Dimensional Solution for Beds from Wood Composites for the Bariatric Population

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The aim of the work was to define a suitable dimensional solution for a single-occupancy bed from wood composites for the adult bariatric population of Slovakia. Current bed dimensions are designed for the adult population for standard human dimensions and weight up to 150 kg. Based on the long-term observation of the development of anthropometric dimensions of the population (secular trend), the height of 95% of the adult male population was defined. Based on the analysis of the bariatric population of Slovakia, regardless of gender, the values of weight, waistline and hipline, and seat width were defined in the years 2020 to 2022. Based on the results, the weight of the bariatric population can be up to 250 kg. New bed dimensions for bariatric respondents were proposed, including bed length according to room dimensions from 220 cm to 240 cm, bed width of 141 cm, and bed height of 55 cm. By adjusting the dimensions of the beds for bariatric respondents, they will be able to move comfortably during rest and sleep. This can prevent many health problems.

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INTRODUCTION

A bed is a basic home furnishing. Bed furniture is intended for regular or occasional sleep. Beds can be constructed as static, folding, or dynamic, for different groups of users according to age, for children, students, adults, seniors, according to the state of health for the healthy, sick, temporarily or permanently, and according to the design for insensitive or sensitive people to geopathogenic zones and electromagnetic smog and the like (Navrátil 2001). None of the other pieces of furniture are subject to such high-quality requirements as bed furniture because a person spends up to a third of his life in bed. A bed is a multipurpose type of furniture. The deck surface is adapted for sleeping or resting (Stransky *et al.* 1990; Matwiej *et al.* 2022). From the point of view of anthropometry, physiology, and hygiene, the size of the bed must be appropriate for the human body and changes in body position during sleep. The functional dimensions of bed furniture are given by the standards, which determine the height, length, and width of the bed (Navrátil 2001). It is not possible to create a bed suitable for the entire population, especially in terms of height and weight. Considering the secular trend of populations all over the world and especially the increase in weight, it is, therefore, necessary to deal with adjusting the

dimensions of bed furniture.

The worldwide incidence of obesity is increasing. In all countries with higher income, the level of overweight and obesity is greater (NCD Risk Factor Collaboration 2019). The growing prevalence of overweight and obesity puts a financial burden on the economy of every state. As defined by the World Health Organization (WHO 2006), obesity affects the socioeconomic status of society in all developed and developing countries (Kosti and Pnagiotakos 2006). Dee *et al.* (2014) concluded that there is a gradient between increasing Body Mass Index (BMI) and direct health care costs and indirect costs due to reduced productivity and early premature mortality. Healthcare costs are 44% higher among severely obese patients. This represents a public health problem in developed and developing countries (Herron 2004). According to data from the Public Health Agency of Canada and the Canadian Institute for Health Information (Garneau *et al.* 2022), a quarter of Canadian adults live with obesity. According to data from the World Health Organization (2020), in 2019, there were 950 million obese adults worldwide with a body mass index (BMI) of at least 30 kg/m^2. BMI growth trends are constantly increasing (World Health Organization 2020). The results of the European Health Examination Survey (EHES 2011) study of health in the Slovak Republic in 2021 show that among the adult population aged 15 to 64 in Slovakia, 13 to 15% of children aged 11 to 15 suffer from obesity, overweight 20%, in the age category from 18 to 24 years old, 41.74 % of people from 55 to 64 years old are obese. In total, 25.6% of the population in the 18- to the 64-year-old group are obese, and 36.2% of the population are overweight.

Wood is a unique organic construction material that has wide applicability in both indoor and outdoor environments. It is a functional, practical, and decorative material. It is characterized by good formability and connectability. Thanks to different variations of the surface treatment, wood can have a diverse appearance, and with proper care, it can last for decades. Wood is an ecological material. The energy intensity of wooden structures is low, both from the point of view of production and use. Strength characteristics in the construction of furniture can also be influenced by the occurrence of quality features in specific types of wood.

Beech (*Fagus sylvatica* L.) is among the most important and most frequently used hardwoods in furniture production. It is the most widespread wood species in the forests of Slovakia (its representation is 34.2%); in Europe, the reserves of beech raw material are significant (Green report, Slovakia 2021). The complex processing of beech is very complex from a technological and economic point of view. This wood has a large share of growth defects, which is reflected in the shape and size changes of semi-finished products and products during its processing. One of the options for achieving the shape and dimensional stability of elements while simultaneously improving their strength characteristics is the production of glued beech elements. The technological process of mechanical splitting of beech raw material into lumber, prefabrication of lumber into dimension stocks, hydrothermal treatment, drying, and subsequent gluing achieves the desired properties of the product. As part of the production of glued beech elements, in complex production and non-production technological operations, the dimension stocks are joined (after exclusion of unwanted qualitative features) with a serrated joint into an infinitely long dimension stock, which is subsequently shortened to the required lengths, and in the next operation, they are glued side by side with polyvinyl acetate glue, resulting in a finished a product made of glued solid wood. It is important in this process that the variance of moisture between individual blanks before gluing is not greater than ±1 %. The required moisture content of glued blanks, which are intended for interior products, should

be within the interval 7 to 9% (Baranski *et al.* 2017).

Modern trends in furniture production are beginning to be oriented towards the use of wood composites, or the combination of different types of wood in the structural elements of furniture (Jansen *et al.* 2000; Zhang *et al.* 2014; Barbosa *et al.* 2015). The sustainability of composite materials based on natural fibers has led to an increase in their applications in various manufacturing sectors (Lau *et al.* 2018; Antov and Savov 2019; Antov *et al.* 2019; Girijappa *et al.* 2019; Chen *et al.* 2022).

A wooden bed is subject to high demands (Cameron 2002). Its size and stiffness must correspond to the human body and changes in position during sleep. From an anthropometric point of view, the length, width, and height of the bed surface are important. Length and width have an effect on the size of the bed surface, while height is of great importance for comfortable standing and possibly sitting (Jelačić *et al.* 2002). Since body height and weight have been increasing in recent years, and the number of people overweight and obese is also increasing (Bolstad *et al.* 2001; Barroso *et al.* 2005; Iseri and Arslan 2009; Chuan *et al.* 2010; Chen *et al.* 2016). Accordingly, there is a need to design beds with a perspective for people with a high BMI (Cole 2003).

This work aims to define the functional dimensions of a single-occupancy bed for bariatric users. Due to the long-term sustainability and greening of production from renewable materials, as well as due to the shape and strength stability of the wooden material, the study focused on single beds made from beech wood composites.

EXPERIMENTAL

When calculating the dimensions of single-occupancy bed furniture, the forecast of the development of the relevant anthropometric dimensions of the population, *i.e.*, secular trend, was considered. By adding standard deviations, a so-called universal design was created. This approach ensures the suitability of the dimensional solution of bed furniture for today and future generations. The dimensions of the bed are based on mathematical relationships taking into account the development of the anthropometric dimensions of the population in the future.

The body height of men was used as the starting point for determining the dimension of the length of the lying surface, which results from the difference in the habit of the sexes (men are on average taller than women). The length of the lying surface of the bed (L) was determined according to Eq. 1 (Prokopec 1998),

$$L = TV_m + 2s_x + K_p \quad (1)$$

where L the length of the bed's lying surface (cm), TV_m is men stature height (cm), s_x is standard deviation, and K_p is the comfort factor varies according to the location of the bed in the space +15 cm if there is a lack of space in the apartment, +25 cm if there is enough space in the apartment, and +35 cm if there is enough free space.

When determining the width of the lying surface, it is usually based on shoulder width for a man (Eq. 2). Due to the fact that bariatric respondents show wider hips than shoulders within their figure, the maximum body width was replaced by the width of the seat ($\check{S}S_m$). Because each person changes their position several times during the night, it is necessary to increase the minimum width of the bed area by another 25%. The width of the lying area (b_1) of the bed was determined according to the formula (Prokopec 1998). However, the width of the lying area on the bed was calculated according to the modified

Eq. 3, where the width of the bed represents the amount of space necessary for the bariatric respondent to be able to turn in both directions without lateral repositioning.

$$b_1 = 1{,}5(\check{S}R_m + 2s_x) + 0{,}25[1{,}5(\check{S}R_m + 2s_x)] \quad (2)$$

$$b_1 = 2(\check{S}S_m + 2s_x) + 0{,}25[2(\check{S}S_m + 2s_x)] \quad (3)$$

where b_1 is the width of the lying area (cm), $\check{S}S_m$ is width of the seat (cm) and s_x is standard deviation.

When determining the height of the lying surface, the assumption is that the bariatric respondent cannot have the same height of the lying surface as a normal user of the bed. The height of the bed was determined according to Eq. 4 (Navrátil and Klein 1994),

$$hp_1 = 5TV_m/20 \quad (4)$$

where hp_1 is the height of the lying area (cm), and TV_m is men's stature height.

Due to the possibility of standing up, it is necessary to adjust the value in the numerator to the value 7 for the needs of bariatric respondents. This will achieve a femur angle when sitting on the bed in the range of 130 to 140°. The resulting relation of the bed height calculation is shown in Eq. 5.

$$hp_1 = 7TV_m/20 \quad (5)$$

Empirical measurements of the height and weight of the current male population were carried out from 2001 to 2022 on a sample consisting of 1678 men aged 18 to 25 from the entire territory of Slovakia. Selected anthropometric dimensions were determined to define the trend of body height and weight. The measurements were carried out by a certified anthropometer. Due to the analysis of the bariatric population of Slovakia, regardless of gender, data was collected in medical facilities between 2020 and 2022. The values of weight, height, waistline, hip width, and seat width were determined. Subsequently, BMI values were defined.

RESULTS AND DISCUSSION

Secular Trend of Population

In the last 40 years, there has been a continual increase in the height of the population in all age categories (Fig. 1 and Table 1). The trend of weight growth by age category is shown in Fig. 2.

Table 1. Secular Trends in Heights

Age	Linear Regression Model				Overall Significance	
Category	Slope	St. error	t	p-Level	F	p-Level
	Male					
≤25	**0.105 ***	**0.016**	**6.7339**	**0.00000**	**45.346**	**0.000**
25-35	**0.104**	**0.028**	**3.7223**	**0.00021**	**13.856**	**0.000**
35-45	**0.124**	**0.030**	**4.2035**	**0.00003**	**17.670**	**0.000**
45-55	**0.187**	**0.022**	**8.4243**	**0.00000**	**70.968**	**0.000**
55-65	**0.203**	**0.040**	**5.0723**	**0.00000**	**25.729**	**0.000**
65-75	**0.135**	**0.034**	**4.0125**	**0.00007**	**16.100**	**0.000**
>75	**0.167**	**0.052**	**3.2322**	**0.00138**	**10.447**	**0.001**

*Bold numbers denote the statistically significant regression coefficients and models at 0.01 level. (Hitka *et al.* 2018)

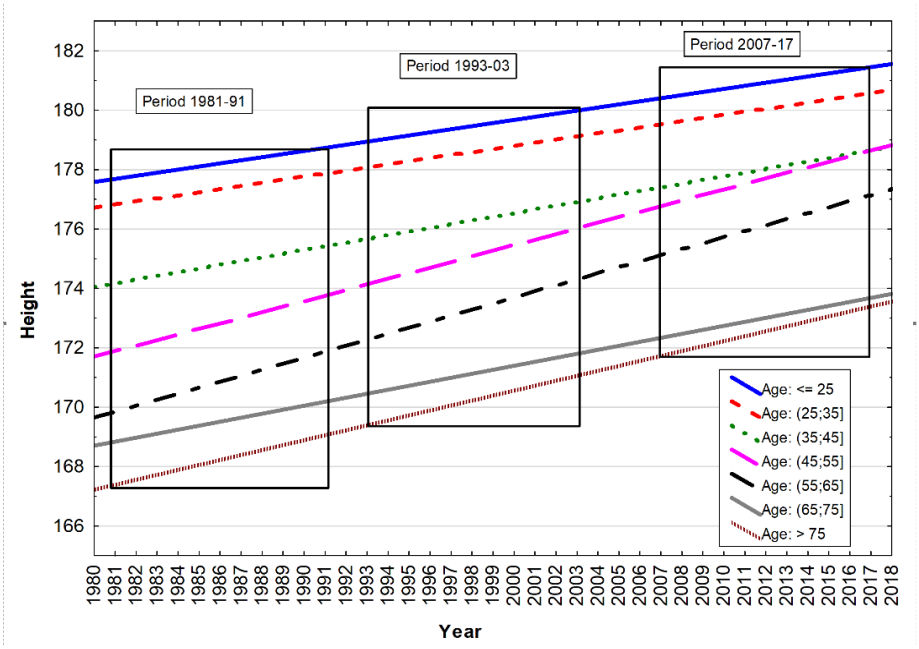

Fig. 1. Secular height trends men in different age categories and their impacts on height size in selected time periods (rectangles display the three compared periods, the displayed trends for this period were obtained by backward extrapolation of linear models parametrized on measurements from 1993-2017) (Hitka *et al.* 2018).

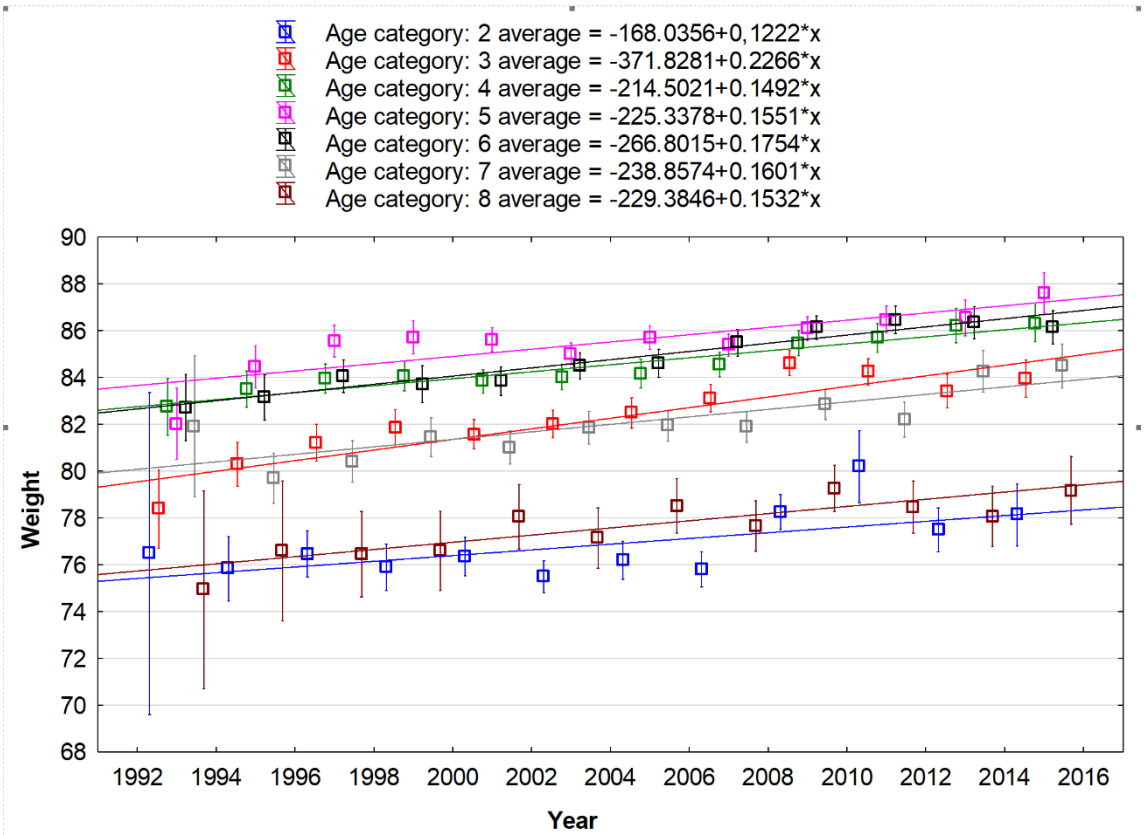

Fig. 2. Secular weight trends men in different age categories (age categories according to Table 1) (Hitka *et al.* 2018)

Figure 3 defines the secular trend of the current population of men aged 18 to 25; Fig. 4 defines the trend of weight growth. Descriptive statistics can be found in Table 2.

Table 2. Descriptive Statistics of the Current Male Population

n = 1680	Average	Min	Max	Standard Deviation	Quantile (1%)	Quantile (5%)	Quantile (50%)	Quantile (95%)	Quantile (99%)
Stature height	181.9	152.0	205.00	6.8	166.0	171.0	182.0	191.0	200.0
Body weight	78.7	35.0	150.00	12.1	56.0	62.0	77.0	95.0	115.0

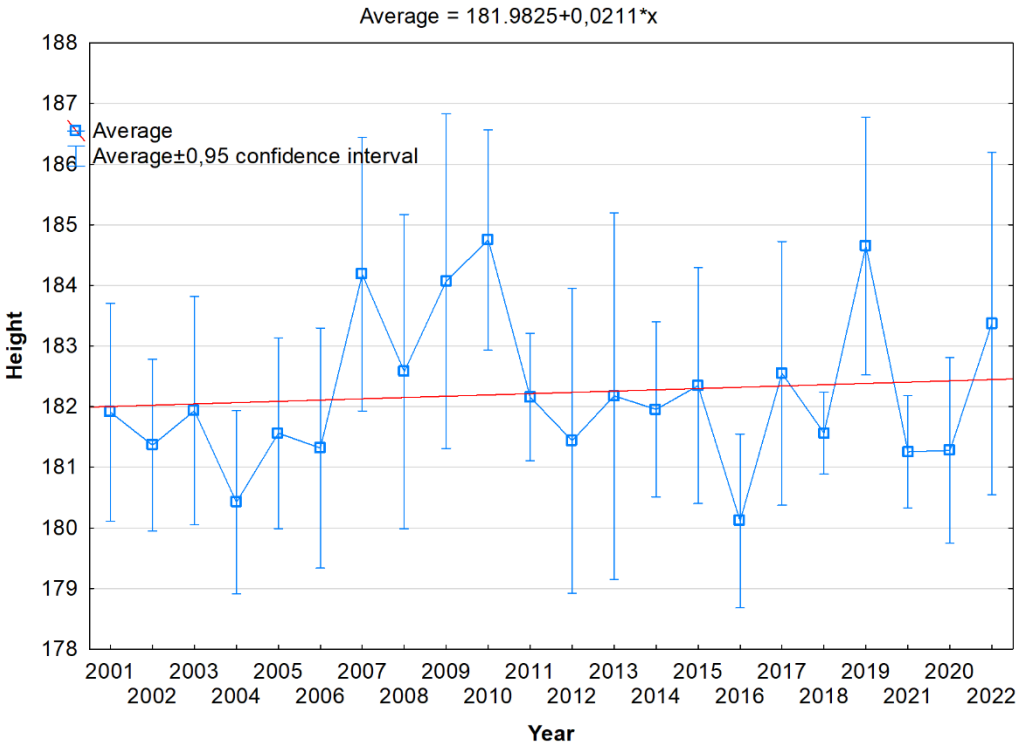

Fig. 3. Stature height growth trend for men in the age group 18-25 years old

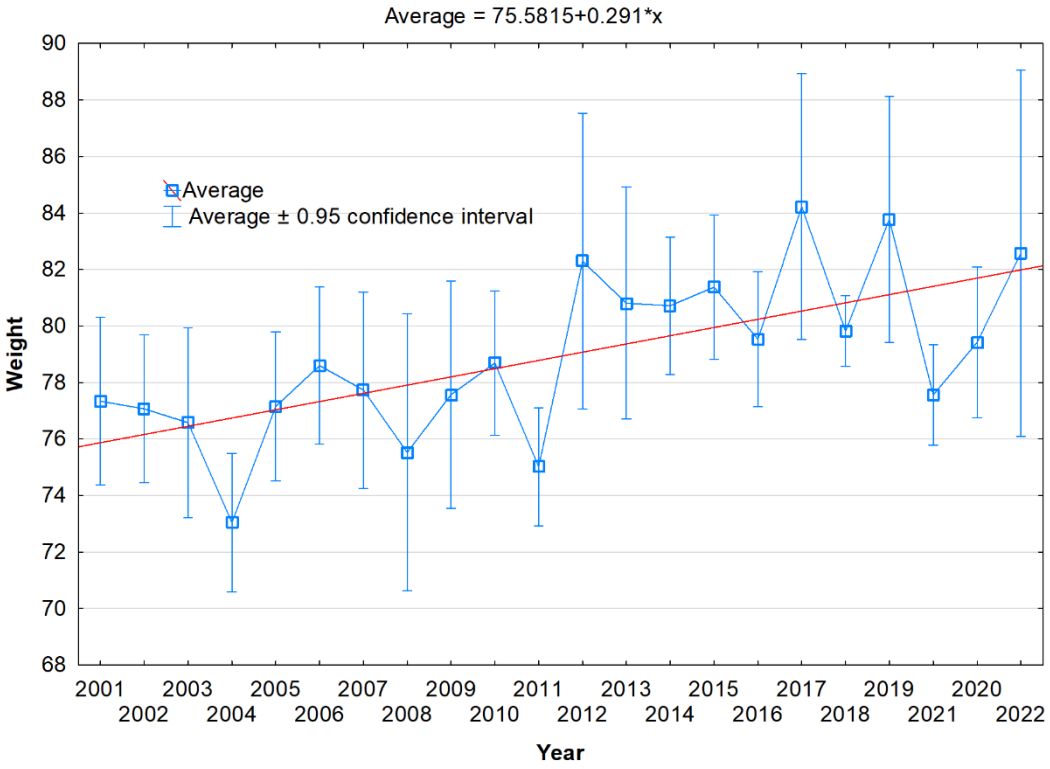

Fig. 4. Body weight growth trend for men in the age group 18-25 years old

Body Weight of Bariatric Respondents

Data on the bariatric population of Slovakia in health care institutions during the years 2020-2022 were collected. The results of the descriptive statistics of the collected data are presented in Table 3.

Table 3. Descriptive Statistics of the Bariatric Population in 2020-2022

Dimensions	Descriptive Statistics												
	N	Aver.	Min.	Max.	Percentiles					Range	Std. Dev.	Var.	Skew-ness
					1%	5%	50%	95%	99%				
Weight	185	142.4	93	242	96	105	138.0	188.0	242.0	149.0	27.0	18.9	0.9
Height	185	171.1	150	199	150	156	170.0	187.0	199.0	49.0	9.1	5.3	0.3
Waist circumference	185	136.2	84	188	100	113	135.0	161.0	188.0	104.0	16.1	11.9	0.5
Hip circumference	185	145.5	108	192	110	120	145.0	170.0	192.0	84.0	15.6	10.7	0.4
BMI	185	48.5	35.5	77.9	36.3	38.9	47.4	59.8	76.4	42.4	7.2	14.8	1.2

Determining the Bed Dimensions for the Bariatric Population

When determining the dimensions of the length of the bed according to Eqs. 1 and 3 and when determining the height of the bed lying area according to Eq. 5, the 95% quantile of the body height of men in a standing position for bariatric respondents was used (Table 4). The width of the bed lying area was based on the width of the bariatric respondent's seat (Table 3). The stated dimensions will provide the bariatric respondent with sleep with the possibility of turning in both directions without lateral repositioning.

However, the stated width of the bed can cause problems when laying the bedding, which can be tolerated when taking into account a comfortable sleep. The obtained values were rounded up to whole numbers.

Table 4. Recommended Length Dimensions of the Bed for Bariatric People According to the Place in the Apartment

	Used Value of 95% Quantile of Body Height	Proposed Value in Centimeters
Length (*L*)	Smaller room space	220
	Middle room space	230
	Large room space	240
Width (b_1)	For all lengths	141
Height (hp_1)	For all lengths	66

Several explanations are possible for the positive secular trend and body weight increase of the population in Slovakia. First, the current generation is affected by the events that have taken place over the last three decades in Slovakia. There is a fundamental change in the political regime and the entry of Slovakia into the European Union. The economic prosperity of the population resulted from economic and political changes. The purchasing power of an average person more than doubled compared to 1989 (www.slovak.statistics.sk). Further, the influence, availability, and quality of diet, adherence to healthy lifestyle or availability of vitamins and medicines all could also have an impact. Also, the positive change in healthcare greatly impacts such trends. It should be noted in the article that bariatric beds pose significant construction problems for furniture designers and producers. It is necessary to take into account the increased strength of the frame or box structure of such a bed.

Grasgruber *et al.* (2016) in their worldwide reviews found that the most important factors affecting the height and body weight in human populations are the consumption of protein-rich food and the human development index (as the measure of society wealth) which are most strongly associated with tall statures. Both factors increased or improved in Slovakia, especially after the country's entry into the European Union, due to favorable economic development. The effects of these changes were manifested both in the change in the diet of the population, as well as in the globalization of Slovak society, whereas a result of the opening of borders is a "mixing" of the population, which may result in a change in the physical dimensions of the current adult population of Slovakia.

Moreover, the social status and the achieved education—one of the factors influencing the development of body physical dimensions of the human population—were improved for many families in Slovakia (Deaton 2007). Following trends from other countries, weight gain will continue as social status increases. Considering this, it is necessary to have defined dimensions of the bed for such a population (Čuta *et al.* 2010).

Improperly constructed lounge furniture has a great influence on the emergence of many health problems. Sleeping on an unsuitable bed has negative effects on the spine and musculoskeletal system. Sleep is an important and basic human need. The quality of sleep depends on the quality of the bed furniture. Inadequate bed furniture has a major impact on a person's mental and physical regeneration. Poor-quality sleep causes fatigue, increased neural lability, reduced receptivity, diseases of the spine, large joints, muscles, and nerves, disorders of psychological expression, and also conditions the emergence of stress.

The application of data from the adult Slovak bariatric population to the area of bed furniture creation allows defining the dimensional characteristics of the bed to the needs of the current population of Slovakia. The current standardized dimensions of the bed are unsuitable for bariatric respondents from the point of view of the quality of rest and maintenance of the bed, but mainly from the point of view of safety (Branowski *et al.* 2018; Skorupińska *et al.* 2022). By introducing new dimensional standards, it is possible to make life easier even for bariatric respondents.

This study is one of the first in Slovakia that deals with correlating the current height of the population with the dimensions of bariatric respondents and relating them to the dimensions of the bed. A similar analysis of bed size was also dealt with (Wiggermann *et al.* 2017). Their results support our conclusions. Wignall (2008) reminds us that when caring for bariatric patients, attention must also be paid to specialized equipment related to the bed (special mattresses, sheets, blankets, lifting equipment, ventilation equipment). A limitation of the study may be the pursuit of greening and sustainability in the form of wooden furniture. The new strength characteristics of the elements and joints of this type of furniture are closely related to the dimensional characteristics.

CONCLUSIONS

1. The height and weight of the population are increasing significantly in all countries. More than 130 thousand men in Slovakia weigh more than 110 kg. At the same time, other anthropometric parameters of residents such as waist width and hip width also increase with weight. The design of bed furniture is directly related to the dimensions and weight of bariatric respondents.
2. Based on the results, we propose to adjust the dimensions for bariatric respondents to values of length 220 to 240 cm (according to spatial dimensions), width of 141 cm, and height of 66 cm. The stated dimensions will enable most users to use the bed comfortably and with the possibility of lateral repositioning. However, the stated dimensions can also be used by the general population.
3. Offering better-fitting products extends their lifetime and reduces material consumption. The less material consumption reduces carbon footprint. Therefore, our research results can support the environmental protection
4. The modification of standard furniture dimensions requires interdisciplinary cooperation between anthropologists, ergonomists, developers and health professionals. A multidisciplinary approach can bring results in the production of health-conscious consumer products, which wooden furniture clearly fulfills. Thanks to its functional properties, the furniture will be able to be used by a wider group of users.

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