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The impact of the secular trend of the Slovak population on the production of wooden beds and seating furniture

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Abstract: Every space used by a person should suit the anthropometric and biomechanical characteristics of the users. Poorly designed premises and types of equipment have a negative impact on human health. Furniture, as a device for daily use, can in the long term, with inadequate dimensions, significantly affect human health. In the work, we define the secular development of selected anthropometric dimensions of the Slovak population. Based on the positive development, we point out the dimensional and strength characteristics of bed and rest furniture and the dimensional and strength characteristics of seating furniture, which anthropometric dimensions influence. At the same time, we note the need to update the calculation formulas for pricing individual products, which will have an economic impact on wood furniture production.

Keywords: wood products, anthropometry, secular trend, sustainability, green economy, adult population, wooden furniture.

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Forests* **2022**, *13*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Firstname Lastname

Received: date
Accepted: date
Published: date

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

One of the conditions supporting work productivity is the effort to ensure that the spaces and equipment that people use are in accordance with the anthropometric and biomechanical characteristics of the users. The use of poorly designed spaces and equipment that does not take into account the anthropometric characteristics of users has a negative impact on human health [1]. From the point of view of the development of industry and technology, great emphasis is placed on achieving the maximum capacities for the use of technologies and equipment purposefully designed for users [2]. It is an important tool not only for increasing work productivity and innovation but also for creating conditions for the development of a person's personality [3]. When designing and assessing the spatial arrangement of workplaces, but also during the production of ergonomically correct work aids, machines, and furniture, the human being must be taken into account as the primary factor, especially his dimensions and strength abilities [4]. The design of an optimal workplace (furniture, work tools, aids, etc.) is therefore always based on measurements of the target interest group of people, which are compared with the data of the entire population living in a certain area, usually divided into men and women [5].

The anthropometric dimensions of the adult population are changing in the long term. With the development of human society and rising living standards, they generally grow. We call this trend of long-term changes in the anthropometric dimensions of the population a "secular trend". It is mainly influenced by nutrition, morbidity, and socio-economic status in population development [6-9]. Dynamic changes in the human population in the social and technological fields are closely correlated and have resulted in regulations in the field of designing things of daily need and consumption [10-11]. These

are mainly furniture that users come into contact with on a daily basis, such as beds, sofas, chairs, tables, etc. Others are clothes, shoes, but also tools, and instruments. Last but not least, the secular trend needs to be taken into account in the industrial area when designing cars and seats in transport, when designing the carrying capacity of lifting equipment, and also in other areas of the industry due to economic sustainability [12].

Wood, as a traditional natural material, has a long service life, excellent thermal and sound insulation properties, perfect dimensional stability, and high strength. It is easy to maintain and does not emit toxic substances. Since each tree has its color, design, and scent, wood is a decorative, aesthetically pleasing, and impressive material. With careful preparation before use, it is possible to ensure its stability from the point of view of drying [13]. The quality of raw wood and the possibilities of its use are evaluated mainly through the occurrence and extent of negative qualitative features. The extent of these features can be influenced by several environmental factors. The fact remains that the share of the highest quality raw wood assortments is constantly decreasing [14-15].

The study aims to evaluate the changes in selected anthropometric dimensions of the adult population in Slovakia affecting selected types of wooden furniture such as beds, deckchairs, sofa beds, chairs, armchairs, and couches. Considering the reduction of the carbon footprint and long-term sustainability in the study, we are considering all-wooden furniture.

2. Materials and Methods

Furniture serves the needs of a person, in most cases directly to a person, that is, there are interactions between a person, his physical and psychological side, and individual furniture items. The closest relationship is characterized by the bed and seating furniture, followed by table furniture, which interacts with humans and other useful objects. In connection with the influence of furniture on human health, Brunecký (2007) [16] states that, in addition to anthropometric, ergonomic, and physiological deficiencies, furniture in homes and the workplace contributes to fatigue, fatigue syndrome, allergies, risks of somatic mutations and initiates latent diseases and endangers genetic information a person.

~~In the course of time periods, growth body height, and body mass changes in the population occur. For this reason, it is necessary to determine population data on selected samples at a certain point in time for various reasons (e.g. the way of nutrition the population, lifestyle, etc.) [17-25]. We understand the secular trend as an increase in the final state of body dimensions of successive generations compared to previous generations. It is a sign of the public health of the population and points to the relationship between economic growth and living standards [26]. It also illustrates aspects of the physiology of intergenerational relationships in growth and size. According to the authors [24; 27] research aimed at determining the anthropometric dimensions of the child and adult population clearly shows long-term changes in body dimensions. Mostly it is the so-called positive trends, i.e. there is an increase in the values of the body measured parameters. The body dimension that is monitored most often and also best characterizes given changes in body height. According to [28], the secular trend in body height slowed in the second half of the 20th century, while weight continues to increase as part of the global obesity epidemic. Somatometry is a method for determining the size of the population. It represents a system of techniques for measuring and observing a person and his body parts. It systematizes and precisely defines a set of relevant anthropometric features of the human body that significantly affect the performance, health, well-being, and safety of people. At the same time, it provides a number of measuring aids and procedures that enable the exact determination of the values of the observed anthropometric characteristics.~~

The shape of the body and its proportions are directly influenced by the length and shape of the bones. Industrial anthropometry, which is a part of anthropology, examines the influence of the body dimensions of population groups on work efficiency. Analyzing

the dimensions of the human body helps to determine the optimal proportions between man and machine in both static and dynamic contexts.

One of the basic anthropometric methods suitable for solving the mentioned problems is somatometry, which represents a system of techniques for measuring and observing a person and parts of his body using the most accurate means and methods for scientific purposes. Somatometry systematizes and precisely defines a set of relevant anthropometric features of the human body, which significantly affect the performance and safety of workers, and at the same time provides a series of measuring aids and procedures that enable the exact determination of the values of the monitored anthropometric features. The most used special anthropometric aids and tools include, for example, personal scale, anthropometer, tarakometer, pelvimeter and cephalometer, tape measure, protractor, caliper, spirometer, etc. We carried out the measurements based on the principles of anthropometric measurements. Anthropometric examinations were performed individually, performed on the right side of the body in the most necessary clothing, and performed in the morning.

The basic issue of dimensioning furniture items is their ratio to the body dimensions of the user. In this work, we analyze selected dimensions of the population that have an impact on the functional dimensions of seating and ~~bed furniture - stature height, body weight, shoulder bi-deltoid breadth, elbow height - sitting, Palm width, Hand length, Forearm fingertip length, buttock-knee length, knee height - sitting with shoes~~. Empirical measurements aimed at defining the development of secular changes in selected anthropometric characteristics of the adult population of Slovakia aged 18–25 were carried out in the years 1993–2022 on a sample consisting of 7,365 men and 7,188 women - students of Slovak universities. Measurements were performed by a certified anthropometer. For the measurements of elbow height - sitting, forearm fingertip length, buttock-knee length, palm width, hand length and knee height - sitting with shoes, the analyzed population sample was somewhat lower, as these dimensions were gradually added to the measurements and analysis only in later years. The detailed structure of the population sample for individual anthropometric dimensions is shown in Table 1.

To characterize the development of the trend in the population, basic quantities of descriptive statistics and percentiles at levels 1 were used; 5; 50; 95, and 99%. The percentile (this term was first used by Galton, 1885 [29]) of a distribution of values is a number x_p such that a percentage p of the population values are less than or equal to x_p. Arithmetic averages of measured dimensions in specific years with 95% confidence intervals were used to graphically display the development of the trend. A basic linear statistical trend was used. Standard statistical parameters were evaluated: arithmetic means, standard deviation and percentiles. Statistical data were evaluated and values were calculated using standard procedures mentioned in the literature [30–32].

The software Microsoft Excel and STATISTICA 12.0 were used for calculating and visualizing the results.

Due to the differences in the dimensions of the male and female population, it is difficult to determine the universal dimensions of the furniture. Individual furniture production can be used for an unlimited number of types of human figures. An object made to order for a specific user must meet all his requirements, unlike mass production, where furniture is designed for an anonymous user belonging to a certain subgroup of individuals. Therefore, the efforts of manufacturers are to optimize and rationally standardize products. During production, it is necessary to limit yourself to a certain set of character types. They must be based on knowledge of the statistical properties of the body dimensions of the expected users [33].

3. Results

Empirical measurements aimed at defining the development of secular changes in selected anthropometric characteristics of the adult population of Slovakia aged 18–25 were carried out in the years 1993–2022 on a sample consisting of 7,365 men and 7,188

women - students of Slovak universities. The sample of 14,537 (Table 1) respondents attending Slovak universities naturally captures the population of various regions of Slovakia, which increases its representativeness. Most anthropometric data are often expressed in percentiles. Percentiles indicate the percentage of people within the population (population sample) who have body dimensions of a certain size (or smaller). The furniture industry uses the 5th or 95th percentile to serve the largest population. The decision about which percentile to use in a particular case depends on the ergonomic criterion being assessed. As part of the results, the values of the arithmetic mean of the individual observed anthropometric data were calculated, as well as the standard deviation and percentiles.

Table 1. Descriptive statistics of the respondents sample.

Anthropometric feature	Arithmetic mean	N-sample	Number of men	Number of women	Standard deviation	Percentiles (%)				
						1	5	50	95	99
Body weight (kg)	73,25	14537	7355	7182	15,57	46	51	72	100	115
Stature height (cm)	171,75	14549	7352	7197	9,95	152	157	171	188	194
Shoulder bi-deltoid breadth (cm)	45,47	8626	4766	3860	6,36	35	37	45	56	62
Elbow height – sitting (cm)	36,93	3725	2095	1630	6,14	26	31	36	43	71
Palm width (cm)	46,13	3628	2054	1574	5,54	30	40	46	54	63
Hand length (cm)	57,08	3756	2109	1647	6,31	39	46	58	65	69
Forearm fingertip length (cm)	10,43	3723	2097	1626	1,539	7	8	10	13	15
Buttock-knee length (cm)	18,52	3715	2091	1624	1,77	15	16	19	21	23
Knee height – sitting with shoes (cm)	45,52	1586	985	601	5,28	30	36	46	54	58

We present the development of secular changes in anthropometric dimensions through linear regression equations. We are investigating the relationship between two variables. We assume that the variable x (years) depends on the variable y (anthropometric feature) that affects it.

Based on the results (Figure 1 - 9), we can conclude that there is a secular trend in most of the monitored characteristics of the Slovak population affecting the dimensions of the bed and seating furniture. This implies the need to update the current standards for the general Slovak population.

The height and weight of the population have a major influence on the dimensional and strength characteristics of bed and rest furniture. Population stature height growth (Figure 1) affects the length of the bed surface, shoulder bi-deltoid breadth (Figure 2) affects the width of the bed surface, and the height of the popliteal fossa affects the bed height. The weight of the population affects the strength characteristics of the elements and joints of bed and rest furniture. In this context, it is also necessary to take into account the body weight of the bariatric population (Figure 3).

The height and weight of the population also affect the dimensional and strength characteristics of seating furniture. Other factors that affect the elements of seating furniture are the elbow height in sitting position (in flexing the elbow) (Figure 4), which ensures comfort when leaning the elbow on the armrest of the chair. Next are the palm width and hand length (Figures 5 and 6) and the forearm fingertip length (Figure 7) when gripping the armrest. The buttock-knee length when sitting has a fundamental influence on the comfort of sitting (Figure 8). The height of the seat surface is influenced by the knee height (when sitting) and the resulting standing up (Figure 9).

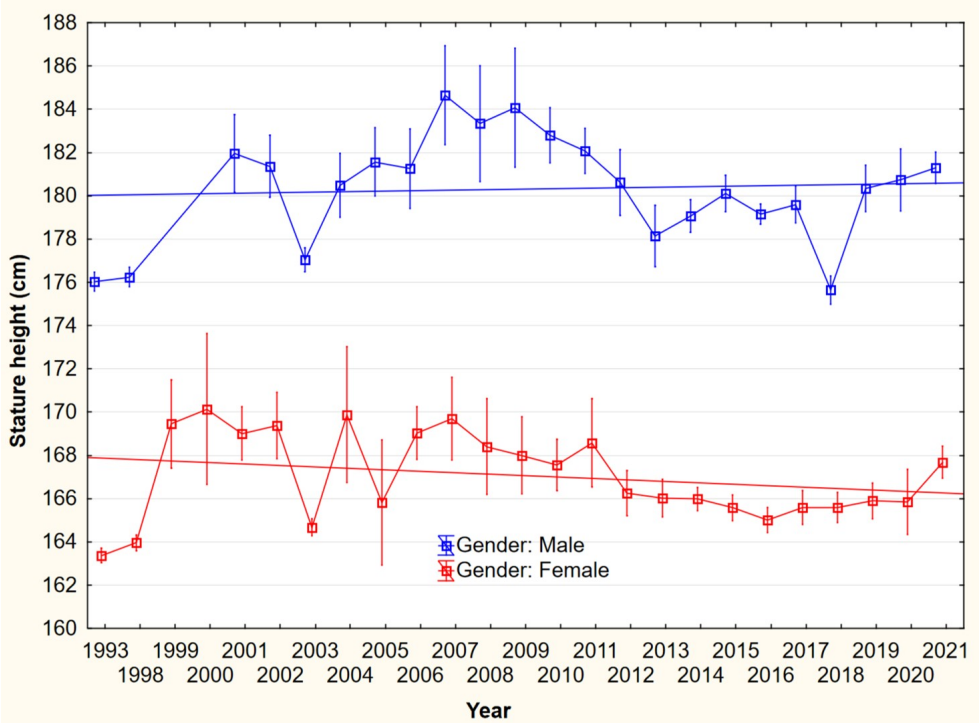

Figure 1. Development of average male and female stature height in years 1993-2021 in Slovakia. 186

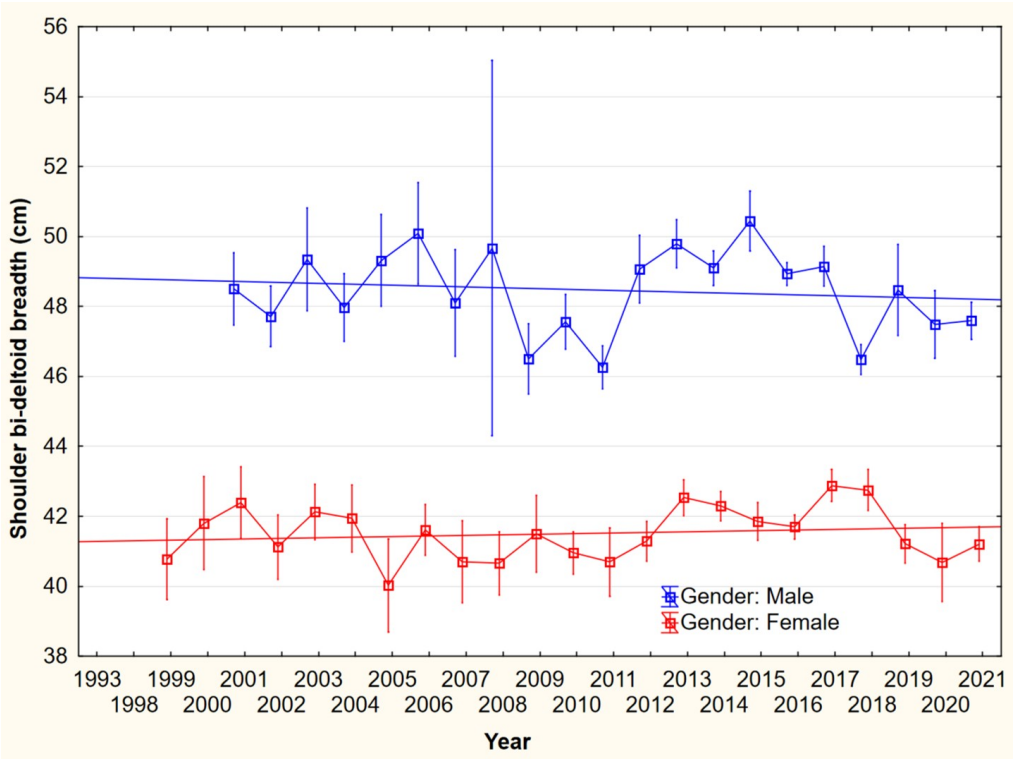

Figure 2. Development of average male and female shoulder bi-deltoid breadth in years 1999-2021 in Slovakia. 187 188

The average stature height of men (fig. 1) shows a slightly rising trend over the entire period. The average stature height of women showed rather a stagnation of the trend in the last 10 years, although in the last 3 years there is an obvious increase in this body parameter. The average shoulder bi-deltoid breadth (fig. 2) has a slightly decreasing 189 190 191 192

trend, especially for men, which is mainly related to the rising standard of living and the decreasing share of physical work, the population playing sports and a comfortable way of life.

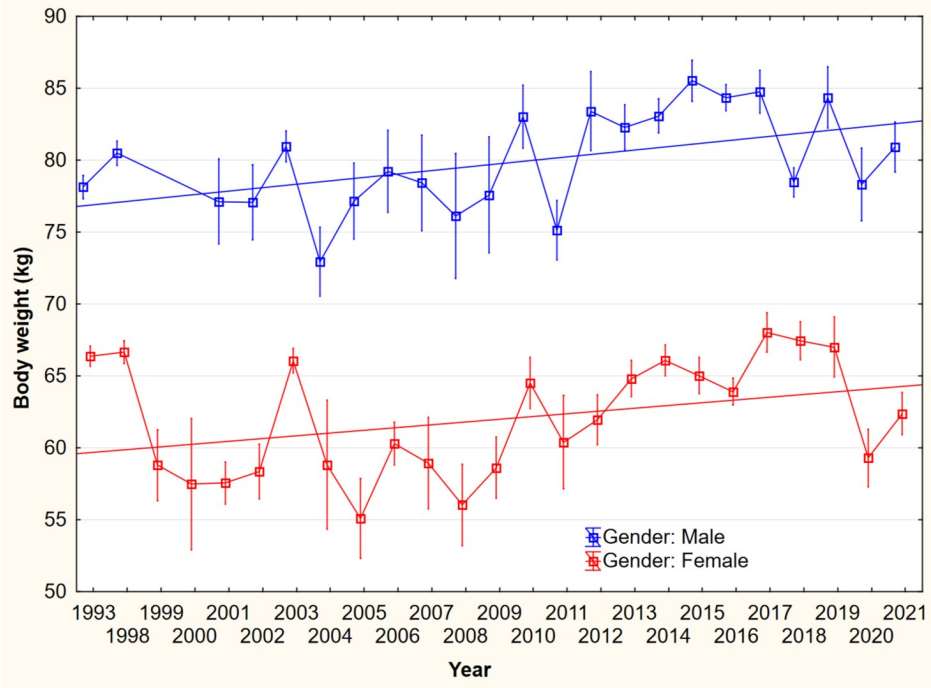

Figure 3. Development of average male and female body weight in years 1993-2021 in Slovakia.

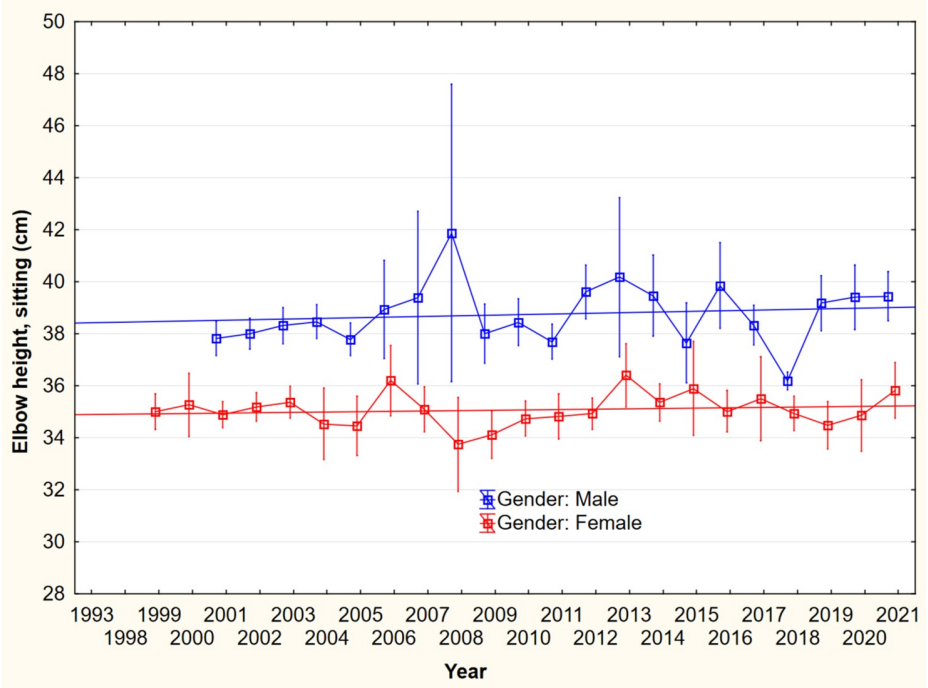

Figure 4. Development of average male and female elbow height, sitting in years 1999-2021 in Slovakia.

Body weight, elbow height - sitting, palm width also showed an upward trend in both populations (fig. 3-5). There was a very slightly decreasing or stagnant trend in the body dimensions of hand length, forearm fingertip length and buttock-knee length (fig.

6-8). The dimension of the knee height - sitting with shoes (fig. 9) shows a significantly increasing trend, even though this result is significantly influenced by the lowest number of measurements in the analysis, since it was measured only from 2016.

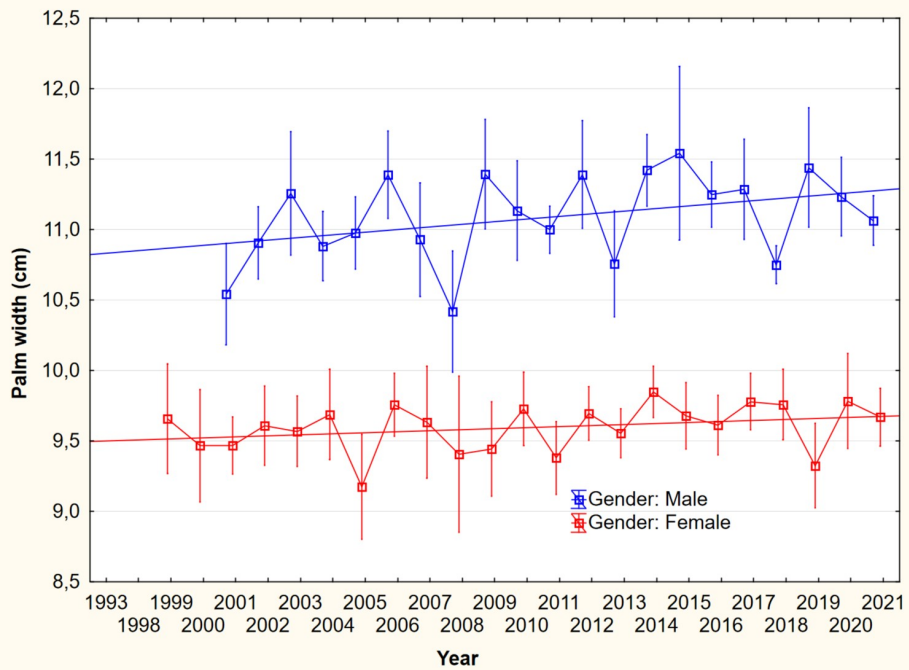

Figure 5. Development of average male and female palm width in years 1999-2021 in Slovakia.

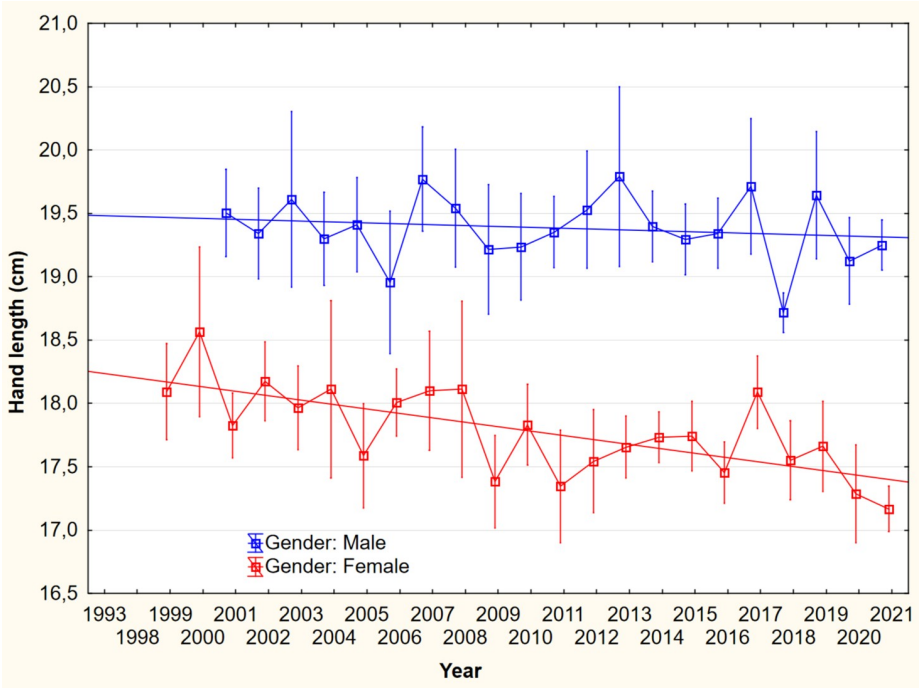

Figure 6. Development of average male and female hand length in years 1999-2021 in Slovakia.

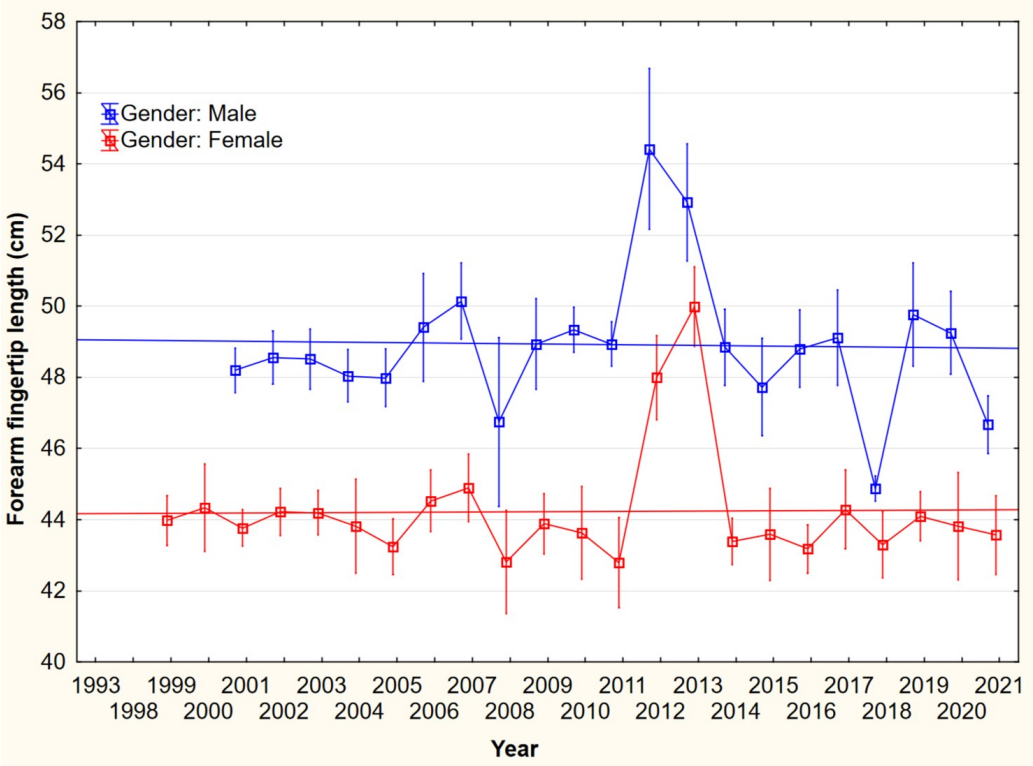

Figure 7. Development of average male and female forearm fingertip length in years 1999-2021 in Slovakia.

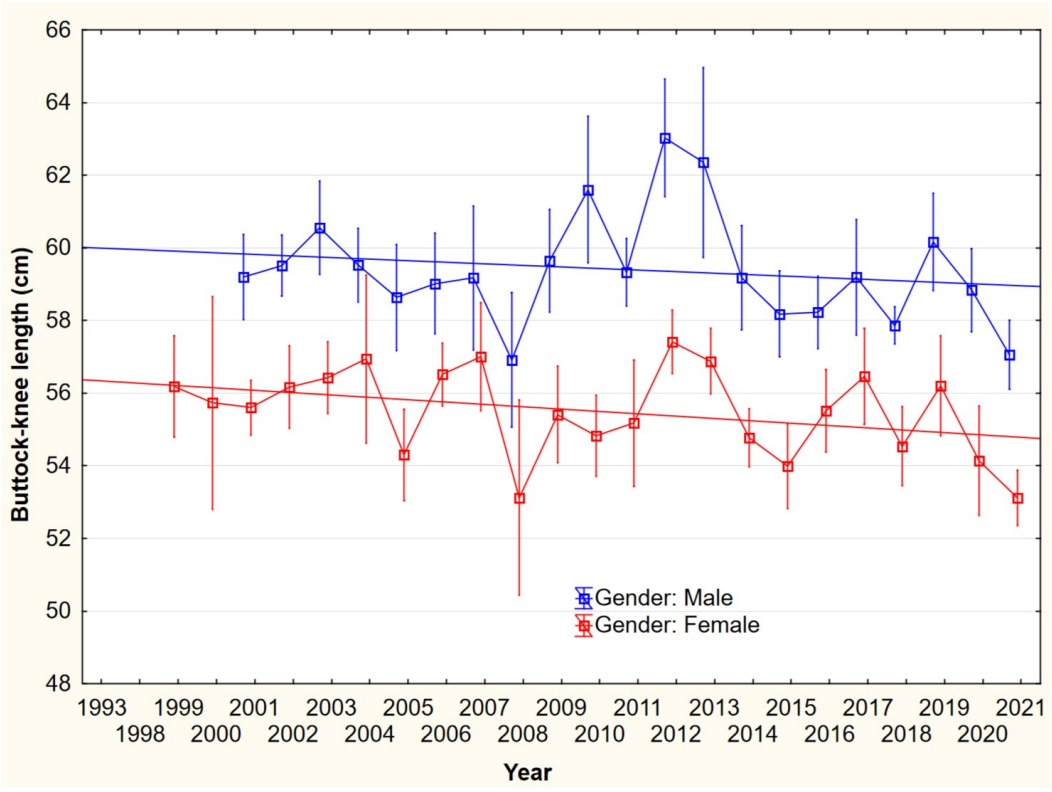

Figure 8. Development of average male and female buttock-knee length in years 1999-2021 in Slovakia.

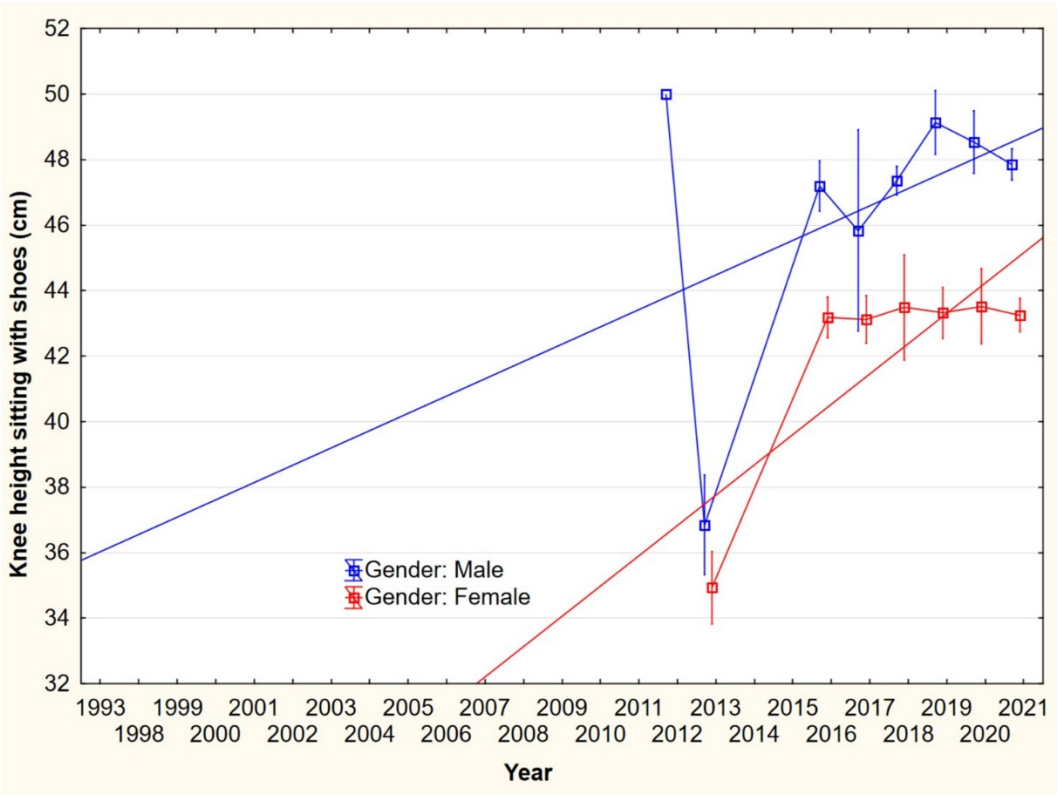

Figure 9. Development of average male and female knee height in years 2016-2021 in Slovakia.

4. Discussion

Over time, population growth and mass changes occur. Secular trends have been documented in many countries of the world since the 19th century [34-36]. These changes must be taken into account when sizing various products of daily consumption (furniture, clothes, shoes, etc.). The manufacturer's efforts to optimize and rationally standardize products must therefore be based on knowledge of current statistical properties of users' body dimensions.

Economic growth causes the intensification of market globalization and, together with a higher standard of living, significantly affects people's diet and overall lifestyle. It causes a significant increase in the body weight of the population all over the world [37]. Other studies over the past decade indicate that body height and weight continue to increase [38-39]. A very rapid increase in body weight occurs especially among young adults [40]. Changes in the dimensions and size of the body are the result of changes in the surrounding environment - increasing the quality of life, better health care, wider options in eating, sedentary employment [37]. However, the secular growth trend is slowing down in many countries. On the other hand, weight gain begins to accelerate. Weight grows more significantly than body height, especially in men. Jirkovský (2003) [27] devoted himself to the anthropometric measurement of men aged 18-25 in the Czech Republic in the second half of the 20th century. The results of the research are comparable to the results of Kovářík (2011) [41] in the area of the expected slowdown of the secular trend of the body height of the population. Jirkovský (2003) [27] states that since the second half of the 80s of the 20th century, growth acceleration has gradually slowed down and body weight has increased. This means that the significant secular trend that took place after World War II slowed down at the end of the last century. Despite this, there is a slight increase in the body height and weight of the male population from the Czech Republic.

Reactions to secular trends in human body height are visible primarily in industries where consumption as the main economic factor has a decisive influence [42-43]. These

are the areas of the automotive, aviation, furniture, clothing, and footwear industries. These changes must be taken into account when sizing various products of daily consumption (furniture, clothes, shoes, etc.). Designing furniture of all kinds, i.e. j. bed, seat, closet, multi-purpose, table, and additional must be in direct relation to the dimensions and weight of the current and future population. Anthropological and ergonomic requirements are decisive in many ways in connection with the shape, and dimensions, i.e. the quality of the furniture and materials used. The manufacturer's efforts to optimize and rationally standardize products must therefore be based on knowledge of current statistical properties of users' body dimensions. One such product, where it is necessary to take into account the anthropometric parameters of the users, is the chair. Anthropometry plays a decisive role in defining the dimensions of chairs and their structural parts. Based on the obtained results, we can state the need to update the current dimensions of the bed and seating furniture suitable for the 95 percentile of the adult population of Slovakia.

When providing furniture for work needs, as well as living, we have to think about the generations that will come after us. Designing furniture of all kinds, i.e. bed, sitting, closet, multi-purpose, table, and additional therefore must be in direct relation to the dimensions and weight of the current and future population. In connection with the increase in the dimensions of the bed and seating furniture, it is also necessary to take into account the need for secondary connections such as sheets, mattresses, quilts, and other accessories.

Since 1980, a number of scientific works have been devoted to calculations and experimental testing of furniture structures. A large part of research is focused on experimental testing, further research is subsequently focused on computational methods, or methods using software tools. A large part of them is devoted to the calculations of chairs and beds, while the authors focus on the joints of parts, as the most critical places [44-45]. In order for the chair seat to provide sufficient support, its height should be slightly less than the length of the human leg measured from the heel to the knee. The ideal formula is given by the so-called popliteal height, which is equal to the length of the back of the thigh plus the heel. The usual dimensions of the chairs are averaged, so smaller people should take into account that they need a lower seat to avoid unwanted compression of blood vessels. Based on the study of the literature, it is shown that the most common method for calculating the stress and deformation of wooden chairs is the finite element method [46-48], which can be used to determine or estimate the bearing capacity the individual dimensions of the joints, as well as the places with critical tension, where damage can occur first. Another method is the method of finite volumes [49-50]. The researches of the mentioned authors point to a very good agreement between the calculated results and the experimentally measured data. A wooden bed and a wooden chair, as basic items of home furnishings, are subject to high demands [51]. Their size and stiffness must correspond to the human body and changes in position during sleep or sitting. From an anthropometric point of view, the length, width, and height of the bed area and the height, depth, and width of the chair are important. As body height and weight have increased in recent years, and the number of overweight and obese people has increased [25; 52], there is a need to design beds and chairs with a perspective for people with high BMI. When calculating the dimensions of the mentioned furniture, we take into account the forecast of the development of the relevant anthropometric dimensions of the population, i.e. secular trend. By adding standard deviations, we create a so-called universal design. This approach ensures the suitability of the dimensional furniture solution for today and future generations. When determining the dimensions, we are based on mathematical relationships taking into account the development of the anthropometric dimensions of the population in the future. The starting and determining dimension can be considered the body height of men, which results from the difference in the habit of the sexes (men are on average taller than women).

5. Conclusions

Anthropological and ergonomic requirements are decisive in many ways in connection with the shape and dimensions of consumer products. On the basis of our research, it can be clearly stated that in the last two decades there has been a positive secular trend in Slovakia. This situation occurred as a result of better nutrition and better socio-economic conditions in which today's population grew up. This trend will continue to a lesser extent. At the same time, it is necessary to state that the change in the dimensions of the bed and rest furniture and seating furniture will also have an economic impact on the production of furniture. From an economic point of view, the mentioned changes can reach up to 50% of the current costs. In this context, it is also necessary to subsequently update the calculation formulas for the pricing of individual products.

The relationship between a person and the objects around him, expressed by the functional dimensions of the furniture, has an impact on work and personal well-being and, last but not least, on his health. These dimensions are contained in the standards but also in various manuals. However, the basis is the standards valid in the country of operation. However, the modification of standard dimensions requires the interdisciplinary cooperation of designers, developers, anthropologists, ergonomists, and health professionals.

Author Contributions: Conceptualization, M.G.; methodology, M.G. and M.H.; software, M.G.; validation, M.G. and M.H.; formal analysis, M.G.; data curation, M.H.; writing—original draft preparation, M.G.; writing—review and editing, M.G. and M.H.; funding acquisition, M.H. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Slovak Research and Development Agency (grant number APVV-20-0004 The effect of an increase in the anthropometric measurements of the Slovak population on the functional properties of furniture and the business processes). Operational Programme Integrated Infrastructure (OPII) funded by the ERDF (grant numbers: ITMS: 313011T720 Progressive research of performance properties of wood-based materials and products (LignoPro); ITMS: 313011T678 Comprehensive research of mitigation and adaptation measures to diminish the negative impacts of climate changes on forest ecosystems in Slovakia (FORRES).

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Not applicable

Data Availability Statement: Data sharing not applicable

Conflicts of Interest: The authors declare no conflict of interest.

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