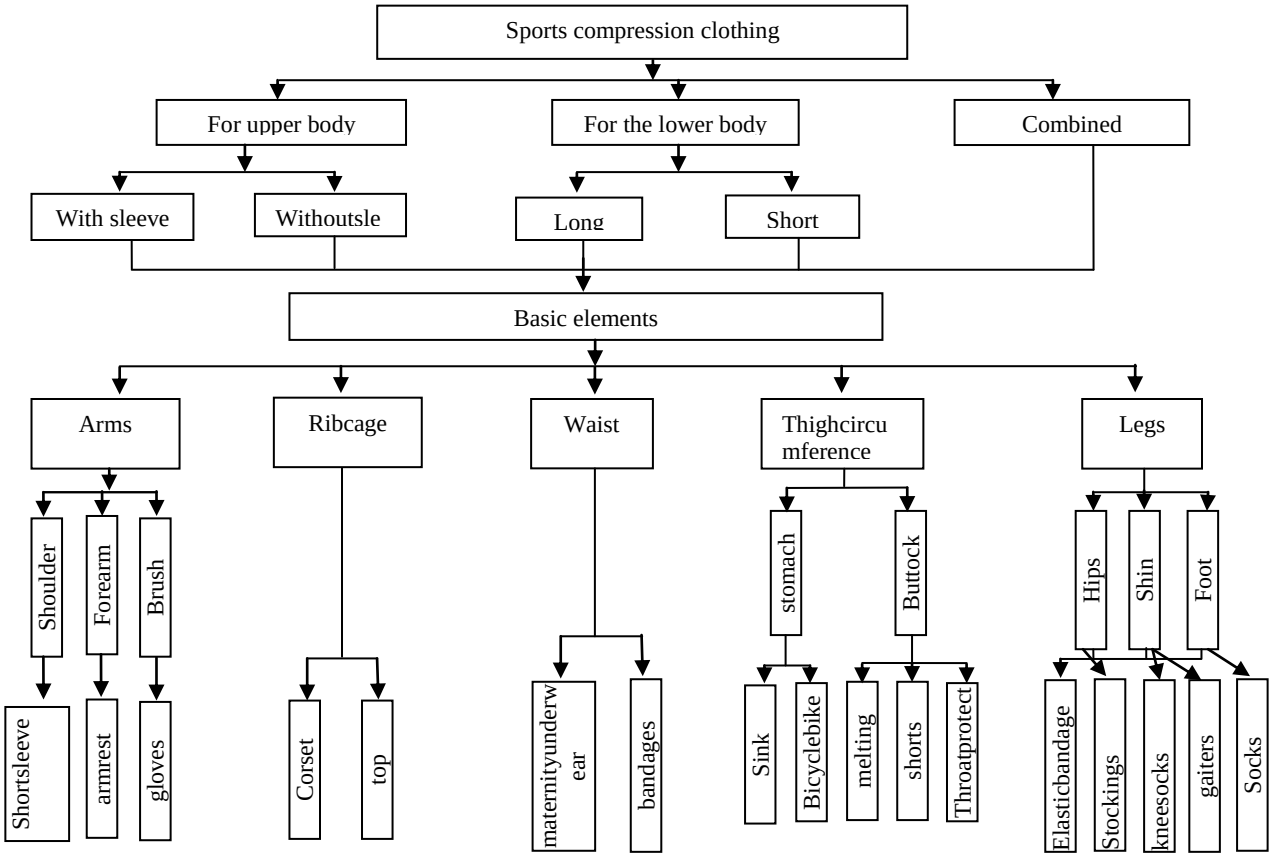

Fig.1. Classification of the range of compression products for sport purposes

In accordance with the classification, all sports compression products are designed for one of five body areas: arms, chest, waist circumference, hips circumference, legs, or combinations thereof. The basic elements, combining with each other, can form one of the existing types of clothing. For example, the combination of basic elements of clothing that covers the arms and chest forms the type of clothing — the top; shoulder, chest and waist - T-shirt and T-shirt; waist and hips girth - sports pants; covering the legs and thigh girth - leggings or shorts (depending on the length of the basic element of clothing for the legs); only the area of the hands - sports gloves, etc. The union of all basic elements is a compression garment covering the entire surface of the body, that is, the overalls.

From a medical point of view, the human body is subdivided into certain zones, characterized either by the superficial location of the main venous highways (neck, upper and lower extremities), or by significant dynamic changes in volume and shape during the functioning of the organs in the chest and abdomen. Consideration of the pressure of products is particularly appropriate in these areas, since exceeding its values above certain limits causes impaired blood circulation, respiratory functions and abdominal organs. The strength with which therapeutic and prophylactic knitwear affects soft tissues is called a compression class. This parameter is very important in order to choose the right compression underwear. Insufficient compression force makes the use of this technique useless, and excessive compression leads to the formation of edema and disturbances of sensitivity and blood supply. In prophylactic sports products, the compression class is usually 0, in the medical, for recovery from injury, it is 1. Stronger compression makes it difficult to perform active activities, therefore it is not used for training.

Depending on the purpose of products with elastomeric threads and the level of pressure, they are classified into comfortable, prophylactic, compensatory, compressional and special (Table 2) with a zonal distribution of pressure over body areas [8].

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Table 2
Classification of products with elastomeric yarns depending on the purpose and pressure level

Products	Purposeofproducts	Pressure	
		В кПа	В мм.рт.ст.
Comfortable	Household, sports	0,66-1,33	5-10
Prophylactic	Sports, sports, medical, medical	1,33-3,32	10-25
Compensation	Household, sportsmedical, medical	3,32-6,65	25-50
Compression	Sportsandmedical	6,65-13,3	50-100
Special	Also	More 13,3	More 100

III. COMFORTABLE PROPERTIES OF COMPRESSION SPORTSWEAR

Designing comfortable clothing that provides thermal equilibrium in the human body under various physical (sports) loads with the external environment is the task that is being solved when creating functional sportswear. In team sports, such as tennis and football, heat exchange processes have features due to the high level of metabolic heat released in the range of 800-1300 watts. This amount of heat can increase body temperature by 1.5-2ºC. To control body temperature, sweat is generated and the heat of evaporation of water is used for a cooling effect [9]. Sweat can reach 2.5 l / h, and therefore the main functional requirement of high active sports clothing is increased hygiene requirements, which can be formulated as follows: 1) the breathability of clothing must be adjustable; 2) the inner layers of clothing should be hygroscopic and easy to dry; 3) sweat (moisture), formed on the body of a person with increased physical activity, should be removed from the skin through clothing; 4) the design of clothes should provide the person with the greatest freedom of various movements of a person, ease when putting on and taking off clothes, also clothes should not constrain breathing and blood circulation; 5) clothing should be as soft and light [10].

In such sports as jumping, running and weightlifting, compression is created by the elastic properties of materials. Elastic sportswear (CAW) provides the necessary compression (compression) and tight fitting clothes on the figure of an athlete. Therefore, they are known as “costumes for the skin” [11]. Other requirements for active sportswear are smoothness, softness, resistance to UV radiation, light weight and easy care.

Long-term preservation of comfortable heat sensations in active sports is possible only under the condition of ensuring the thermal balance of the body, which in general terms can be represented as:

$$E + Q_u = Q_o + A \pm \Delta Q\,, \quad Bm \qquad (1)$$

where E is the energy generated by metabolic processes of the body (metabolic heat); Q - heat received by man from outside due to solar radiation or other sources of radiant heat (Fig. 1); ± ΔQ is the change in the heat content of the organism relative to a comfortable condition; + ΔQ - overheating (heat accumulation) of the body; -ΔQ- overcooling (lack of heat); Qo - heat transfer given to the external environment.

In formula (1), the heat transfer Qo consists of the following terms [13]: Qkond - heat loss by conduction; Qconv - heat loss by convection; Qrad - heat loss by radiation; Qдых - heat losses during respiration due to heating of inhaled air; Qisp - heat loss due to evaporation of moisture. Thus, formula (2) takes the form:

$$E + Q_u = Q_{конд} + Q_{конв} + Q_{рад} + Q_{дых} + Q_{исп} + A \pm \Delta Q. \qquad (2),$$

where A is a mechanical work, spent during sports; Qi - the heat received by the human body from the outside in the form of solar radiation from the external environment.

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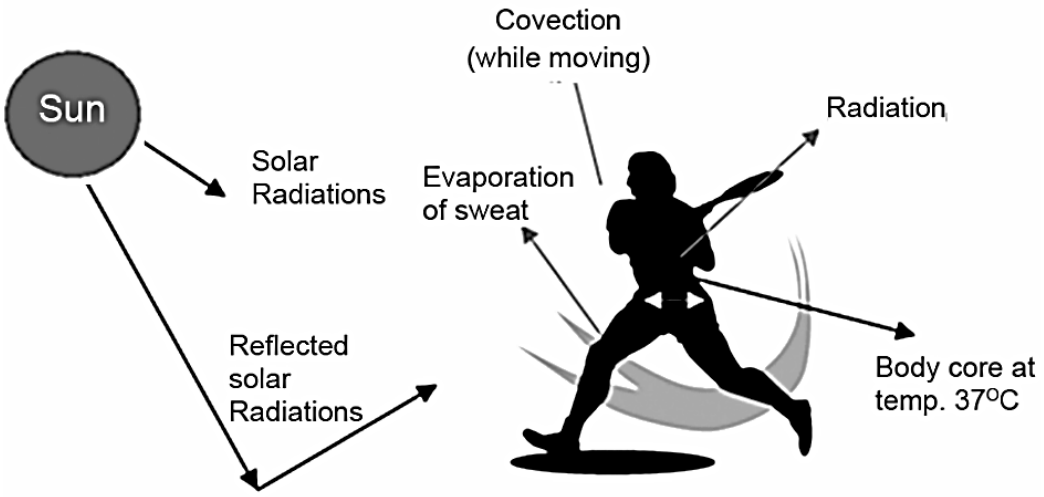

Figure 1 - Heat transfer modes in active sports [12].

There are four different aspects of comfort, namely: thermo physiological comfort, sensual comfort of the skin, comfort of ergonomics and psychological comfort.

The human body is trying to maintain the core temperature at 37 ± 1°C. There are four modes of heat transfer to maintain thermoregulation of the human body, namely conductivity, convection, radiation and evaporation [14]. The most powerful mechanism of thermoregulation in case of overheating and the performance of muscular work by a person is sweating. The magnitude of moisture loss through the skin through the diffusion of water vapor closely correlates with heat sensations [15] and is one of the indicators of the thermal state of a person (Fig. 2).

When active sports are engaged, 80% of energy is converted into heat and in warmer areas, when air temperature is higher than body temperature, convection is added to thermal loads (Fig. 1). In these conditions, evaporation remains the only mode for heat loss. The requirement for evaporation to maintain the core temperature of the body is determined by the sum of metabolic heat, as well as radioactive and convective heat exchange. The amount of heat loss depends on the rate of evaporation of sweat, which further depends on the evaporating capacity of the material [16]. Therefore, hygienic properties of the materials from which it is made (air permeability, vapor permeability, evaporation, water consumption, hygroscopicity, etc.) are important for compression sportswear.

The most powerful mechanism of thermoregulation in case of overheating and the performance of muscular work by a person is sweating [17,18,19]. The magnitude of moisture loss through the skin by diffusion of water vapor, is closely correlated with heat sensations and is one of the indicators of the thermal state of a person.

Studies have shown that the moisture of the poddezhny layer and the accumulation of moisture in it determine the comfort of sportswear during sports [19,20]. Thermal insulation of clothing decreases during sweating, and the amount of reduction ranges from 2% to 8% due to the accumulation of water in clothing, which can cause an "after chill" effect in athletes after heavy training [21]. For outdoor sports, sweat can rise up to 2.5 l / h in hot and humid due to additional convective and radiation heat loads [22]. There is a regional distribution of sweat on the human body. At the same time on the back of the area of sweating is much higher than on the chest.

Thermo physiological comfort determines the breathability of clothing and the management / regulation of humidity. It involves the transfer of heat and moisture in the form of vapor and liquid through the material. Clothing provides a microclimate (Fig. 2) between the body and the external environment and acts as a barrier to the transfer of heat and steam between the skin and the environment [23]. There are three main processes associated with the transmission of moisture through the fabric [24], namely the diffusion of moisture due to the moisture gradient in the strip [25], sorption-desorption by hydrophilic sites on the fabric [26] and forced convection by moving air near the skin [27].

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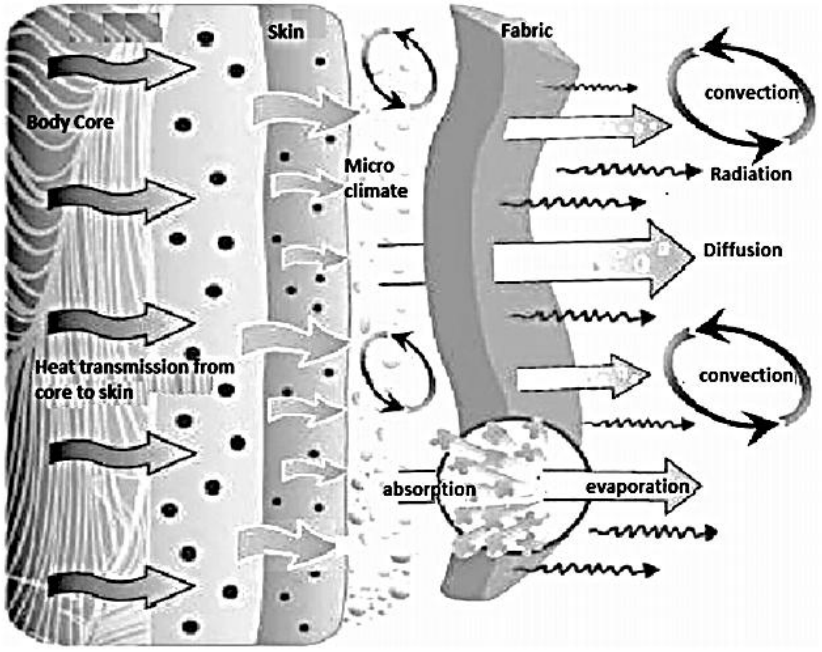

Fig.2 - Heat and moisture transfer through textile material [12]

Sensual or tangible comfort of sportswear is determined by surface friction, roughness and softness of the material [28].

Ergonomic comfort determines the freedom of movement, which depends on the design of parts, the elasticity of the material [28]. In active sports, such as jogging, cycling, body movement causes stretching and contraction of the muscles of the skin of the body, and consequently a change in the corresponding dimensional signs of the body. Sportswear should not restrain these movements, otherwise discomfort will be created due to undesirable pressure on the body [29]. It must be borne in mind that the initial (static) pressure created by tight-fitting sports clothing on the human body increases due to an increase in dimensional signs due to dynamic growth in the process of performing physical (sports) load. Therefore, the specificity of the design of compression knitwear is to take into account not only the deformation properties of the canvas, but also the anthropometric data of a person, affecting the dynamic increase of dimensional signs in the operating conditions [30].

IV. Requirements for materials for the manufacture of sports compression clothing.

For the manufacture of sports compression clothing used modern materials that have a high tensile properties with low operating loads, high elasticity and moisture resistance. When wearing such clothes, the heart rate decreases and blood flow to the muscles increases. This significantly increases the endurance of the athlete and leads to improved results. As a result of the snug fit of the kit to the athlete's body, there is an active release of lactic acid from the loaded muscles. As a result, the procedure of recovery of the body after exercise is reduced several times. In addition, compression prevents muscle tension during exercise. Thus, the use of compression clothing is a good prevention of sports injuries.

Among the indicators of elastic properties of tensile textile materials most important for designing clothes are as follows:

1. Extensibility, defined as a relative change in length samples under the action of a given load. Dependence "effort-stretching"is nonlinear, so measurements are carried out for different loads, and the most complete data obtained on the basis of the analysis of the schedule the dependencies of these quantities obtained by automated measuring complexes Insitron, Kawabata-FB1 [31,32].

2. Elasticity equal to the ratio of the shares of elastic and total strain expressed as a percentage. With fast amplitude movements during the occupation of active sports material sizes must be restored at the same speed to maintain contact with body surface. Therefore, for sportswear materials important is the value of dynamic elasticity

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(DER), numerically equal the ratio of the areas under the unloading and loading curves of the material, expressed as a percentage [33].

3. Residual deformation, which determines the relative increase in the size of the material after removal of the load. As well as elasticity, it has a complex dependence on the magnitude and method of loading. Most informative for solving design problems will be residual deformation under operational loads of the material .For tight clothing, the shaping of which occurs due to the elastic tensile properties of the material, important isthe requirement to preserve the size and performance of properties throughout the periodoperation? Therefore, in scientific research the index of elastic-elastic and plastic deformation of materials is also determined [34]. Increased stretch ability with a high degree of elasticity, i.e. a significant proportion (more than 95%) of rapidly reversible deformation, creating a complex of valuable properties characteristic of highly elastic materials. Clothing from them, including sportswear, tightly fits the figure, while providing sufficient freedom of movement and, at the same time, maintaining the necessary muscle tone, which is especially important for athletes when achieving high results. Materials intended for sports compression clothing, perform their functions in the range of stretching from 20 to 70%. Therefore, the tensile properties of such materials are investigated in the strain range up to 100%. With a relative deformation of 100%, the tensile force of sportswear materials is 140-210 N / cm [35].

Stretch ability of the compression material can occur due to the stretching of fibers consisting of elastic chains of molecules of polymeric materials, for example, elastane or latex; thermally or chemically textured textured fiber; "Springy" looped structure (weave) of the material, easily changing under the action of an external load. It is known that knit materials, which include elastomeric fibers, have the best ratio of properties of elasticity and dimensional stability [4]. Studies of knitted fabrics, differing in the ratio of lycra in the composition, showed that the stretch ability of the material can occur due to the structure and properties of elastane fibers, parameters of the looped structure, weave and methods of knitwear production [36]. The amount of elastane depends on the purpose of the sports product. In casual clothes use materials containing 2 to 5% lycra. This content is enough to create the necessary properties of drape and fit the product. In the composition of materials for compression clothing (foundation garments) the content of elasticfibers can reach 45% [37]. Materials with a lycra content of up to 15–40% are used for clothing for active sports [38], providing elastic deformations in excess of 100%.

The elasticity of the web can be achieved by using elastomeric yarns (rubber, latex or polyurethane), yarns or yarns that have elastic properties

V. Threads and materials for the manufacture of compression products.

The most characteristic feature of compression knitwear is its elastic mechanical properties. They make it an effective membrane stretching element acting on a curved part of the human body. Elastic fibers and filaments exhibit good tensile properties and elastic recovery, are used for the manufacture of elastic materials. Cloths used in the manufacture of compression materials, most often in their structure contain polyurethane filaments. The embedding of these threads gives the materials a complex of valuable properties, which, first of all, include increased tensile properties with low operating loads and a high degree of elasticity. New types of elastic fabrics can be divided into two groups: the Tactel® group, used in materials for sports products, and the Lycra® group, which has a wide range of uses [39].

Special polyamide Tactel® fiber is intended for the manufacture of sportswear, subjected to a variety of loads. Tactel® yarns are made of durable, ultrathin fabrics and knitted fabrics used in top and sportswear for skiers and climbers. They give sportswear the following properties: strength, durability, protection from wind and moisture, the ability to divert body sweat to the outer surface of clothing, quick drying, a variety of aesthetic effects, light weight, easy care. The combination of Tactel® with Lycra® gives softness, comfort, ease of care for clothes, long-term preservation of shape, comfortable fit, freedom of movement, good appearance.

Very often Tactel technology is used in compression knitwear. It consists in the fact that fibers with a large diameter are in direct contact with the skin, while fibers of a smaller diameter are located on the outer surface, the effect of biometrics. But at the same time, the density of the loop from the wrong side is higher, which leads to an increase in the area between the yarn on the inside and the lower density of the structure on the face, imitating the taper of the aqueducts on the trees. The loops on the back side are formed by two threads, connected together on each other needle on the weft of a knitting machine, which facilitates the transport of fluid from the back to the face, creating a process similar to the “grip-tension” mechanism in plants. These materials have significantly better water absorption [40].

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Biometric knitwear with a branched structure was developed using two guide rods with polyester and nylon [41]. In the structure of such knitwear a smaller number of longer loops on the inside than on the outside, which creates a branching tree structure, pumps up the moisture from the inside to the outside and facilitates water transport properties. The area of evaporation increases significantly (about 8-10 times depending on the characteristics of the fabric), so the product remains dry, which is important when in a warm and humid climate.

Materials with a biometric effect maintain a constant body temperature, absorbing excess heat and moisture from the body, while maintaining the body's comfortable sensations [42]. Inotek® fiber is an innovative biometric. When the fiber absorbs moisture, it shrinks to a fine structure, resulting in microscopic open air pockets, which increase breathability. This answer is reversible and the fibers can return to their original size in the dry state of the body [43].

In chemical terminology, Lycra® is classified as segmented polyurethane [44]. Available in various ranges from 8 to 2550 dtex. Lycra fibers have 5 fold extensibility without permanent deformation, they are chemically neutral and resistant to chemicals. Due to the higher strength, polyurethane threads are produced thinner in the range of linear densities of 2.2-125 tex, which allows to obtain the effect of compression in the widest limits, as well as significantly expand the scope of their application. A spandex-type thread can be used as braided or without braid, which is also an advantage, since the process of braiding threads complicates the technology [45]. It should be noted that when knitting on machines, a forced feed of this thread to the loop-forming organs is used, which allows you to create the necessary tension on the thread and give elasticity to the product. Products in which spandex-type threads are used are very resistant to washing and aging [46].

According to the method of manufacture, all elastomeric threads can be [47] molded, cut, complex. All processing elastomeric yarns are of the form: homogeneous monofilaments; reinforced heterogeneous filaments obtained by wrapping an elastomeric core with filaments or fibers of different nature [48].

The percentage investment of elastane fibers is determined by the type and purpose of the products, ensuring their optimum performance properties and aesthetic characteristics. So 2% of the Lycra thread is enough to increase the durability, fitability and dimensional stability of products for everyday use. In swimwear, underwear and clothing for outdoor activities, their specific content is from 14 to 40% (by weight). In many types of sportswear (cycling t-shirts and shorts, skater suit) where a high degree of fitting is required while maintaining the necessary ergonomic properties, as well as ensuring sufficient compression forces on the athlete's body, Lycra content ranges from 15 to 20%. The embedding of polyurethane fibers in knitted fabrics, due to their high elasticity and elasticity, provides sportswear with significantly higher comfort and fulfillment of the above requirements, which has a direct impact on the consumption of elastomeric yarns and production growth in this sector [49,50].

VI.CONCLUSION

Compression knitted fabrics can differ from each other in the type of polyurethane fibers used with different characteristics of properties, their percentage, structure of elastomeric yarns, methods of fabric production, its weaving and other structural parameters, i.e. have a rather complicated internal organization, which determines the differences between their properties and the properties of traditional knitwear. These canvases have a small mass, pleasant appearance. Embedding them in the composition of natural and chemical fibers affects the change in the structural, physic mechanical and operational properties of the latter, which, in turn, necessitates the development of methods for designing clothes made from such fabrics compared to traditional knitwear. Clothing from them, including sportswear, tightly fits the figure, while providing sufficient freedom of movement and, at the same time, maintaining the necessary muscle tone, which is especially important for athletes when achieving high results.

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