

QUALITY MANAGEMENT FOR FOOTWEAR USED IN OUTDOOR ACTIVITIES

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Introduction. According to the World Health Organisation, physical activity is any movement of the body produced by the skeletal muscles that requires energy, and moderate to vigorous physical activity improves health. In particular, regular physical activity has been shown to be beneficial [1]:

- improves muscle and cardio-respiratory fitness, bone health and functional state of the body;
- reduces the risk of hypertension, coronary heart disease, stroke, diabetes, various types of oncological diseases, depression, injuries of the musculoskeletal system;
- helps to maintain a healthy body weight.

Review of the latest sources of research and publications. Like culture and the arts, recreation, leisure and sport play an important role in community life, significantly improving people's health and well-being, empowering people and developing inclusive communities. Recreation, leisure and sport activities can involve individuals, small groups, teams or whole communities, and can involve people of all ages, abilities and skill levels. The types of recreation, leisure and sport activities in which people participate vary widely according to local traditions and tend to reflect social systems and cultural values [2].

From this point of view, scientific researches on footwear for active recreation are of special importance, as they are an obligatory and important part of the material component of the complex of cultivation, formation and practical implementation of a healthy lifestyle of the population and ensuring its physical health. At the same time, the process of improving the existing ones and finding new ways to improve the consumer properties of the mentioned footwear is complex and is studied by commodity experts, manufacturers, technologists, material scientists, marketers and other specialists [3].

The development of consumer culture and production technologies results in the constant improvement of complex product characteristics that are important to the consumer. Therefore, the modern goods market,

through the eyes of a modern consumer, evaluates, on the one hand, the social significance and practical usefulness of a given pair of shoes and, on the other hand, the ease of use and aesthetic perfection, economic efficiency and safety throughout the entire life cycle (production-consumption (use)-storage-disposal), which correspond to the social and biological classes of requirements for shoes [4].

It is known that the high quality of footwear is achieved mainly by creating such a design and form that can ensure the best fulfilment of all the requirements desired by the consumer. In the modern market the functions, design and forms of footwear are developing and improving, that is why their historical development is divided into three stages: manual, mechanised and automated (chemical) production [5], but the approval of each of these stages does not mean the complete disappearance of the previous ones: for example, in the XXI century the number of hand-made shoes is increasing.

It is also known that in each of the specified stages of the manufacture of leather footwear there are two main stages – the manufacture of the upper and the application of the sole, while the basic design has not changed – the parts of the upper are sewn into the upper and the sole is applied to the upper.

Setting objectives. The above convincingly proves that the study of the nomenclature and importance of individual factors in the formation of consumer properties of modern footwear for active recreation is a current scientific and theoretical problem that has a significant impact on the cultivation, formation and practical implementation of a healthy lifestyle of the population and ensuring its physical health.

Main material and results. The subject of the research is active leisure footwear and the subject of the research is the consumer characteristics of footwear.

Merchandising aspects of assortment formation and consumer characteristics of footwear in general and active leisure footwear as a specific component – primarily involve taking into account consumer requirements for footwear materials, their construction and footwear as a whole.

The quality of footwear for active recreation is a complex hierarchical structure, on the upper levels of which there are the most important (complex) characteristics, on the lower levels – groups, subgroups and separate (individual) characteristics. For the satisfaction of consumer needs, the most important are the consumer properties of footwear – a group of properties of a particular pair of footwear, which are revealed in the process of operation and are related to the possibility of satisfying individual social or personal needs with this pair of footwear in accordance with its purpose [4].

Therefore, the basic factors of ensuring the quality of footwear for active recreation are:

- friction properties (slip resistance). The requirements for the friction properties of these shoes vary according to the type of active recreation and are most important for those types of recreation that require quick stops, changes in direction of movement, etc.; therefore, an important problem in such shoes is the selection of materials for the sole and its design [6];

- shock absorption (cushioning function). Taking into account the requirements for cushioning is particularly important for footwear used for active leisure on hard surfaces. Therefore, the design of the specified footwear must include an intermediate sole, special components (inlays), inserts and other additional details to absorb impact energy, minimise the risk of excessive vibration exposure, reduce pressure at the points of greatest load on the foot, injuries to the ankle, knee, hip, lower back, etc. [7];

- flexibility. Stiff shoes require more energy to flex, but can provide support and protection for the foot on uneven surfaces. On the other hand, different types of active recreation require different levels of stability. Therefore, depending on the requirements, one of the two main types of flexibility is chosen for active leisure footwear: longitudinal, which describes how easily the shoe 'bends' along its length, and rotational, which shows how easily the shoe rotates around the heel-to-toe axis [8].

The above requirements for active leisure footwear must ensure a high level of biomechanical properties, which are always a priority for this type of footwear.

The elimination of potential discomfort and even injury during the use of active leisure footwear is ensured by taking into account the morphological characteristics of the consumer's feet and the anthropometric conformity of the footwear, which in turn performs a certain preventive function and is an integral part of ensuring comfort. Therefore, the anthropometric conformity of active leisure footwear is the basis for ensuring its ergonomics and impact on the rate of foot fatigue and possible injuries [5].

Ensuring the comfort of footwear for active recreation is impossible without the appropriate level of hygienic properties of raw materials, construction and footwear as a whole, as these footwear are intended for use in conditions of constant physical stress on the foot. In particular, indicators of moisture, vapour and heat

permeability, moisture transfer of individual components, parts and footwear as a whole, resistance to dirt and cleanability, etc. are very important. In practice, this means that high quality footwear for active recreation should not prevent the transfer of heat from the foot to the outside environment due to the presence of air layers created by the use of materials with a highly porous structure or due to design features.

For demi-season footwear for outdoor activities, moisture-resistant properties are important, which are provided in the upper materials mainly through special treatments [9], and in the sole – through the use of materials of a certain nature (rubber, polyurethane compositions) and edging around the entire perimeter of the sole. Shoes with adequate moisture management properties prevent the free transfer of heat and water vapour to the outside, creating a closed environment with high temperature and humidity. Such a microclimate inside the shoe will allow the foot to maintain a higher skin temperature and moisture content than barefoot by reducing convective heat/mass exchange and sweat removal to the outside.

It is becoming more and more important that footwear for active recreation does not have a harmful effect on the human body (due to the use of polymeric materials in tanning compositions, dyes, glues, fittings, etc.) and that its disposal does not harm the environment. For this reason, the choice of materials for footwear requires special attention, with textile materials increasingly being used in addition to natural leather. Therefore, the product characteristics of footwear materials are a very important factor influencing the operational characteristics of footwear for active recreation [10].

One of the modern ways of improving the hygienic properties of active leisure footwear, especially antibacterial properties, is the use of special antimicrobial preparations. Most natural textile materials are particularly susceptible to the action of microorganisms in humid and warm conditions (due to their large surface area, moisture content and chemical composition): cellulose carbohydrates can be a source of energy for various microorganisms and are broken down by enzymatic hydrolysis; wool, silk and other protein fibres can be enzymatically degraded by proteolytic enzymes (protease) and/or keratinolytic enzymes. Synthetic fibres are more resistant to the action of microorganisms, the degradation process and are more durable [11].

The presence of microorganisms on textile materials, especially pathogenic bacteria, is a health hazard. Their presence can be evidenced by the appearance of stains, odours, deterioration of strength and stiffness, etc. Therefore, antimicrobial treatment of textiles is carried out to prevent this risk by controlling and eliminating the growth and reproduction of microorganisms.

There are a number of requirements for antimicrobial treatment: efficacy against a wide range of micro-organisms, low toxicity for consumers and the environment, no influence on the natural flora of non-pathogenic bacteria present on human skin and its natural protection, durability under various conditions (operation, washing, dry cleaning, production conditions), compatibility with various chemical agents and textile processes, no influence on the quality and appearance of textiles, resistance to sterilisation conditions (medical textiles), ease of use and economic efficiency [12].

Natural leather is widely used for active leisure footwear, but its protein structure is susceptible to the action of microorganisms, which cause staining and degradation of the material, resulting in a reduction in the life of the products. For this reason, there is a growing interest among consumers and manufacturers in the creation of natural leather with bactericidal properties, which can be used in the manufacture of footwear for active recreation, leather upholstery for cars, medical products, etc. In particular, to confer antimicrobial properties to natural skin, its surface is treated with metal nanoparticles or organic compounds [13].

The particular relevance of the issue of raw material safety for all gender and age groups of active leisure footwear is underpinned by the fact that the consumer comes into direct contact with these materials in products from an early age and that the compounds present in shoe materials can migrate into the human body. This is not only relevant for shoes that come into direct contact with the skin of the foot due to the specific conditions of use (summer, indoor, beach, etc.), but also for all shoes, as the sweat released by the foot comes into contact with chemicals and the skin of the foot through the hosiery.

The social and economic characteristics of active leisure footwear are important for the consumer and the results of their use: reliability (storability, durability, wear resistance, maintainability) and resistance to ageing (moral and physical). In addition, the increasingly important properties of modern active leisure footwear are its aesthetic characteristics, which are of great importance both for consumers who want to use active leisure footwear as they do every day, and for people who want to create or maintain their own image and fashion, even when on holiday.

All of the above allows us to state unequivocally that the product evaluation of active leisure footwear is relevant, as it allows us to determine the general level of their quality and the conformity of the consumer properties of the materials used with the consumer needs.

In the classical commodity science, the verification of the degree of suitability of the product to meet the established requirements is most often carried out by means of a comprehensive assessment of its quality level [14]. The integrated approach to quality assessment has become one of the main methods due to its significant advantage over other approaches, which consists in expressing the assessment result with only one final assessment, which can be compared with other similar assessments without additional manipulations (conversion of measurement units, additional calculations, etc.). The peculiarity of the definition of a comprehensive quality indicator is the need to compare the indicators of the studied materials with the indicators that meet the established and expected consumer needs [15].

The most effective comprehensive assessment of quality is the generalized desirability indicator G – the geometric mean value from a certain number n of individual dimensionless desirability indicators d_i , calculated taking into account their weight y_i in a specific set of properties, and the desirability function is used to determine the dimensionless desirability indicator [16].

Within the framework of this study, the authors used an algorithm for the comprehensive evaluation of footwear for active recreation, which included: analysis of the existing nomenclature of indicators of physical and mechanical properties of footwear for active recreation; selection of the nomenclature of indicators of consumer properties of footwear for active recreation; determination of the importance of individual indicators in the general hierarchy of indicators; study of physical and mechanical properties of footwear for active recreation; selection of levels of indicators of consumer properties according to the quality grades "bad", "satisfactory", "good", "excellent"; construction of xyd -nomograms and construction of transition tables from natural indicators of properties x to dimensionless indicators of desirability d ; calculation of a complex quality indicator based on a generalized desirability function; analysis of the quality level of footwear for active recreation based on comprehensive and differential evaluations.

In order to implement the algorithm of comprehensive assessment of the quality of footwear for active recreation, first of all a nomenclature of individual indicators for comprehensive assessment of the quality level was established. The specified nomenclature was formed using expert methods, taking into account the analysis of scientific literature sources and the opinion of manufacturers, indicators of consumer properties and their weighting factors. The formed nomenclature consists of five indicators, which according to experts are the most important (Tables 1-2).

Table 1

Average statistical data of the results of the tests of the physical and mechanical properties indicators of the footwear for the active recreation

№	Indicator name, unit of measurement	Actual value of the indicator (arithmetic mean)	Rate
1.	Strength of the connection of the top and bottom parts, N/mm	2,7	4,0
2.	Insulation of the sole from the cold (<i>minus 17±2°C</i>)	3,4	±10
3.	Absorption of energy in the heel, J	14,3	>20
4.	Shoe sole stiffness, $N^{1).2)}$	12,2	<15
5.	Density of sole materials, Mg/m^3	1,09	<2,0

¹⁾ increase in puncture by 98.7 mm; complete cracking of the sole in the line of bending (bend)

“N” method, which is not included in the scope of PCA Nr AB 033 accreditation

²⁾ increase in puncture by 9.6 mm; two cracks outside the bend, 7.4 mm and 3.9 mm long

“N” method, which is not included in the scope of PCA Nr AB 033 accreditation

Table 2

Nomenclature of the main indicators of the consumption characteristics of the footwear studied

№	Indicator, its notation, unit of measurement	Weight coefficients
1.	Absorption of energy in the heel part, J	0,26
2.	Density of sole materials, Mg/m^3	0,22
3.	Strength of the connection of the top and bottom parts, N/mm	0,20
4.	Shoe sole stiffness, N	0,18
5.	Insulation of the sole from the cold (<i>minus 17±2°C</i>)	0,14
Total		1,00

The next step in the comprehensive evaluation of the quality levels of active recreation footwear was the selection of the level indicators of consumer characteristics according to quality gradations. For this purpose, the entire interval of the function of desirability values was divided into conditional segments: "poor" – "satisfactory" – "good" – "excellent". Within the three main intervals "bad" – "satisfactory" – "good", base points were selected that correspond to the quality level limits. At the same time, it was considered that the scale of "desirability" proposed by Harrington correlates well with the results of experimental studies and establishes the correspondence between preferences in empirical and numerical form: "excellent" – 1.00-0.80; "good" – 0.80-0.63; "satisfactory" – 0.63-0.37; "poor" – 0.37-0.20; "very poor" – 0.20-0.00.

For each of the three base values y_i , the corresponding normative indicator x_i in natural units was calculated. With a uniform linear scale of the normative indicator, when

$$y_i = a_0 + a_1 x_i \quad (1)$$

only extreme base points are used – "satisfactory" and "excellent". Then a system of equations is used to calculate the coefficients a_0 and a_1

$$\begin{cases} 0 = a_0 + a_1 x_{sat} \\ 1.530 = a_0 + a_1 x_{exc} \end{cases} \quad (2)$$

where, a_0 and a_1 are coefficients of linear dependence between the dimensionless parameter y_i and the dimensional value x_i of the quality indicator;

x_{sat} – the normative value of the dimensional quality indicator corresponding to satisfactory quality;

x_{exc} – the value of the normative value of the dimensional quality indicator, which corresponds to excellent quality.

The selection of indicator levels according to quality gradations was carried out for two extreme base points – "satisfactory" and "excellent". The limit values of the dimensional indicators of the base points were chosen on the basis of the analysis of the regulatory documentation, the generalisation of the literature data and the laboratory research data obtained by the authors. The limits of the indicators d chosen in this way are shown in Table 3.

Table 3

Levels of shoe quality dimensional indicators

Index	Gradation of quality indicators			
	poor	satisfactory	good	excellent
Desirability index, d	<0,37	0,37-0,62	0,63-0,79	≤0,80
dimensionless indicator, y	<0	0,00-0,76	0,77-1,52	≤1,53
Shoe sole stiffness, N	<15	15,0	12,5	10,0
Density of sole materials, Mg/m^3	>2,0	2,0	1,4	0,8
Strength of the connection of the top and bottom parts, N/mm	<1,0	1,0	2,5	4,0
Absorption of energy in the heel part, J	<6,0	6,0	13,0	20,0
Insulation of the sole from the cold ($minus\ 17\pm 2^{\circ}C$)	<2,0	2,0	6,0	10,0

The computer program "Estimate_of_Quality" was used to process the obtained research results, the main advantages of which are acceleration of the process of processing the obtained results, ensuring the research process of a high level of objectivity, reliability of calculation and elimination of the influence of the human factor [17].

For different natural values of x , the determination of d and y values is clearly and simply carried out using a 3-axis xyd nomogram. Therefore, based on the data given in the Table 3, using the computer program "Estimate_of_Quality" 3 axial xyd -nomograms were constructed (Figure 1).

On the basis of the constructed three-axis xyd nomograms, taking into account the transition equations, the desirability indicators of the researched indicators of footwear for active recreation were determined. In order to assess the level of the researched quality of footwear for active recreation according to the researched most important indicators of consumer characteristics, the method based on the desirability function already tested by the authors was used. To calculate the complex indicator K , the logarithm of the desirability indicators of individual consumer properties lgd_i was found and multiplied by their corresponding weighting factors γ_i , the obtained values were added and the antilogarithm of this sum was found. The comprehensive quality indicator obtained in this way allowed a general assessment of the quality level of the studied active leisure footwear. The determination of the desirability index for all selected indicators of the quality of the researched footwear

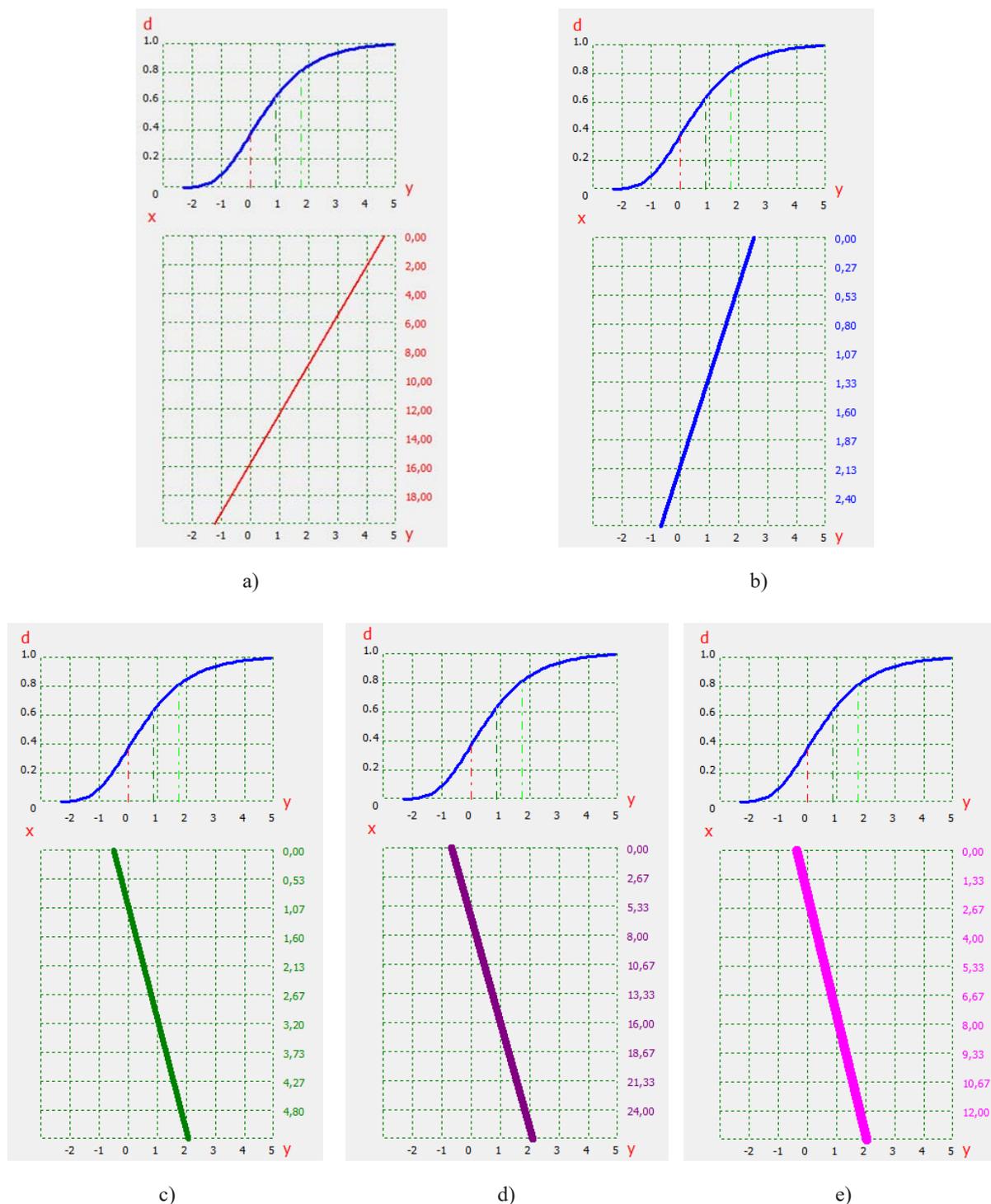


Figure 1. xyd-nomograms of the studied footwear indicators:

a) stiffness of the sole of the footwear; b) density of sole materials; c) the strength of the connection of the top and bottom parts d) energy absorption in the heel part; e) insulation of the sole from the cold

was carried out using the "Estimate_of_quality" computer program. The results of the calculation of the comprehensive indicator of the quality of the researched footwear for active recreation are shown in Table 4.

Conclusions. The condition system "Human physical activity – footwear for active recreation" was studied from the point of view of positive influence on human health. The relevance of scientific research on footwear for active recreation as an obligatory and important component of the material segment of the complex of cultivation, formation and practical implementation of a healthy lifestyle of the population and ensuring its physical health is substantiated. The nomenclature of the main factors ensuring the quality of footwear for active recreation (friction

Table 4

Calculation of a comprehensive quality indicator for the researched footwear

Sample option	Shoe sole stiffness, <i>N</i>	Density of sole materials, <i>Mg/m³</i>	Strength of the connection of the top and bottom parts, <i>N/mm</i>	Absorption of energy in the heel part, <i>J</i>	Insulation of the sole from the cold (<i>minus 17±2°C</i>)	Comprehensive quality indicator
Shoes for active leisure	12,2	1,09	2,7	14,3	3,4	0,643

properties (slip resistance), shock absorption (damping (spring) function), flexibility, level of hygiene, harmlessness and bactericide) was established and the main general consumer requirements for the specified properties were outlined. The expediency and advantages of using the method of comprehensive evaluation of the level of quality to determine the degree of suitability of the tested footwear for active recreation to meet the requirements of modern consumers have been proven. Using the complex evaluation algorithm and the results of the study of the most important indicators of the consumption properties of the investigated footwear for active recreation (stiffness of the sole of the shoe, density of the sole materials, strength of the connection of the upper and lower parts, absorption (absorption) of energy in the heel part, insulation of the sole from the cold at minus 17±2°C) a comprehensive indicator of its quality was calculated. The value of this indicator at the level of 0.643 proves the need for further research aimed at increasing the general level of consumer properties of footwear for active recreation, in particular – through the development of new and improvement of existing materials based on the use of innovative technologies (for example, providing natural leather with antimicrobial properties by treating its surface with metal nanoparticles or surface modification with organic compounds).

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The condition system "Human physical activity – footwear for active recreation" was studied from the point of view of positive influence on human health. The relevance of scientific research on footwear for active recreation as an obligatory and important component of the material segment of the complex of cultivation, formation and practical implementation of a healthy lifestyle of the population and ensuring its physical health is substantiated. The nomenclature of the main factors ensuring the quality of footwear for active recreation (friction properties (slip resistance), shock absorption (damping (spring) function), flexibility, level of hygiene, harmlessness and bactericide) was established and the main general consumer requirements for the specified properties were outlined. The expediency and advantages of using the method of comprehensive evaluation of the level of quality to determine the degree of suitability of the studied footwear for active recreation to meet the requirements of modern consumers have been proved. Using the complex evaluation algorithm and the results of the study of indicators of individual consumer properties of the studied footwear for active recreation, a comprehensive indicator of its quality was calculated. The results of the research justified the need to develop new materials for active leisure footwear.

Key words: footwear for active recreation, consumer properties, quality assessment, product characteristics, consumer requirements.

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Управління якістю взуття для активного відпочинку.

Умовну систему «рухова активність людини – взуття для активного відпочинку» досліджено з позиції позитивного впливу на опорно-рухову систему людини, а саме для зміцнення скелета та розвитку м'язів. Обґрунтовано актуальність наукового дослідження взуття для активного відпочинку як обов'язкової та важливої складової матеріально-технічної частини комплексу культивування, формування та практичної реалізації здорового способу життя населення задля забезпечення його фізичного здоров'я. Встановлено номенклатуру основних факторів, що забезпечують якість взуття для активного відпочинку (фрикційні властивості (стійкість від ковзання), ударопоглинання (амортизаційна (пружинна) функція), еластичність, рівень гігієнічності, нешкідливість та бактерицидність), а також основні загальні вимоги до нього. Визначено коло споживачів на вказані властивості. Проаналізовано взаємозв'язок особливостей фізичних навантажень на стопу під час заняття різними видами активного відпочинку та показники споживаних властивостей взуття для активного відпочинку. Доведено доцільність та переваги використання методу комплексної оцінки рівня якості з використанням коефіцієнтів вагомості для встановлення ступеня придатності досліджуваного взуття для активного відпочинку вимогам сучасного споживача. Показано, що фактори формування споживчих властивостей взуття для активного відпочинку є складовою частиною управління якістю взуття для активного відпочинку. Із застосуванням алгоритму комплексного оцінювання та результатів дослідження показників індивідуальних споживчих властивостей досліджуваного взуття для активного відпочинку розраховано комплексний показник його якості, що підтверджує доцільність подальшого вдосконалення вже існуючих інновацій та розроблення принципово нових інноваційних систем матеріалів, технологій тощо. За результатами досліджень обґрунтовано необхідність розробки нових матеріалів для взуття для активного відпочинку, а також доцільність вдосконалення окремих вузлів у конструкції взуття, в тому числі у пакеті матеріалів верху та пакеті матеріалів низу.

Ключові слова: взуття для активного відпочинку, споживчі властивості, оцінка якості, характеристика товару, вимоги споживачів.