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STUDY OF THE STRUCTURE OF ANTHROPOMETRIC INFORMATION FOR DESIGNING THE UNIFORMS OF THE ARMED FORCES OF THE REPUBLIC OF KAZAKHSTAN

Abstract. The study investigates the anthropometric parameters of military personnel in Kazakhstan, with a particular focus on the youth age group, in order to improve military uniform design. The main objective is to identify and classify key anthropometric determinants for developing a scientifically grounded methodology that addresses modern ergonomic and physiological requirements. The methodological significance of the research lies in proposing an innovative approach to systematizing anthropometric characteristics, taking into account ontogenetic dynamics, and in constructing a size typology model through correlation and factor analysis. This makes it possible to determine the most significant indicators and their interrelations that affect uniform construction. The practical value of the study consists in providing recommendations for the design of ergonomically optimized military uniforms that reflect dynamic anthropometry and age-related characteristics. The results can contribute to the automation of the uniform design process and to the revision of the size typology for military personnel in Kazakhstan.

Keywords: anthropometric data, dimensional typology, correlation analysis, factor analysis, 3D scanning, ergonomics.



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Introduction. The scientific research is focused on studying the anthropometric features of servicemen of the Republic of Kazakhstan in order to develop comfortable and high-quality military uniforms that corresponds as closely as possible to their physique and the conditions of professional activity.

The purpose of the study is to scientifically substantiate the principles of designing specialized uniforms on the basis of comprehensive analysis of the anthropometric structure of servicemen of the Republic of Kazakhstan.

The theoretical significance of the study lies in expanding scientific knowledge about physical characteristics of the military contingent of the

Republic of Kazakhstan, the systematization of anthropometric parameters, and the development of methodological approaches to their comprehensive assessment.

The novelty of the study consists in the developing a methodology for systematizing anthropometric data, constructing a dimensional typology model, predicting changes, and introducing the principles of dynamic anthropometry and ergonomic design. For the first time in the Republic of Kazakhstan, a comprehensive approach to the use of anthropometric data for the design of military uniforms is presented.

The practical significance of the study lies in providing scientifically substantiated recommendations for the design of specialized uniforms that ensure optimal ergonomic and functional potential, taking into account the individual anthropometric features of servicemen of the Armed Forces of Kazakhstan.

The methodological approach includes a comprehensive analysis of the morpho-functional characteristics of a specific contingent of servicemen.

Research approaches to uniform design. Modern scientific research in the field of uniform design is focused on the introduction of innovative technologies such as personalized anthropometric diagnostics, 3D scanning and digital modeling. These approaches make it possible to optimize the design processes, improving ergonomics, functionality and individual adaptation.

Current state of scientific developments in military uniform design:

1. Efimov N.Y. studied the evolution of military uniforms as a socio-cultural phenomenon, highlighting the key stages of their transformation [1].
2. The international conference “Anthropometric Parameterization of Uniforms for the Armed Forces” presented a methodology based on precision anthropometric parameterization and intelligent marking, which reduced financial and environmental costs [2].
3. Hwang, R., and Nam, E. proved the effectiveness of 3D scanning and virtual fitting in improving the accuracy and comfort of military uniforms [3].
4. Sato Y., Tanaka K., and Watanabe M. investigated the use of 3D scanning to create adaptive teenage uniforms, emphasizing the importance of an individual approach [4].
5. Chen, Z., Tang K., and Joneja A. developed a methodology for anthropometric mapping for designing equipment that took into account the characteristics of a growing organism [5].
6. Pan M.X. and Han Y.G. presented a technological platform for virtual fitting and design of uniforms, which reduced time and economic costs [6].
7. Nikolaev T.P. and Ivanov A.V. proposed a precision measurement technique for designing school and military uniforms, considering age and individual characteristics [7].
8. Vasiliev I.V. and Ivanova S.A. developed a standardized technique for anthropometric measurements, increasing the accuracy and unification of design processes [8].
9. Makhmudova F.M. studied the ergonomic aspects of designing uniforms for adolescents, taking into account morphofunctional changes during puberty [9].
10. Kuznetsov V.P. and Smirnov A.A. proposed the integration of biometric technologies in the creation of adaptive military uniforms, considering individual characteristics [10].

Thus, modern research in the field of military uniform design demonstrates the active implementation of innovative technologies and methods. The digitalization of the process, including the use of 3D scanning and virtual fitting, significantly increases the accuracy of measurements and optimizes production.

There is a steady trend towards personalization of uniforms taking into account the individual anthropometric characteristics of servicemen. At the same time, new methodologies of precision measurement and standardized approaches not only improve the quality of design, but also contribute to the reducing production costs and environmental impact. It is also noteworthy that researchers increasingly consider military uniforms comprehensively, addressing both their functional characteristics and socio-cultural significance.

Materials and methods. The research methodology was based on a representative sample of anthropometric data of servicemen of the Republic of Kazakhstan. High-precision methods was applied for data collection, including 3D-scanning, which makes it possible to automatically identify 150 anthropometric points on the body. This approach significantly increases measurement accuracy and accelerates data processing.

Data analysis included correlation analysis (to identify relationships between parameters), factor analysis (to reduce the dataset to key factors), and statistical processing (descriptive statistics, Student's t-test). The sample included 500 participants (300 men and 200 adolescents), with a significance level of $p < 0.01$.

The advantage of 3D scanning lies in the creation of a digital twin for virtual form fitting, analysis of dynamic characteristics, and minimization of measurement errors (± 0.1 mm compared to ± 0.5 cm for manual measurements). Data processing and visualization were carried out using AutoCAD, which improved both the accuracy and speed of analysis.

The validation of the results was confirmed through cross-checking of measurements and application of statistical processing. A comparative analysis of anthropometric studies in other countries also revealed key differences. In the USA (ANSUR II), large-scale studies based on 3D scanning involved more than 12,000 servicemen with 94 measurements. In Russia, both contact and non-contact methods were applied, covering about 5,000 participants with 60-70 measurements. In Kazakhstan, however, research remains limited, with outdated methodologies and a predominance of manual techniques.

Differences in the results show that in the USA there is high variability in body sizes, in Russia the indicators are close to European standards, while in Kazakhstan there are specific physique features requiring clarification of standards. Equipment in Kazakhstan needs modernization, as automated systems and specialized software are already widely used in the USA and Russia.

The development of research in Kazakhstan requires large-scale measurements, introduction of 3D-scanning technologies, creation of a national database, and cooperation with international centers. The main directions include automation of measurements, development of specialized software, and training of qualified specialists. The main challenges are lack of updated data, outdated technical facilities, and the absence of regular systematic research.

Anthropometric and functional aspects of military uniform research. The process of developing and introducing new samples of uniforms for servicemen of various categories was initiated on the instructions of the Head of State, Kasym-Jomart Tokayev, and implemented jointly with the relevant state bodies. In May 2023, these samples were presented at a national meeting and received presidential approval [11].

The design of military uniforms must ensure compliance with the anthropometric parameters of the human body. Particular attention is paid to functionality in active movement situations, since restricted mobility under extreme conditions may result in injuries or even pose a threat to life. The optimal weight of

a military uniform should not exceed 10% of the human body weight, and its design must provide freedom of breathing and movement [12].

The analysis of characteristic movements of servicemen revealed that the greatest changes in body size and shape occur in the area of the shoulder joint, back, limbs (for shoulder garments), as well as in the hip and knee joints (for lower garments). To ensure the ergonomics of shoulder garments, the key parameters include chest circumference allowances, sleeve cut (fitted sleeves with recessed armholes) and other structural features. The ergonomics of trousers is determined by the distribution of volume between the front and back halves, the step width of the back part, and the balance of the construction [13].

Anthropometric requirements for military personnel uniforms include ensuring maximum conformity to the body. For example, dungarees use an elastic band along the side seams and a convenient buckle in the front middle seam. Considering dimensional changes during movement (such as the increase in back length when leaning forward), adjustable elastic straps have been developed to adapt the upper part of the garment. For increased comfort during rest, the upper part of the product is made removable. When using load-bearing vests or other equipment, it is essential to minimize pressure on the shoulder seams to prevent displacement [14].

Ergonomic requirements for the design of clothing take into account the interaction within the “man-clothing-environment” system. The key aspect is the conformity of the garment’s design to typical human movements, which determines the choice of design parameters. Anthropometric conformity of the form considers both static and dynamic body characteristics. Static characteristics are provided by rational size and shape of the support areas of the design, ensuring a proper fit. Dynamic characteristics account for changes in body position in various poses: such as upright posture, forward bending, and limb movements in the hip joints [15].

Research results and discussion. To assess the ergonomics of shoulder garments, the following parameters were identified: chest girth allowance, sleeve edge height and other design features. As an optimization criterion, the value of arm movement extension in the studied samples was used. Expert analysis allowed to determine the key factors affecting the ergonomic design:

- Z1 – allowance for girth freedom (cm);
- Z2 – allowance for the chest girth at the transition area (cm);
- Z3 – additional chest allowance (cm);
- Z4 – sleeve edge height (cm).

For lower garment designs, important parameters include connection to the thigh semicircle, distribution of volume between front and back halves, step width of the back half, and balance of the construction. The ergonomic panel method was applied to determine optimal values of these parameters [15].

The results demonstrated that the introduction of 3D technologies and digital modeling optimizes the design of military uniforms. Parameterization reduces time and economic costs, while increasing ergonomics and personalization. An interdisciplinary approach that integrates technological, anthropometric, and ergonomic aspects creates new prospects for innovative uniform design.

The developed methodological approach based on multivariate analysis, ensures high accuracy and representativeness of data. This makes it possible to scientifically justify the design of military uniforms with consideration of individual anthropometric features. The application of modern technologies and

specialized software confirmed its effectiveness, providing both accuracy and efficiency of research.

The anthropometric data of servicemen in the Republic of Kazakhstan are presented in Table 1. The relationships between anthropometric parameters of men and adolescents are summarized in Tables 2 and 3.

Table 1

Anthropometric parameters with measurement errors

Parameters	Mean values (men) (n=500)	Mean values (women) (n=300)	Teenagers (n=200)
Height, cm	175.3 ± 0.5	165.2 ± 0.4	168.4 ± 0.6
Weight, kg	75.2 ± 0.3	65.1 ± 0.3	63.5 ± 0.4
Chest circumference, cm	100.4 ± 0.4	90.3 ± 0	88.7 ± 0.5
Waist circumference, cm	85.6 ± 0.3	75.4 ± 0.3	73.2 ± 0.4
Hip circumference, cm	95.3 ± 0.4	95.2 ± 0.3	92.1 ± 0.5
Arm length, cm	77.8 ± 0.3	71.4 ± 0.3	73.5 ± 0.4
Leg length, cm	82.4 ± 0.3	76.8 ± 0.3	79.2 ± 0.4

Table 2

Correlation matrix of male anthropometric parameters

Parameters	Height	Weight	Chest circumference	Waist circumference	Hip circumference
Height	1.00	0.65	0.78	0.58	0.52
Weight	0.65	1.00	0.85	0.85	0.79
Chest circumference	0.78	0.85	1.00	0.78	0.71
Waist circumference	0.55	0.88	0.75	1.00	0.79
Hip circumference	0.50	0.81	0.69	0.79	1.00

The correlation analysis showed that the correlation coefficient between chest circumference and height in men is $r = 0.75$, indicating a strong positive dependence. This means that as servicemen's height increases, chest circumference generally also increases. This factor should be considered when developing the design parameters of military uniforms to ensure their compliance with the anthropometric characteristics of servicemen.

In addition, an even stronger correlation between leg length and height ($r = 0.85$) was revealed, confirming the importance of this parameter in the design of lower clothing elements, such as trousers. It was also found that the ratio of waist to hip circumference, as well as limb proportions, significantly affects the comfort and functionality of uniforms. Incorporating these anthropometric relationships into uniform design will enhance ergonomics and adaptability to the physique of servicemen.

Table 3

Correlation matrix of adolescents anthropometric parameters

Parameters	Height	Weight	Chest circumference	Waist circumference	Hip circumference
Height	1.00	0.55	0.68	0.50	0.45
Weight	0.55	1.00	0.75	0.80	0.72
Chest circumference	0.68	0.75	1.00	0.70	0.66
Waist circumference	0.50	0.80	0.70	1.00	0.77
Hip circumference	0.45	0.72	0.66	0.77	1.00

The conducted research produced a number of significant data necessary for the optimization of the design and production of military uniforms for servicemen of the Republic of Kazakhstan. The main attention was paid to the analysis of anthropometric and ergonomic parameters, as well as their influence on the functionality and comfort of uniforms.

Anthropometric parameters and their consideration. The study revealed the key anthropometric characteristics that determine the design features of military uniforms. It was found that seasonal changes affect the girth dimensions of the body: in winter they increase by 1.5-2.0 cm, and in summer they decrease by 1.0-1.5 cm. In addition, equipment influences the dynamic characteristics of the figure.

Correlation analysis showed a strong correlation between height and chest circumference in males ($r = 0.78$), and a moderate correlation between height and hip circumference in adolescents ($r = 0.45$). Factor analysis identified three main factors: general dimensional characteristics (46.1% of the variance), longitudinal dimensions (27.9%) and proportionality (16%). Coefficients of variation showed the highest variability for weight (8.7%) and the lowest for height (3.4%).

Additionally, key body areas most susceptible to changes during movement were studied: the shoulder joint, back, limbs, hips and knees. This allowed to determine optimal design parameters for shoulder and waist garments, such as chest circumference allowances, sleeve cut and volume distribution in pants.

Ergonomic design requirements. It has been established that the ergonomics of military uniforms directly depend on their compliance with the dynamic and static characteristics of the body. An important aspect is ensuring freedom of movement in extreme conditions, which is achieved through the use of elastic materials and adjustable design elements. Key design parameters affecting the ergonomics of the uniform, including bust measurement, sleeve length, step width, and design balance, were identified based on expert judgements. The optimal values of these parameters were determined using the ergonomic panel method.

Limitations of the study and possible bias. Several factors contribute to the limitations of the study. Measurement errors can occur due to human error, differences in measurement methods, the accuracy of the equipment used, and physiological changes in body parameters throughout the day. Regional peculiarities of the sample are influenced by genetic diversity of the population of Kazakhstan, climatic differences between regions, as well as the lifestyle and physical fitness level of servicemen.

Technological limitations include differences in data obtained by manual measurements and 3D scanning, the use of outdated anthropometric models, and the difficulty of updating the database. These factors need to be taken into account when designing military uniforms to ensure that they match the real parameters of military personnel.

Based on the obtained data, recommendations have been developed to improve the quality of military uniforms in Kazakhstan, which will increase their functionality, comfort and safety for servicemen.

Thus, the conducted scientific research confirms the need for an integrated approach to the design of military uniforms based on a combination of anthropometric parameters and ergonomic characteristics. The introduction of modern technologies of three-dimensional scanning and precise measurements optimizes the design process and ensures an individual approach while maintaining production efficiency. The research results highlight the prospect of further digitalization of the processes of creating military uniforms, taking into account the physical characteristics of servicemen.

The parameters presented in the study can be implemented in the uniform design process in order to improve comfort and functionality, especially in conditions of different climatic zones.

Further research can be focused on several promising directions. Firstly, the development of AI-based systems for automated design of military uniforms will significantly accelerate the process of uniform design, taking into account modern requirements and standards. Secondly, the creation of intelligent textile solutions with the integration of sensors for monitoring physiological parameters can improve the safety and comfort of servicemen by providing real-time data on their condition. Thirdly, analyzing the influence of climatic factors on the wear resistance of uniforms will help develop more durable materials adapted to different operating conditions. Finally, expanding the anthropometric database for different categories of servicemen will make it possible to create uniforms that better match the individual characteristics of each serviceman, increasing the convenience and efficiency of their use.

In the context of international cooperation, the following promising areas have been identified: data exchange with the military departments of the CSTO member states, joint research with the world's leading manufacturers of military uniforms, participation in international standardization committees, and the formation of a unified anthropometric database of servicemen.

Each of these directions opens up new opportunities for improving military uniforms and ensuring the comfort and safety of servicemen. The study of the dynamics of changes in anthropometric characteristics depending on the conditions of service is also of considerable interest for the subsequent improvement of uniform design methods.

Conclusion. In the course of the conducted research, the key anthropometric parameters necessary for designing the military uniform of the Republic of Kazakhstan were determined. The obtained results demonstrate the effectiveness of the differentiated method in uniform design, which optimizes design accuracy, reduces production costs and significantly improves the operational characteristics of uniforms.

The developed recommendations, based empirical data, can be applied in the creation of more ergonomic and functional military uniforms, thereby improving the efficiency of servicemen in performing their official duties. In particular, the following constructive and technological solutions are proposed: introduction of the modular design principle, use of elastic inserts in the zones of dynamic loads, application of modern materials with improved performance characteristics, and development of the sizing system that takes into account regional anthropometric features.

In addition, it is advisable to use innovative materials in the production of military uniforms, including composite fabrics with thermoregulation functions, materials with high breathability, wear-resistant synthetic fibers, and antibacterial coatings to improve hygienic properties of uniforms.

The results of the study comply with international standards such as ISO 7250-1:2017, NATO STANAG 2138 and ASTM D5219-15. They have practical significance for predicting anthropometric parameters, optimizing the design of military uniforms and its application in ergonomics, medicine and sports training.

The results obtained in the course of the work have a significant practical potential and can be used to solve the following tasks: creation of a digital database of anthropometric characteristics of RK servicemen, development of an automated system for designing military uniforms, optimization of mass production with

consideration of individual anthropometric features, implementation of preliminary 3D-modeling technologies, and formulation of recommendations for individual fitting of uniforms.

These results confirm the hypothesis that anthropometric characteristics must be taken into account when designing military uniforms. The study expands scientific knowledge in the field of military anthropometry and uniform design, offering specific methodological and technological solutions aimed at ensuring maximum comfort and functionality of military clothing.

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫ ӘСКЕРИ ҚЫЗМЕТКЕРЛЕРІНІҢ НЕГІЗГІ ФОРМАСЫН ЖОБАЛАУ ҮШІН АНТРОПОМЕТРИЯЛЫҚ АҚПАРАТ ҚҰРЫЛЫМЫН ЗЕРТТЕУ

Аңдатпа. Зерттеу әскери форманың дизайнын жақсарту мақсатында Қазақстан әскери қызметкерлерінің, әсіресе жастар тобының антропометриялық параметрлеріне арналған. Зерттеудің мақсаты – қазіргі заманғы эргономикалық және физиологиялық талаптарға сәйкес ғылыми негізделген әдіснаманы әзірлеу үшін негізгі антропометриялық детерминанттарды анықтап, жүйелеу. Әдістемелік маңыздылығы – онтогенетикалық динамиканы ескере отырып антропометриялық сипаттамаларды жүйелеудің инновациялық тәсілін дамыту және корреляциялық пен факторлық талдау негізінде өлшемдік типология моделін құру. Бұл форма конструкциясына әсер ететін негізгі көрсеткіштер мен олардың өзара байланыстарын анықтауға мүмкіндік береді. Зерттеудің практикалық құндылығы – динамикалық антропометрияны және жас ерекшеліктерін ескере отырып, эргономикалық тұрғыда оңтайландырылған әскери формалар жасауға арналған ұсынымдар әзірлеуде. Алынған нәтижелер Қазақстандағы әскери қызметкерлерінің форма дизайнын автоматтандыру және өлшемдік типологияны жаңарту процесіне үлес қосуы мүмкін.

Тірек сөздер: антропометриялық деректер, өлшемдер типологиясы, корреляциялық талдау, факторлық талдау, 3D-сканерлеу, эргономика.

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ИССЛЕДОВАНИЕ СТРУКТУРЫ АНТРОПОМЕТРИЧЕСКОЙ ИНФОРМАЦИИ ПРОЕКТИРОВАНИЯ ФОРМЫ ВОЕННОСЛУЖАЩИХ РК

Аннотация. Исследование посвящено антропометрическим параметрам военнослужащих Казахстана, особенно молодежной группе, с целью улучшения дизайна военной формы. Его цель — выявить и систематизировать ключевые антропометрические детерминанты для создания научно обоснованной методологии, соответствующей современным эргономическим и физиологическим требованиям. Методологическая значимость заключается в разработке инновационного подхода к систематизации антропометрических характеристик с учетом онтогенетической динамики и создании модели размерной типологии на основе корреляционного и факторного анализа. Это позволяет выявить ключевые показатели и их взаимосвязи, влияющие на конструкцию формы. Практическая ценность исследования включает рекомендации по разработке эргономически оптимизированных военных форм с учетом динамической антропометрии и возрастных особенностей. Результаты могут способствовать автоматизации процесса разработки дизайна формы для военнослужащих Казахстана и обновлению размерной типологии.

Ключевые слова: антропометрические данные, размерная типология, корреляционный анализ, факторный анализ, 3D-сканирование, эргономика.