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# Dimensional Solution of Wooden Chairs for the Adult Bariatric Population of Slovakia: Observational Study

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**Abstract:** Chairs are furniture that are intended for direct contact with people, they are heavily loaded by forces, and they must meet a number of criteria, such as ergonomics, safety, economic sustainability, feasibility, and aesthetic requirements. This study aimed to define the dimensional solution of wooden chairs for the adult bariatric subpopulation of Slovakia. Long-term observations of the changes in the anthropometric dimensions of the population (secular trend) allowed the determination of the body height of 95% of the adult male population. Based on the analysis of the bariatric population of Slovakia, regardless of gender, the values of weight, waist and hip circumference, and seat width were defined in the years 2020 to 2022. The increased population's average body mass makes the researched topic highly relevant and necessary. Based on the obtained data, new dimensions of wooden chairs for bariatric respondents were designed: seat height 49 cm, seat width 67 cm, and seat depth 47 cm. Adjusting the dimensions of wooden chairs makes it possible to ensure comfortable sitting and standing for bariatric respondents and prevents many health problems. For furniture manufacturers, the introduction of the production of wooden furniture for bariatric respondents can be a competitive market advantage.

**Keywords:** furniture; wooden furniture; chair; bariatric chair; furniture design; anthropometry

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## 1. Introduction

Wooden chairs are typically home, school, restaurant, and conference furniture. They can be designed as general-purpose furniture or furniture that is intended for groups of users according to age (for children, students, adults, and seniors) and health status (for healthy, sick, temporary, or permanent). Since these are furniture that are intended for direct contact with people, they are heavily loaded by forces, and at the same time, an aesthetic value is required from them—thus, the overall design requirements for chairs are antinomic [1].

Anthropometry pertains to measuring the human body. Some authors have studied the relationship between chair design and the anthropometry of obese people. They specifically researched how to design appropriate sizes and chair component structures to include specific features and indicators of the human body, mainly obese people [2]. In engineering anthropometry, the human body's physical size and shape, mass, strength, and body movement capabilities are used in designing products, systems, and methods to improve comfort, safety, and productivity [3–5]. Gupta [6] characterizes engineering anthropometry as a field of knowledge that is focused on providing the correct body dimensions to achieve a good product fit for the user [6]. Engineering anthropometry is closely related to user-centered design methodology [7] and ergonomics [8,9].

Adults' range and average anthropometric dimensions are changing in the long-term [9–11]. With the development of human society, the average body size tends to grow. The long-term changes in the anthropometric dimensions of the population are a secular trend. As stated by Fetter et al. [10], with age, the human body constantly changes, grows, develops, and this is also reflected in its dimensions. The secular trend is an effect of changes in nutrition, morbidity, and socioeconomic status of a human population [12–14]. Dynamic changes in the human population in the social and technological fields are closely correlated and have resulted in regulations in designing daily life and consumption products [15–17]. These changes also apply to furniture that comes into contact with users, such as beds, sofas, chairs, tables, etc. [18]. These factors influence all industrial areas and include economic and environmental product sustainability [1,19,20].

The adjective bariatric was coined around 1965 from the Greek root bar–, the suffix –iatr, and the suffix –ic ("relating to") [21]. The bariatric issues include diet, physical activity, behavioral therapy for weight loss, drug therapy, and surgery. The term is also used in the medical field to refer to people of larger sizes regardless of their participation in any specific weight loss treatment. Being overweight and obese are increasing health problems [22]. Obesity occurs when a body mass index (BMI) exceeds 30. Class 1 obesity means a BMI between 30 and 34, Class 2 is a BMI of 35 to 40, and Class 3 includes a BMI of 41 or more. Classes 2 and 3, also known as severe obesity, have many harmful health effects of obesity [23,24]. Individuals with a BMI above 30 have a much greater risk of health problems [25,26]. The number of bariatric respondents in the population is growing. As part of bariatric care, it is also necessary to consider the appropriate selection of furniture not only in the hospital but also in the home [27,28]. If these patients have suitable chairs, armchairs, and beds, transferring them to a standing or mobile device will be easier, allowing users to be more mobile and participate in therapy [29,30]. According to the NCD Risk Factor Collaboration (NCD-RisC) [31], if such trends continue, the obesity problem worldwide will concern 18% of men and more than 21% of women by 2025. Along with severe obesity, it will be prevalent in more than 6% of men and 9% of women.

There is no commonly accepted definition of sitting comfort. The objective measure of this comfort could be the contact stresses between the body of the sitting person and the chair [30]. Other vital factors affecting the ergonomics of the seat are the angle of the backrest [31], the seat's height, width [1], and the number of adjustability controls [32]. People with a high BMI use a chair slightly differently than people with a normal BMI. Benden et al. studied two groups of people with a standard BMI and people weighing more than 102 kg; the study results showed that people with more body weight more often lean their back against the back of the chair and stand up much less [33]. Modifying the essential dimensions of the chair, such as the chair's backrest angle or seat height, has a different effect on the seating comfort of obese people than on the comfort of people with standard body weight. Studies on this subject were conducted by Liu et al., who showed that increasing the angle of reclining the backrest does not increase the sitting comfort of obese people as much as people of normal body weight [34].

All of these factors justify producing items of everyday consumption and necessities, including furniture, for the bariatric subpopulation. Furniture manufacturers must also adapt to this trend, which must meet hygienic, anthropometric, physiological, and psychological criteria for bariatric respondents [32]. For furniture manufacturers, introducing wooden furniture production for bariatric users can be a competitive market advantage [33]. It must also meet the requirements of general safety, durability, and increased strength, along with basic design requirements [34]. Due to the secular trend of populations worldwide, it is necessary to adjust the current dimensions of seating and lying furniture to those changes [35–38]. Due to the environmental sustainability features, excellent machinability, and good specific strength of the wooden material, this study focuses on chairs that are made of composite beech wood. In Slovakia, beech wood is still an affordable raw material for constructing wooden furniture, and given the tree species composition of the forests in Slovakia, predictions of the market development for this assortment are optimistic [39,40].

Since the critical dimension in chair seat width design is a bi-trochanteric width, the work aims to define the main functional dimensions of a bariatric wooden chair.

## 2. A Brief Analysis of the Design of Wooden Chairs

Modern wooden chairs are complex structures that are made of various auxiliary materials, including engineered wood, metal, plastic elements, coatings, fabrics, foams, and other synthetic materials. Common types of chairs, based on their usage, include school chairs, office chairs, and more or less universal chairs (including dining room chairs, conference room, waiting room, and restaurant chairs). There are used wooden lounge chairs (including armchairs, recliners, sliding, kneeling, and rocking chairs). Chairs may contain mechanisms; for example, a classroom chair could be adjustable or have an attached desktop, which is sometimes movable; garden or dining chairs could be folded. Special-purpose wooden chairs are also used (such as medical, dental, salon, and others). According to the generally accepted classification of furniture, wooden chairs can be divided according to: purpose, functionality, form, structure, technology, and quality [1]. The criterion of functionality was chosen as most valuable item from the user's point of view.

The fundamental question of dimensioning furniture is their well-fitting to the user's body dimensions [41]. In this work, we analyzed selected population dimensions that impact the dimensions of seating furniture. This is a specific set of character types based on knowledge of the expected users' statistical properties of the body dimensions. These are body weight, stature height, buttock–knee length, knee height—sitting with shoes, hip width and hip circumference, and body-mass index (BMI) [42].

In principle, the seat's height should not be considered alone when designing the proper dimensions of a wooden chair. Although this is essential in decision-making, chair height, seat width, and depth are equally important to ensure optimal spinal alignment [43]. The legs should form a 90-degree angle with the floor when sitting. The current recommended dimensions of a wooden chair for the general population are height $h$ = 1150 mm, armrest height $h_r$ = 690 mm, seat height $h_s$ = 490 mm, seat width $w$ = 450 mm, and seat depth $d$ = 470 mm. The cross-sections of the structural elements are for the front and rear legs 25 × 42 mm, front and rear lob, internal partitions 70 × 18 mm, and stilts 25 × 42 mm [44]. Beechwood is mainly used as a construction material.

Chairs for bariatric users are large seating furniture that are designed for sitting and evenly distributed weight. This type of furniture is used in medical facilities. Seating bariatric furniture must allow the user to sit down and get up without any physiological demands. Those requirements result in the need to increase the seating area compared to ordinary seating furniture. Bariatric wooden chairs must include armrests, which ensure more comfortable standing. At the same time, they strengthen the structure. The armrests should have rounded surfaces that allow painless palm support when sitting down and standing up. The load capacity must be sized for the bariatric user. There must be no noticeable structural elements on the upholstered surfaces of the seating furniture, which would cause pain, hematoma, or even injury when sitting for a long time. At the same time, sitting must prevent unwanted compression of the popliteal vessels. For bariatric chairs, a shallow seat is more suitable, which prevents you from falling into the chair and makes it easier to get up. A seat tilted forward is suitable, which makes it easier for the user to sit down and get up. The seat width needs to be greater than that of a standard chair. It is also necessary to be able to slide the legs under the seat when standing up. The material for production can be from grown wood or agglomerated materials [45,46]. The choice of material will affect the product's price [47,48].

## 3. Materials and Methods

Empirical measurements were aimed at measuring selected anthropometric characteristics of the adult population of Slovakia aged 18–25 when body growth ends. At this age, the growth of the epiphyseal plates, responsible for bone growth, stops. The data were collected from 1993 to 2022 on 14,664 Slovak university students. The sample captured the

population of various regions of Slovakia. Such a large research sample justifies recognizing it as representative of the entire country. Measurements were performed with a certified anthropometer. For the measurements of buttock–knee length, knee height—sitting with shoes, hip width, and hip circumference, the analyzed population sample was somewhat lower, as these dimensions were gradually added to the measurements and analysis only in later years. The natural differences in the dimensions of the male and female population make it difficult to determine the universal dimensions of furniture, so it is necessary to accept the dimensions based on percentiles. As it is known, the percentiles indicate the percentage of people within the population with specific size body dimensions. The furniture industry uses the 5th or 95th percentile to offer general-purpose furniture. The decision about which percentile to use in a particular case depends on the applied ergonomic criterion. As part of the results, the arithmetic mean values of the individual observed anthropometric data were calculated as the standard deviation and percentiles.

Data on the bariatric population of Slovakia in healthcare institutions during the years 2020–2022 were collected. The anonymity of the respondents was guaranteed. The analyzed data included age, gender, stature height, body weight, hip circumference, waist circumference, seat width according to the waist, and seat width according to the hips. The BMI coefficient was calculated from the obtained data. Due to the non-confirmation of the dependence of weight on age and gender, these were not evaluated.

## 4. Results

Tables 1 and 2 collect the results of empirical measurements of anthropometric characteristics. Table 1 presents the data of the adult population of Slovakia aged 18–25.

**Table 1.** Descriptive statistics of respondents aged 18–25 in 1993–2022.

| Dimensions | N | Arithmetic Mean | Median | Standard Deviation | Percentiles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1st | 5th | 50th | 95th | 99th |
| Body weight | 14.664 | 73.2 | 72 | 15.67 | 46 | 51 | 72 | 100 | 115 |
| Stature height | 14.664 | 171.9 | 171 | 18.35 | 152 | 157 | 171 | 188 | 195 |
| Buttock–knee length | 3.869 | 57.2 | 58 | 6.98 | 39 | 46 | 58 | 66 | 70 |
| Knee height—sitting with shoes | 1.736 | 44.7 | 45 | 9.26 | 30 | 36 | 45 | 54 | 59 |
| Hip width | 1.303 | 39.9 | 39 | 8.21 | 23 | 31 | 39 | 50 | 63 |
| Hip circumference | 1.055 | 98.1 | 97 | 12.03 | 67 | 81 | 97 | 118 | 130 |
| BMI | 14.664 | 24.9 | 24 | 20.63 | 17 | 18 | 24 | 33 | 38 |

Dimensions are in cm.

**Table 2.** Descriptive statistics of the bariatric population in 2020–2022.

| Dimensions | N | Arithmetic Mean | Median | Standard Deviation | Percentiles | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1st | 5th | 50th | 95th | 99th |
| Body weight | 199 | 142.7 | 138 | 27.2 | 96 | 105 | 138 | 191 | 242 |
| Stature height | 199 | 171.1 | 170 | 9.0 | 150 | 156 | 170 | 187 | 199 |
| Waist circumference | 199 | 136.8 | 135 | 16.4 | 104 | 113 | 135 | 167 | 188 |
| Hip circumference | 199 | 146.0 | 145 | 15.6 | 110 | 120 | 145 | 172 | 192 |
| Seat width according to waist | 199 | 43.6 | 43 | 5.2 | 33 | 36 | 43 | 53 | 60 |
| Seat width according to hips | 199 | 46.5 | 46 | 5.0 | 35 | 38 | 46 | 55 | 61 |
| BMI | 199 | 48.6 | 47 | 7.4 | 36 | 39 | 47 | 61 | 76 |

Dimensions are in cm.

Table 2 summarizes the data of the bariatric subpopulation.

When defining the optimal dimensions of a wooden chair for bariatric patients, we based our definition on the 95th dimension centile of the adult population (buttock–knee length, knee height—sitting with shoes) and on the 95th of the dimensions of bariatric respondents (seat width according to the hips, and seat width according to the waist). Based on the obtained data from bariatric respondents, we derived the width dimensions for wooden chairs (Table 3). For the sake of comfortable sitting and standing, we added an excess of 12 cm (6 cm on both sides) to the obtained dimensions of the bariatric respondents' seat width. The recommended width of the wooden chair for the 95th percentile of the bariatric population is highlighted in bold. We accept the height and depth of the seat according to the currently valid standards for furniture production [44].

**Table 3.** Recommended dimensions of a wooden chair for bariatric users.

| Parameter | Recommended Values for Centiles | | | | |
|---|---|---|---|---|---|
| | 1st | 5th | 50th | 95th | 99th |
| Seat height | 49 | 49 | 49 | 49 | 49 |
| Seat width | 47 | 50 | 58 | 67 | 73 |
| Seat depth | 47 | 47 | 47 | 47 | 47 |

Dimensions are in cm.

## 5. Discussion

The Association of Business and Institutional Furniture Manufacturers (BIFMA) has proposed the ANSI/BIFMA X5.41-2021 standard for seating furniture in public places for bariatric users. This standard describes two levels of chair strength: X5.41-400 and X5.41-600. 181.4 kg load capacity is the base chair, and 272.2 kg load capacity is an auxiliary chair. Chair manufacturers in the USA must clearly state which performance levels apply to the product they offer.

It is worth mentioning that a common standard for school seating furniture, EN 1729:2015 [49], gives too small widths (for stature range = 2070 mm, the seat width = 400 mm). Lawson reported wider standard seat widths, but they are also too small for bariatric users (because they are based on the "normal" population in the 5–95 percentile range). The problem of the increased weight and body size of seating furniture users

has been noticed in scientific and engineering literature. The various chair dimensions for bariatric users are recommended; for example, the recommended seat width includes a 55.9–70.0 cm range. Kasal [48] reported a width of 70 cm, while the ANSI/BIFMA X5.41-2021, Large Occupant Public and Lounge Seating [50] and ANSI/BIFMA X5.11-2015 (R2020) [51] Large Occupant Office Chair [52], for the 99th centile, postulated the minimum seat width for the 400 lb user be 22 inches (55.9 cm), whereas the minimum seat width for the 600 lb user is 26 inches (66.0 cm). The results of our research indicate a different range of recommended seat widths. Depending on the 95th or 99th percentile, this range should be within 67–73 cm.

There are fundamental issues about sitting comfort that must be addressed in research, including the effects of body size, the sensitivity to changes in adjustability parameters, and the capability to sense and express comfort and discomfort. Helander et al. [50] found that people of small body sizes dislike oversized chairs because the seat depth is too long and the lumbar support of the backrest is too high. On the other hand, large-size individuals dislike small chairs because the seat is too short and narrow, and the lumbar support is too low [52].

Anjani et al. [53] compared the seating comfort of 17 and 18 inch wide airplane seats (432 and 457 mm). They found that comfort was higher and discomfort was lower while sitting in wider seats, regardless of the user's hip width. The authors concluded that increasing the width of the seat provides more room for movement and reduces overall discomfort. This highlights the importance of the freedom movement opportunity during sitting in a chair. This conclusion indicates that seat width is a crucial parameter of the chair. According to the cited authors, widening the seat is more effective in terms of comfort than increasing the inclination of the backrest; this discovery could help the aerospace industry use space more efficiently.

Bahrampour et al. [54] obtained the buttock–knee length (BKL) based on a sample of 194 university students (120 females and 74 males). The 5th percentile value of the BPL was 402 mm. The authors stated that the seat depth equal to the 5th percentile' BKL caused the lowest discomfort after 90 min of sitting compared to other tested seat depths.

A system for the design of customized ergonomic furniture (chairs, beds, kitchen interiors etc.) using anthropometric dimensions or other specific needs influenced increasing demand from customers to manufacturers. This trend is related to customization and has increased in the wood products industry and gives consumers more product choices (including material use) like tables, doors, closets, timber windows, etc. An example could be a product where consumers can choose the wood species, finish, and hardwood that will be applied to a given design [55,56].

## 6. Conclusions

When applying the anthropometric method of examining human dimensions, it must be remembered that the human organism develops naturally depending on the external environment. A complex of factors and several organic regularities apply to individual development. A secular trend has been observed for body height over the years. A higher average weight reflects the state of an aging organism, in which muscle mass decreases with age and the fat component increases. When monitoring changes in human morphology, the most significant changes must be considered, such as heredity, growth patterns, puberty, sexual differentiation, dependence on form and functions, variability, correlation, compensation, elasticity, reactions, and adaptation. The digital revolution, and the associated technological and scientific progress have caused a change in the type of reproduction from extensive to intensive. A high mortality and birth rate characterized the extensive type. A low birth rate characterizes the intensive type, and the population lives to increasingly old age.

In our work, we proposed the dimensions of chairs for Slovak bariatric respondents, which are currently not defined. Due to the worldwide increase in population weight, the

issue of furniture creation is highly relevant and necessary. Sooner or later, the mentioned problem will have to be addressed on a societal level.

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