Impact of Anthropometric Secular Trends (1980–2025) on the Dimensional and Structural Requirements of Wooden Beds

Miloš Hitka,[a] Miloš Gejdoš,[b,c] Miluše Balková,[d] Milan Naď,[e] Tomáš Gergeľ,[c] and Maciej Sydor,[f,*]

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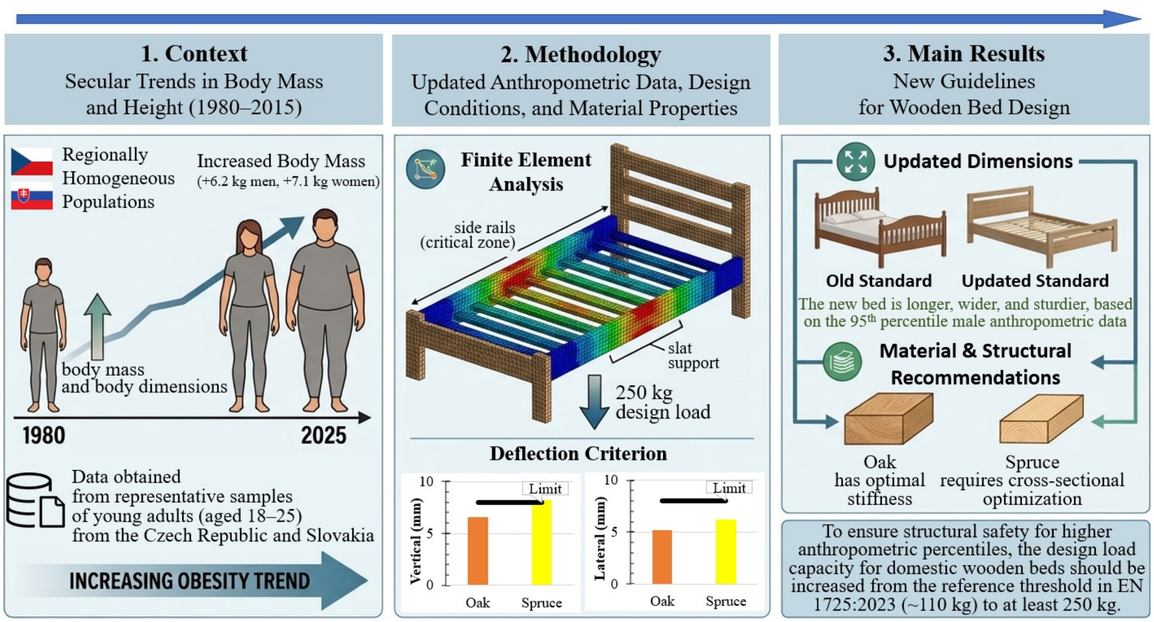
GRAPHICAL ABSTRACT



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Long-term anthropometric changes (1980 to 2025) of young adults (aged 18 to 25) were evaluated in the Czech Republic and Slovakia to inform the design of wooden beds. Both populations exhibited identical anthropometric parameters and secular trends: mean body mass increased by 6.2 kg (~1.4 kg/decade) in men and 7.1 kg (~1.6 kg/decade) in women. To address these changes, updated single-bed dimensions are proposed, extending the bed length from 200 cm to a minimum of 220 cm (recommended: 240 cm) and increasing the width from 90 cm to a minimum of 100 cm (recommended: 141 cm). A 3D finite-element (FE) model evaluated structural performance under a design load of 250 kg, which surpasses the reference single-user body mass (~110 kg) specified in EN 1725:2023. The analysis identified the side rails as the most critical structural components. Stiffness was verified against the Eurocode 5 (EN 1995-1-1) L/300 criterion (an 8.0 mm limit for a 2400 mm span). Maximum vertical deflections (6.2 mm for oak and 8.2 mm for spruce) and lateral deflections (5.2 mm and 6.8 mm, respectively) demonstrated that oak satisfies the stiffness requirements, whereas spruce marginally exceeds the allowable deformation limit. The findings confirm that current furniture design standards fail to align with the anthropometric realities and require updates.

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Keywords: Wood engineering; Wooden bed frames; Finite element analysis (FEA); Eurocode 5; Anthropometry; Furniture design standards; Structural optimization

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INTRODUCTION

Temporal changes in the biological characteristics of human populations are referred to in scientific literature as secular trends (Boas 1912). These trends are primarily reflected in an increase in mean body height and a more rapid rise in body mass than in linear growth (Tanner 1981). The secular increase in stature is mainly attributed to improvements in nutritional quality, advances in medical care and public health, better socioeconomic and hygienic living conditions, and the effects of heterosis, understood as hybrid vigor resulting from population admixture (Wolański 1984; Cole 2003). While the increase in average human height reflects a positive trend driven by improved health, the contemporary secular trend in body weight poses a significant social challenge (Cardoso and Caninas 2010). BMI increases are heavily influenced by excessive caloric intake of highly processed foods and by hypodynamia, characterized by reduced physical activity in favor of a sedentary lifestyle (Stubbs and Lee 2004).

The Body Mass Index (BMI), developed by Adolphe Quetelet in 1832 and later popularized in population-based studies by Keys *et al.* (1972), serves as a tool for assessing the proportionality of body mass gain. Despite its well-documented limitations, particularly in individuals with high muscularity (Keys *et al.* 1972), BMI is widely recognized as an effective metric in population studies of overweight and obesity, including those conducted within the ergonomics framework (Sweatt *et al.* 2024). This measure is complemented by the waist-to-hip ratio (WHR), which is utilized in medicine and anthropometry to evaluate fat distribution and identify body shape patterns (WHO 2008). While indices based on direct body composition assessment – such as body fat percentage (BF%) and the fat-free mass index (FFMI) – provide more detailed metabolic insights, their application in industrial ergonomics is constrained by greater measurement complexity. Consequently, BMI remains the predominant metric used in this field (Gažarová *et al.* 2022).

These secular population dynamics provide a foundation for applied engineering anthropology. Aligning furniture dimensions with ongoing secular trends requires up-to-date anthropometric data to ensure functionality without excessive material consumption. Conversely, furniture manufactured according to outdated standards, dating back 30 to 40 years, exhibits insufficient structural integrity, inadequate clearances, or overly constrained lateral dimensions relative to the physical requirements of current populations (Woo *et al.* 2016; Pérez-Gosende 2019; Gejdoš and Hitka 2022).

In the context of the secular trend, furniture can be categorized into two distinct groups: trend-insensitive and trend-sensitive. The group of furniture that is insensitive to the secular trend primarily comprises storage units, such as cabinets, shelving units, and chests of drawers. Because these products do not maintain constant, direct contact with the user's body, somatic changes are secondary to their primary utility. Minor fluctuations in average height (2 to 3 cm) or body weight do not significantly alter their design assumptions, which are instead determined by available spatial layout, aesthetics, and storage volume. The impact of the secular trend in this category is limited strictly to the ergonomics of reach zones: while increased body height facilitates easier access to upper shelves, a significant increase in body mass can make utilizing low-positioned compartments uncomfortable, as it requires deeper trunk flexion.

Conversely, trend-sensitive (or body-support) furniture includes products in direct, prolonged contact with the user's body, such as seating, beds, tables, and desks. Within this category, the secular trend directly necessitates adjustments to both functional dimensions and load-bearing parameters. Seating furniture exhibits the highest sensitivity; increases in the population's transverse dimensions and average weight require wider seat pans and enhanced structural strength. Similarly, standard single-bed dimensions – typically 200 cm long by 90 cm wide in Europe, and 191 cm long by 99 cm wide in the United States – are increasingly insufficient for younger generations with larger body builds. These anthropometric shifts also extend to workstations, where taller users require expanded clearance for the lower limbs and higher working surfaces. At 75 cm, standard desk heights do not match Generation Z's body measurements, leading to poor posture. A particularly critical issue is the insufficient load-bearing capacity of standard chairs (frequently limited to 120 kg) and beds (up to 150 kg), which fail to accommodate modern weight distributions (Hitka *et al.* 2024). Translating this anthropometric change into design practice, however, requires more than an enlarged dimensional envelope: the product's load-bearing system must be re-verified, because the mechanical response of a furniture frame does not scale linearly with the mass of its user.

From a mechanical standpoint, a wooden bed is a frame structure whose reliability depends less on the strength of the individual members than on the interaction between the side rails, the slat-support system, and the corner connections (Eckelman 2003; Smardzewski 2015). Since the pioneering finite-element (FE) studies of wooden furniture frames (Gustafsson 1995, 1997), numerical simulation has progressively replaced – or at least rationalized – costly destructive performance testing, and it is now routinely used to predict the rigidity, the stress distribution, and the failure modes of frame-type furniture with acceptable accuracy (Smardzewski 1998; Kasal 2006). Analyses carried out for whole bed frames under the loading schemes of EN 1725:2023 have consistently identified the side rails as the most heavily stressed components. When a user sits on the edge of the bed, the load is transmitted through the mattress and the slats as an eccentric action that produces simultaneous vertical deflection and lateral (outward) displacement of the rail; the latter is a frequent precursor of slat disengagement and sudden collapse (Réh *et al.* 2019; Hitka *et al.* 2022; Matwiej *et al.* 2025). For a user of 150 kg, the stresses in a spruce support beam of conventional cross-section exceed the design strength determined according to EN 1995-1-1:2004 (Eurocode 5) by 60 to 75%, so that a change of cross-section, a change of material (*e.g.*, beech instead of spruce), or an additional central support becomes unavoidable, whereas the side board of a conventional 2000-mm-long bed still remained within the allowable stresses (Réh *et al.* 2019). Because the relevant furniture standards specify no explicit deformation limits, serviceability is usually verified against the L/300 deflection criterion adopted from EN 1995-1-1:2004; under such a criterion the modulus of elasticity of the timber, and not its strength, becomes the governing design parameter, and the shear stresses concentrated at the slat-support interface and at the rail-to-post connection must additionally be checked against the design shear strength of the material (İmirzi *et al.* 2015; EN 338:2016; Hitka *et al.* 2024).

The corner joints that connect the side rails to the headboard and footboard are equally critical because service failures in frame furniture originate predominantly in the connections rather than in the members themselves (Eckelman 1988, 2003). Several decades of experimental work have produced quantitative design data on the bending moment capacity (BMC) and the rotational stiffness of furniture joints: of rectangular (Erdil *et al.* 2005; Eckelman *et al.* 2016) and L-shaped mortise-and-tenon joints under compression and tension (Likos *et al.* 2012; Kasal *et al.* 2015), of joints reinforced with glued corner blocks (Kasal 2006), of doweled frame joints loaded in shear (Kasal 2008), and of demountable, screw-fastened corner joints typical of ready-to-assemble beds (Simek *et al.* 2010). These studies consistently demonstrate that joint performance is governed by wood species and density, tenon geometry and grain orientation, the presence of shoulders, adhesive type, and fastener spacing, and that joints behave as semi-rigid elements whose substitute (equivalent) stiffness has to be introduced explicitly into the numerical model of the whole structure; otherwise the predicted deflections are underestimated (Smardzewski *et al.* 2014; İmirzi *et al.* 2015). For users with above-average body weight, the required joint capacity increases disproportionately: for a 150-kg user, the cross-sections of the leg frame and of the side rail of seating furniture had to be enlarged by 20% and 25%, respectively, to maintain an acceptable degree of safety (Hitka *et al.* 2018). Verification of such requirements relies on the standardized test methods of EN 1725:2023 and ISO 19833:2018; however, both documents calibrate their recommended loads to a reference user mass of approximately 110 to 120 kg and – like the furniture standards in general – prescribe no explicit serviceability limits for deformation.

Furniture sensitive to secular trends should incorporate current anthropometric data to accommodate changing population dimensions and support ergonomic comfort (Hitka et al. 2022). Unfortunately, the availability of ergonomic, aesthetically pleasing solutions for exceptionally tall or overweight individuals remains limited, leading to discomfort in both public and private spaces (Siu 2005; Daniel 2024). The literature reviewed above also reveals three persistent gaps. First, structural analyses of beds have been performed almost exclusively for the traditional 200 cm × 90 cm geometry and for design loads of 110 to 150 kg, *i.e.*, for the late-twentieth-century population (Réh *et al.* 2019; Hitka *et al.* 2022; Matwiej *et al.* 2025). Second, the effect of the slat support position on the lateral deformation and stress state of the side rail has not been quantified for the extended bed lengths and widths required by contemporary users. Third, no study has coupled long-term secular trend data with a frame-level FE verification conducted under a design load corresponding to the upper percentiles of present-day body mass. A common misconception is that high-strength furniture requires massive, specialized construction, supposedly preventing mass-produced, aesthetically pleasing, and cost-effective manufacturing (Bai *et al.* 2024). This view stems from a traditional association of durability with high material volume and expensive resources. In reality, modern materials science and advanced structural optimization allow for the design of lightweight, affordable products. These solutions can maintain an attractive design while still meeting rigorous standards for load-bearing capacity and durability (Jasińska *et al.* 2024; Nawi and Yusof 2024).

The close economic cooperation and cultural-historical proximity between the Czech Republic and the Slovak Republic justify a comparative analysis of the physical development of their inhabitants, specifically tailored to the requirements of the furniture industry. Specifically, this study aims to: (1) quantify the secular trends in body dimensions among Czech and Slovak young adults to assess the rate of morphological change; (2) perform a comparative statistical analysis to verify if population homogeneity justifies unified furniture standards across both nations; and (3) establish evidence-based recommendations for single-bed dimensions and strength requirements, verified by finite-element analysis of the bed frame under a design load representative of the upper percentiles of contemporary body mass.

EXPERIMENTAL

Empirical measurements of selected anthropometric characteristics of the population in the Czech Republic and the Slovak Republic were conducted in 1980 and 1985 during the Czechoslovak Spartakiads. The sampling cohort consisted of 1,115 men and 1,010 women in 1980, and 1,593 men and 1,725 women in 1985. Subsequently, measurements were carried out between 2007 and 2009 on a sample comprising 93 men and 119 women from the Czech Republic, as well as respondents aged 18 to 25 years from across the Slovak Republic (85 men and 65 women). Additional measurements were performed in 2023 to 2025, involving 522 women and 822 men from the Slovak Republic and 134 men and 173 women from the Czech Republic (Table 1).

Table 1. Description of the Research Sample

Year	Czech Republic		Slovak Republic	
	Men	Women	Men	Women
1980	678	642	437	368
1985	1,142	1,291	451	434
2007-2009	93	119	85	65
2023-2025	134	173	822	522

The 18 to 25 age group was selected because it represents full skeletal maturity while minimizing age-related body composition changes (sarcopenia, compression fractures) that do not reflect genetic-environmental trends.

The measured sample data were described using standard measures of central tendency and variability – arithmetic means ($\bar{x}$) and standard deviations (s_x) – which characterize the magnitude and dispersion of the individual measured values. For both characteristics of each observed trait, relative differences (*dif%*) were calculated according to Eqs. 1 and 2,

$$dif\%_{\bar{x}} = \frac{\bar{x}_1 - \bar{x}_2}{\frac{\bar{x}_1 + \bar{x}_2}{2}} \tag{1}$$

$$dif\%_{s_x} = \frac{s_{x1} - s_{x2}}{\frac{s_{x1} + s_{x2}}{2}} \tag{2}$$

where $\bar{x}_1$ and $\bar{x}_2$ represent the sample arithmetic means, while s_{x1} and s_{x2} denote the sample standard deviations of the first (Czech) and second (Slovak) populations, respectively.

In addition to a simple comparison of descriptive statistics, the study tested the equivalence of the arithmetic means and standard deviations of selected traits for the two populations examined – the Czech and Slovak – given the sample-based nature of the measured data.

The purpose of these tests was to determine the statistical significance of differences in the sample arithmetic means and standard deviations of the anthropometric traits under consideration, ensuring that, at a chosen significance level α, the observed differences in descriptive statistics could not be attributed solely to sampling error.

When assessing the equivalence of arithmetic means between the two populations, the null hypothesis H_0: $\mu_1 = \mu_2$ was tested, stating that the mean values of the anthropometric traits in the Czech and Slovak populations are equal. Testing the equality of means, assuming independent samples and unequal variances in the underlying populations, was carried out using the classical test statistic given by Eq. 3,

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_{\bar{x}_1}^2}{n_1} + \frac{s_{\bar{x}_1}^2}{n_2}}} \tag{3}$$

which is compared with the critical value of Student's t-distribution, $t_{\alpha/2(f)}$, with $f = n_1 + n_2 - 2$ degrees of freedom, where n_1 and n_2 represent the sample sizes of the first and second populations, respectively. The null hypothesis H_0: $\mu_1 = \mu_2$ is accepted at the chosen significance level α if $|t| \leq t_{\alpha/2(f)}$and, conversely, is rejected if $|t| > t_{\alpha/2(f)}$. If the null hypothesis is not rejected, it can be concluded that the difference between the sample means $\bar{x}_1 - \bar{x}_2$ is small enough to be attributed solely to sampling variability. Conversely, if H_0 is rejected, then at the chosen significance level, it is inferred that the difference in sample means $\bar{x}_1 - \bar{x}_2$ is too significant to be explained exclusively by sampling error.

Similarly, the null hypothesis H_0 that the standard deviations (or variances) of the measured traits are equal across the two populations can be tested. This test is based on the sample variances s_1^2 s_2^2 and employs Fisher's F-distribution. The test statistic F is computed as the ratio defined in Eq. 4.

$$F = \frac{s_1^2}{s_2^2} \quad (4)$$

To simplify result interpretation, the larger of the two sample variances is conventionally assigned to the numerator of the *F* test statistic. Therefore, the indices 1 and 2 accompanying the symbol s^2 serve purely notation-based purposes. The conclusion of the test is then drawn by comparing the calculated value of the *F* statistic with the critical value of the F-distribution, $F_{1-\alpha/2(f_1,f_2)}$corresponding to the two degrees of freedom $f_1 = n_1 - 1$ a $f_2 = n_2 - 1$. The null hypothesis H_0: $\delta_1^2 = \delta_2^2$ regarding the equality of variability of the anthropometric trait in the Slovak and Czech populations is rejected if $F > F_{1-\alpha/2(f_1,f_2)}$.

RESULTS AND DISCUSSION

Secular Trend in the Czech Republic and the Slovak Republic

A comparative analysis of secular trends from 1980 to 2025 reveals insufficient evidence of systematic anthropometric differences between men in the Czech Republic and the Slovak Republic. As detailed in Table 2, the statistical comparison demonstrates that these variations were not significant.

Table 2. Statistical Comparison of Anthropometric Parameters between Czech and Slovak Men

Variable	*t*-statistic	*p*-value
Body height	−0.867	0.477
Body mass	−0.508	0.662
BMI	0.491	0.672

It should be emphasized that conclusions regarding regional population homogeneity are based strictly on the inferential statistical testing of sample means and variances (Tables 2 and 3), whereas the graphical trend lines serve primarily as visual representations of long-term population dynamics. This high degree of population homogeneity, as confirmed by the statistical tests in Table 2, is visually illustrated by the corresponding trend lines showing similar temporal trends for male body height (Fig. 1), male body mass (Fig. 2), and male BMI (Fig. 3). Figure 1 demonstrates a curvilinear trajectory of male height, with rapid increases between 1980 and 2007 (+2.8 cm) followed by deceleration in 2007–2025 (+1.0 cm), consistent with the approach to genetic height potential. The Slovak trend line (orange) shows a slightly steeper slope after 2007, though this difference remains statistically non-significant (p = 0.477).

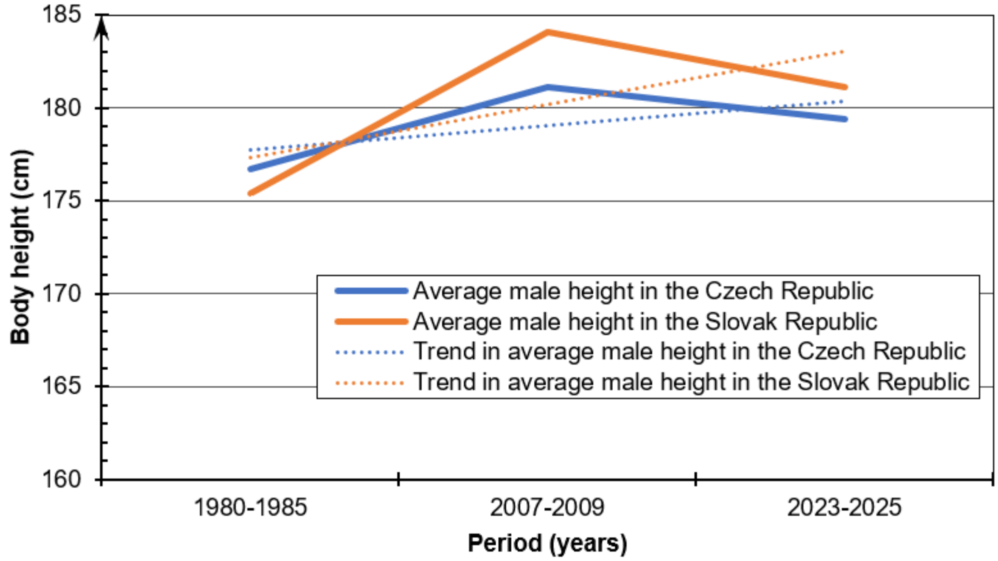

Fig. 1. Secular trend of male body height (1980–2025)

Figure 2 reveals a near-linear increase in male body mass across all measurement periods, with no evidence of a plateau. The comparable secular trajectories of Czech (blue) and Slovak (orange) trends visually illustrate the shared demographic pattern, while the consistent upward slope indicates ongoing weight gain despite height stabilization—a hallmark of the obesity transition (Ng and Popkin 2012).

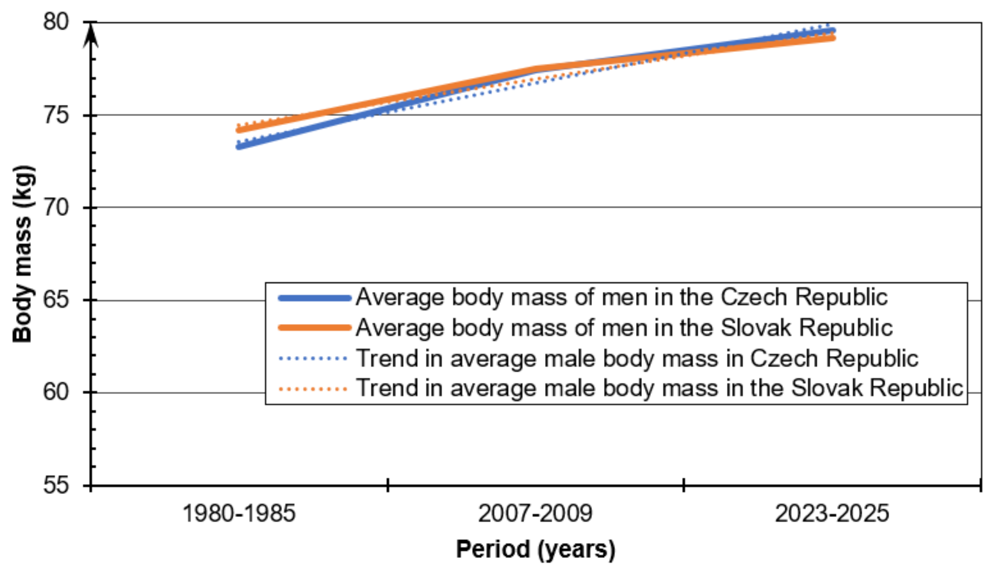

Fig. 2. Secular trend of male body mass (1980–2025)

Similar consistency was observed in the female populations, as summarized in Table 3. The statistical data indicate no significant differences in female body height (Fig. 4) or female body mass (Fig. 5) between the two countries. However, while the difference in female BMI (Fig. 6) remained statistically non-significant, the p-values for body mass and BMI approached the significance threshold, suggesting a possible emerging trend that warrants close monitoring in future studies.

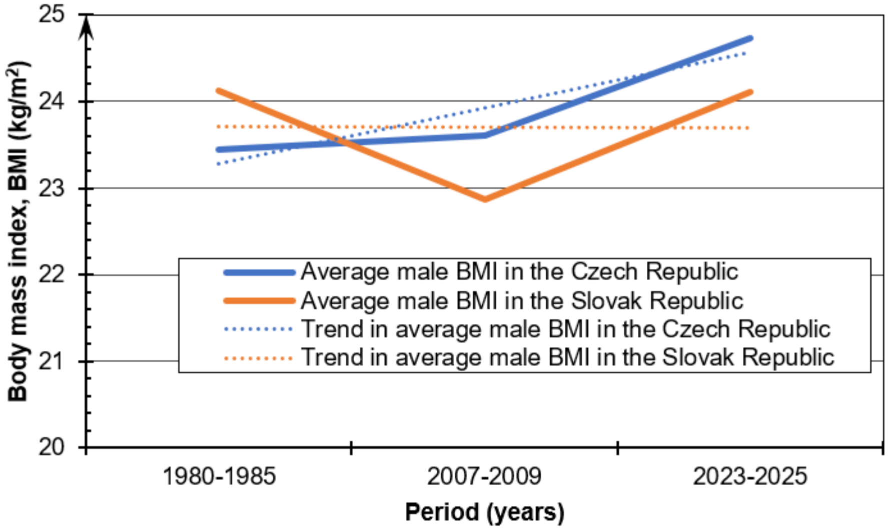

Fig. 3. Secular trend of male BMI (1980–2025)

Table 3. Statistical Comparison of Anthropometric Parameters between Czech and Slovak Women

Variable	*t*-statistic	*p*-value
Body height	0.269	0.813
Body mass	2.940	0.099
BMI	2.472	0.132

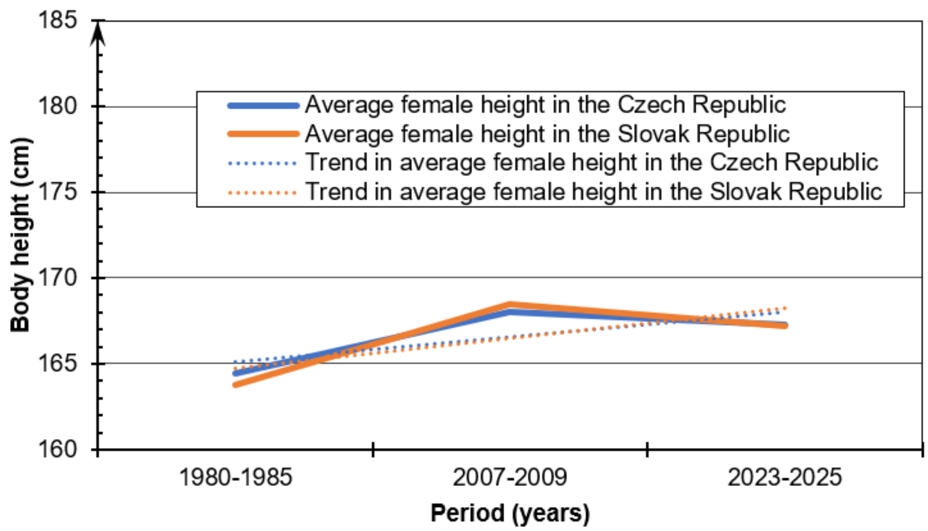

Fig. 4. Secular trend of female body height (1980–2025)

Figure 5 shows the steepest secular trend among all measured parameters: female body mass increased continuously from 59.2 kg (1980) to 66.3 kg (2023–2025), with the Czech population (blue line) exhibiting marginally higher values in recent cohorts, reflected in the borderline-significant p-value (p = 0.099, Table 3).

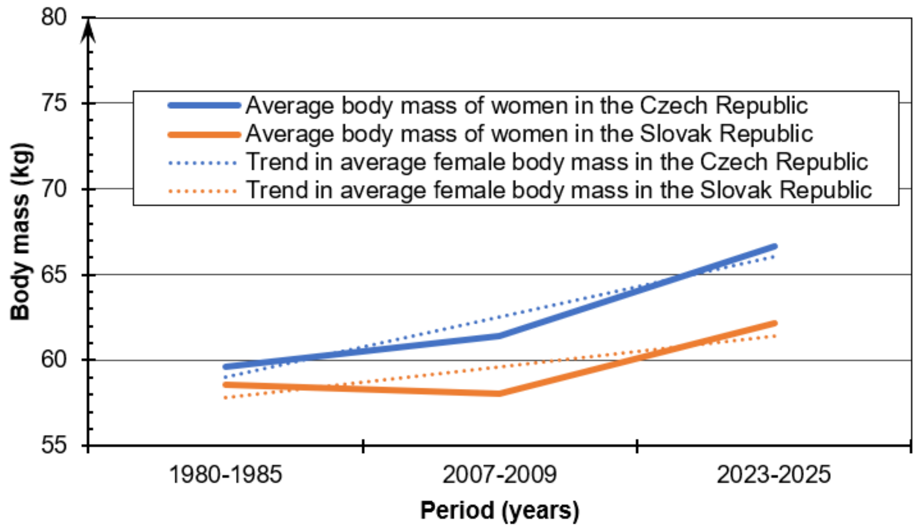

Fig. 5. Secular trend of female body mass (1980–2025)

Figure 6 illustrates a concerning epidemiological pattern: the female BMI trend line shifts from the low-normal range (22.0 kg/m² in 1980) toward the population mean (23.6 kg/m² in 2023–2025), approaching the threshold at which obesity prevalence begins to accelerate (WHO, 2000). The divergence between the Czech (blue) and Slovak (orange) lines after 2007 warrants monitoring in future studies.

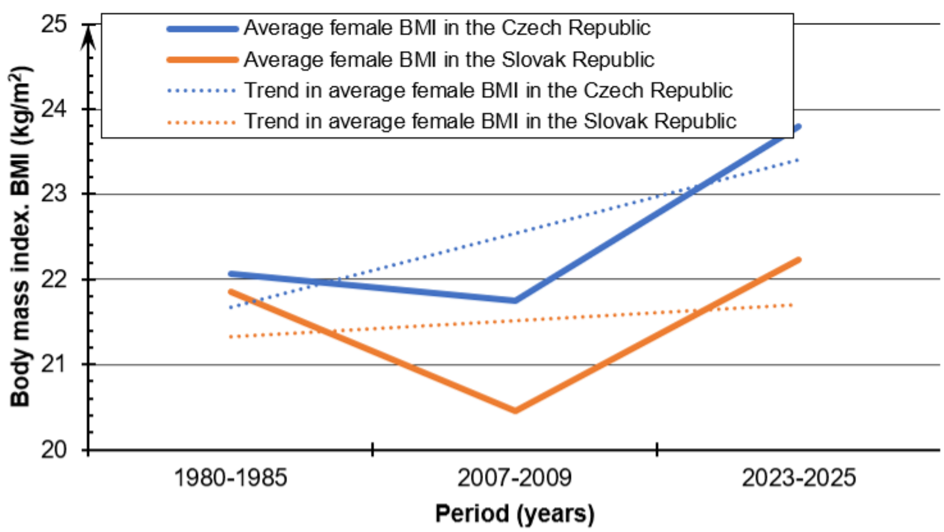

Fig. 6. Secular trend of female BMI (1980–2025)

Over the 45-year observation period, quantitative analysis revealed that changes in body mass have substantially exceeded changes in stature. Male body mass increased significantly by 6.2 kg (an 8.5% increase, equating to a linear trend of +1.4 kg per decade). Female body mass exhibited an even more pronounced shift, increasing by 7.1 kg (12.0%, or +1.6 kg per decade). In contrast, the increase in body height was much more modest: male stature rose by 3.8 cm, while female stature increased by 3.2 cm. This differential rate of change—rapid weight gain coupled with slow height growth—resulted in a net increase in BMI of 1.2 kg/m^2 for men and 1.6 kg/m^2 for women. Consequently, the population mean has shifted dangerously close to the WHO-defined overweight threshold (BMI ≥ 25 kg/m^2)

(WHO 2000). Ultimately, the longitudinal data from these 45 years indicate substantial shifts in the somatic profiles of the studied populations. While stature appears to plateau—particularly in the most recent cohorts—body weight and BMI continue to rise, with no evidence of stabilization. These divergent trends provide a compelling argument for revising current furniture strength and load-bearing standards to better accommodate modern users.

When comparing t-statistics and p-values for men and women from the Czech Republic and the Slovak Republic across height, weight, and BMI (Fig. 7), it can be concluded that higher t-statistics indicate larger differences between the groups. In contrast, p-values below 0.05 indicate statistical significance. For both men and women, the differences between the Czech Republic and the Slovak Republic are not statistically significant ($p > 0.05$), meaning that height does not differ notably between the two countries.

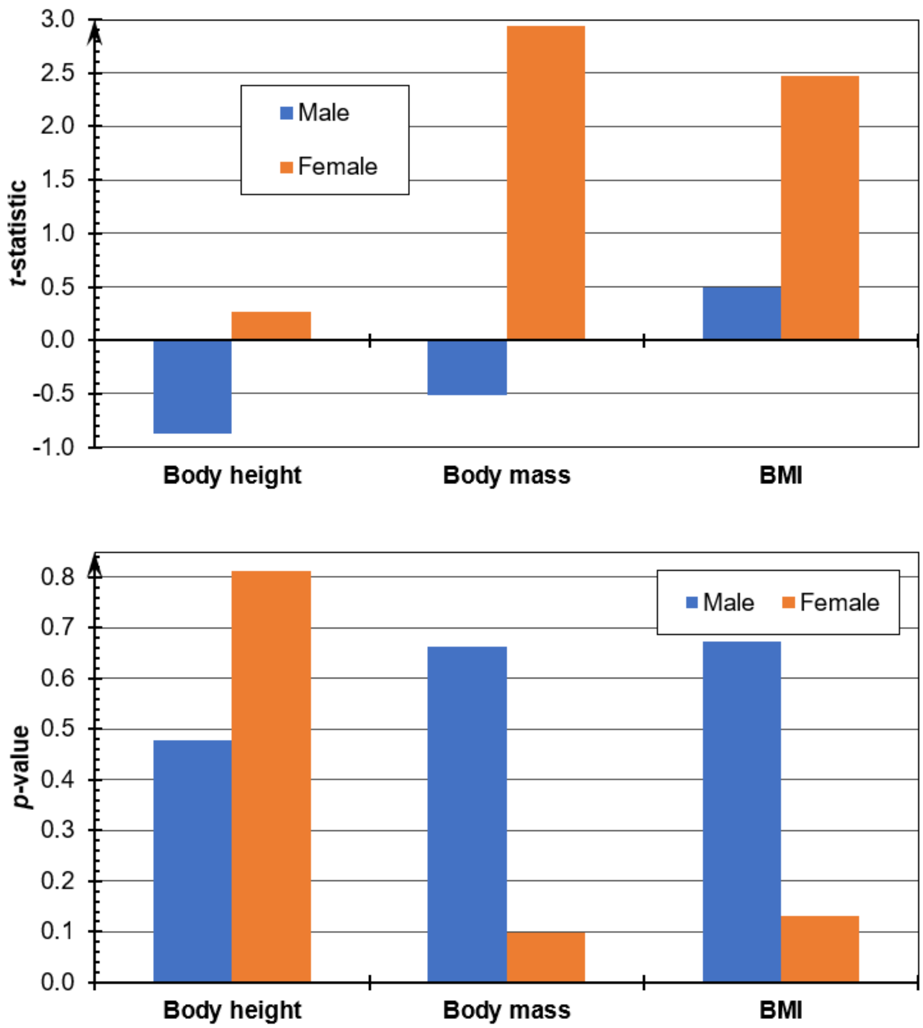

Fig. 7. Comparative graph of t-statistics and p-values for height, weight, and BMI among men and women from the Czech Republic and Slovakia

For body weight, the difference among men was not statistically significant. Among women, the difference was close to the significance threshold ($p = 0.099$), suggesting a mild trend toward higher weight among Czech women than among Slovak women. For BMI, the difference among men was not statistically significant, while among women it was again close to the significance boundary ($p = 0.132$), likely reflecting the trend observed in weight combined with comparable height.

Overall, it can be concluded that, among adult male and female populations in the Czech Republic and the Slovak Republic, no statistically significant differences were found for any of the variables analyzed. However, among women, a slight trend toward higher body weight and BMI was observed in the Czech population, though these differences did not reach statistical significance (Fig. 7).

Strength Characteristics of Single Beds Depending on Dimensional Parameters

Based on the secular trend in the Czech and Slovak populations, a positive trend was evident in both sexes. Since increases in body height and body weight are closely related to the strength characteristics of furniture's structural elements and joints, the following section defines a computational model of single-bed strength.

The overall dimensions of a single bed – length (L_p), width (B_p), and sleeping surface height (H_p) – must accommodate the user's body while ensuring the required structural rigidity and load-bearing capacity. The bed length (L_p), combined with the section modulus and the mechanical properties of the selected timber species, directly determines the overall strength performance of the bed frame. Following the methodology of Hitka *et al.* (2022), the recommended spatial requirements presented in Table 4 are derived from the 95th percentile male standing height, with bed width parameters specifically adapted for individuals with higher BMI, while Table 5 outlines specific dimensional adjustments for users with higher BMI, with the width parameter significantly expanded to ensure safety and comfort.

Table 4. Recommended Dimensional Parameters of Single Beds according to Room Size

	95th Percentile Body Height Value Used	**Recommended Value**
Length (L_p)	Small space	220 cm
	Medium space	230 cm
	Large space	240 cm
Width (B_p)	For all lengths	141 cm
Height (H_{p1})	For all lengths	66 cm

Source: (Hitka *et al.* 2022)

Table 5. Recommended Length and Width Dimensions of Single Beds for Users with Higher BMI

Bed length (cm)	**Bed width (cm)**	**Bed width (cm)**	**Bed width (cm)**
200	100	120	141
220			
240			

Source: own research and (Hitka *et al.* 2022)

The dimensional matrix in Table 5 reflects the need for modular design approaches that accommodate the spectrum of contemporary body sizes. The standard width (100 cm) corresponds to traditional European single-bed dimensions, while the extended width (120 cm) addresses users at the 75th to 90th percentile for body mass. The largest width (141 cm) is calculated based on the 95th-percentile male biacromial breadth (47 cm), with bilateral clearance allowances, consistent with recommendations in ISO 7250-1:2017 and empirical studies of turning space requirements for high-BMI individuals (Wiggermann *et al.* 2017). The constant sleeping surface height (H_p = 66 cm) is derived from the mean knee height of users aged 18 to 65 to facilitate safe transfers, particularly for bariatric users with reduced mobility (Hignett and Lu 2010).

Computational Model of a Single Bed and Strength Analysis Results

The design of furniture intended for people with higher BMI must account for their anthropometric parameters. This mainly concerns their body size, but significant attention must also be paid to their weight, which can exceed that of the standard population. A typical single-bed design with slats supported by a frame in the middle of the bed is shown in Fig. 8a.

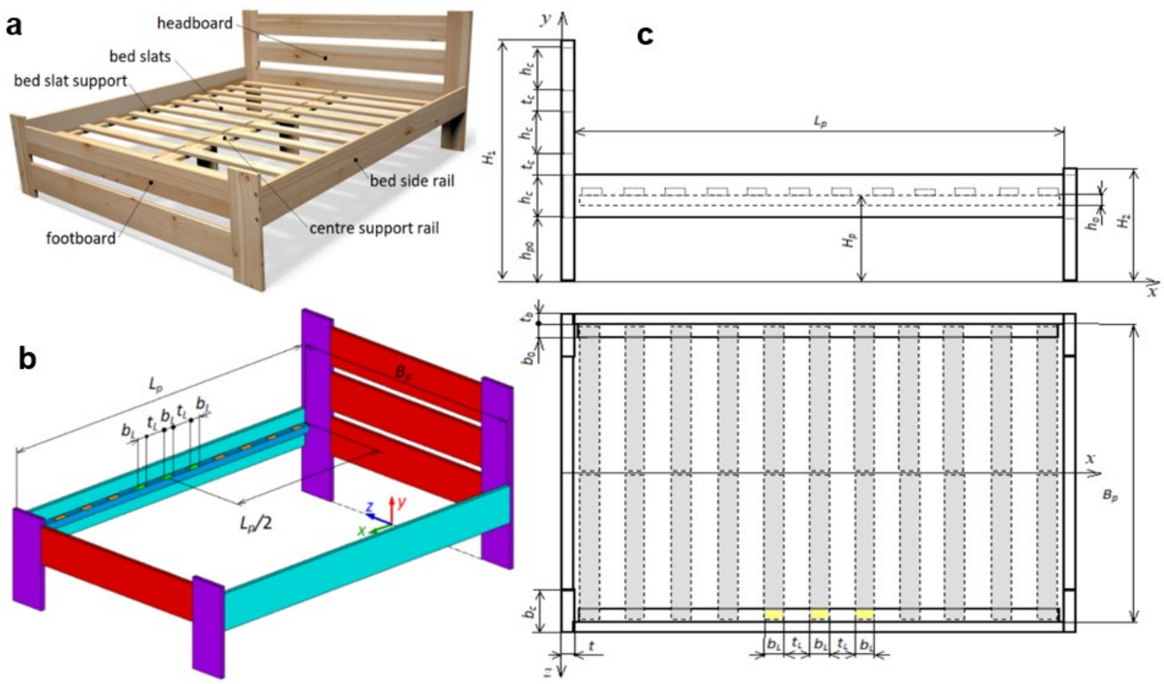

Fig. 8. Typical single-bed design: a – overall view; b – FEM model; c – dimensioned technical drawing

Table 6. Main Overall and Functional Dimensions of a Single Bed

Parameter Name	Designation	Unit	Values		
Length of a single bed (Fig. 8c)	L_p	(mm)	2000	2200	2400
Width of a single bed (Fig. 8c)	B_p	(mm)	1000	1200	1410
Bed slat support – dimensions of cross-section (Fig. 9)	$b_0 \times h_0$	(mm)	40 × 40		
Position of slats support – h_{op} (Fig. 9)	$\langle h_{op,min} ; h_{op,max} \rangle$	(mm)	$\langle 10 + h_0 ; h_{bsr} - 10 \rangle$		
Design body mass for higher-BMI users	m_b	(kg)	250		

Based on: (Hitka *et al.* 2022)

The components critical to bed strength, classified by mechanical properties, are represented by colors, as shown in Fig. 8b. The dimensional model of the bed structure is shown in Fig. 8c, and its basic dimensions are given in Table 6.

As depicted in Table 6, L_p represents the length of the single bed, B_p denotes the width of the single bed, $b_0 \times h_0$ indicates the cross-sectional dimensions of the slat support (ledger strip), h_{bsr} corresponds to the height of the bedside rail (h_{bsr} is illustrated on Fig. 9), hop specifies the vertical position of the slat support relative to the bottom edge of the bedside rail, and mb defines the design body mass for higher-BMI users. Furthermore, the allowable vertical range for positioning the slat support along the bedside rail height (h_{bsr}) is defined by the interval $\langle h_{op,min} ; h_{op,max} \rangle = \langle 10 + h_0 ; h_{bsr} - 10 \rangle$ to ensure structural safety and assembly feasibility. Specifically, the lower bound $h_{op,min} = 10 + h_0$ ensures a minimum edge distance of 10 mm from the bottom edge of the side rail to the bottom edge of the slat support (where h_0 is the height of the support itself) to avoid wood splitting or stress concentrations near the edge, whereas the upper bound $h_{op,max} = h_{bsr} - 10$ ensures that the top edge of the slat support stays at least 10 mm below the top edge of the side rail, preventing the mattress or slats from sliding off while maintaining overall structural integrity.

The 250 kg design load was selected to accommodate: (a) a single user at the 99.9th percentile for body mass (≈150 kg), (b) mattress weight (≈10 kg), (c) a safety factor of 1.5, and (d) potential dynamic loading scenarios. It should be noted that the value of 250 kg used in this study does not represent the static mass of an individual user, but the total equivalent design load (F_{design}) applied to evaluate the structural margin of safety. While the secular trend data (Figs. 2 and 5) establish the maximum anticipated user body mass (m_b), the selection of a 250 kg design load complies with standard bariatric furniture testing guidelines and accounts for a structural safety factor ($k \approx 1.5$ to 2.0) combined with dynamic impact effects (*e.g.*, rapid sitting down) and potential dual-occupancy scenarios (such as a caregiver sitting on the edge of the bed alongside the user).

This section investigates the mechanical strength of the bed components and their structural resistance to extreme loading conditions. Beyond the slats, the bedside rail constitutes the most heavily stressed structural element. The critical loading state occurs when a user sits directly in the mid-zone of the bedside rail. Under this condition, the total body mass is transmitted via the mattress and slats, inducing a peak force on the slat support system, which is modeled as perfectly bonded to the bedside rail. To account for a higher-mass user's anthropometric profile, this concentrated load is distributed across the support areas corresponding to the three central slats (Fig. 8c).

The force effects cause eccentric loading of the bedside rail, resulting not only in its vertical deflection but also in lateral deformation. Based on these considerations, the primary focus is on analyzing deformation and strength in the bedside rail. Of course, the load on the connections of the bed components cannot be overlooked. These are mainly the connections between the bed's sideboards and the headboard and footboard. These connections can take many forms. For these reasons, it would be necessary to perform strength analyses for each design version of the connection. Given the objectives of this article, the strength analysis of the connections between the bed's structural components will not be included in the study. Reliable and safe use of the bed under the considered load states requires meeting the strength and deformation conditions defined by limit states.

In general, the following strength limit condition must be met when assessing the strength of bed components (Eurocode 5),

$$S_d \leq R_d \,, \tag{5}$$

where S_d is the value caused by action effects (the internal force, stresses, *etc.*) caused by the load, and R_d is the design value of the resistance (*i.e.*, load-carrying capacity).

All design strength values for a given material are defined as follows,

$$f_d = k_{\text{mod}} \frac{f_k}{\gamma_M} \,, \tag{6}$$

where f_k is the characteristic strength value for a given wood material, k_{mod} is the modification factor considering the loading process and moisture, and γ_M is the partial factor for the material property.

The bedside rail, which is a beam in geometric terms, must meet not only strength requirements but also deformation requirements. Since furniture-specific standards do not prescribe explicit deflection limits for non-structural applications, the $L/300$ serviceability criterion was adopted from Eurocode 5 (EN 1995-1-1:2004), while the mechanical properties used for the analysis correspond to the strength classes defined in EN 338:2016. The structural behavior of the bedside rail is satisfactory if its maximum vertical displacement ($u_{y,max}$) caused by the load is less than the limit value, *i.e.*, the recommended maximum permissible deflection in the furniture industry is $L_p/300$.

The dimensions of the bed (Fig. 9), the dimensions of the cross-section of the bedside rail (Fig. 9b), as well as the weight parameters of the person, used in the computational analyses, are in accordance with the statistical data in the study (Hitka *et al.* 2022), and are presented in Table 6.

The structural analysis of the bed was performed using finite element analysis (FEA) software ANSYS Mechanical 2024 R1 (ANSYS, Inc., Canonsburg, PA, USA). To perform strength analyses of the bed, a computational model was created using the 3D volumetric finite element SOLID186. In the computational model, perfect adhesion of the slat support to the bedside rail is assumed. Orthotropic wood properties (Table 7) are assigned to the bed model components created in ANSYS, in accordance with their orientation relative to the global coordinate system (Fig. 8b).

Table 7. Assigning Mechanical Properties to the Bed Components According to the Coordinate System in the FEA Model

Mechanical Properties		①	②	③	④
Young's modulus (GPa)	E_L	E_x	E_y	E_z	E_x
	E_T	E_y	E_z	E_y	E_z
	E_R	E_z	E_x	E_x	E_y
Shear modulus (GPa)	G_{LR}	G_{xz}	G_{xy}	G_{xz}	G_{xy}
	G_{LT}	G_{xy}	G_{yz}	G_{yz}	G_{xz}
	G_{RT}	G_{yz}	G_{xz}	G_{xy}	G_{yz}
Poisson's ratio (–)	μ_{LR}	μ_{xz}	μ_{xy}	μ_{xz}	μ_{xy}
	μ_{LT}	μ_{xy}	μ_{yz}	μ_{yz}	μ_{xz}
	μ_{RT}	μ_{yz}	μ_{xz}	μ_{xy}	μ_{yz}
L – longitudinal, *T* – tangential, *R* – radial					

Due to the symmetrical bed design, the loading condition, and also the analysis objectives, the strength and deformation analyses can be performed on a half computational model (Fig. 9a). In cross-sections of bed components that are cut by the "*x-y*" symmetry plane, the boundary conditions consider the predicted symmetry of the bed computational model (*i.e.*, $u_z = 0$). All degrees of freedom are removed from the areas of the bed legs that are in contact with the floor.

In the computational model, two types of wood (spruce and oak) are considered as materials for bed production. The basic mechanical properties of both types of wood (Niemz *et al.* 2023) are given in Table 8.

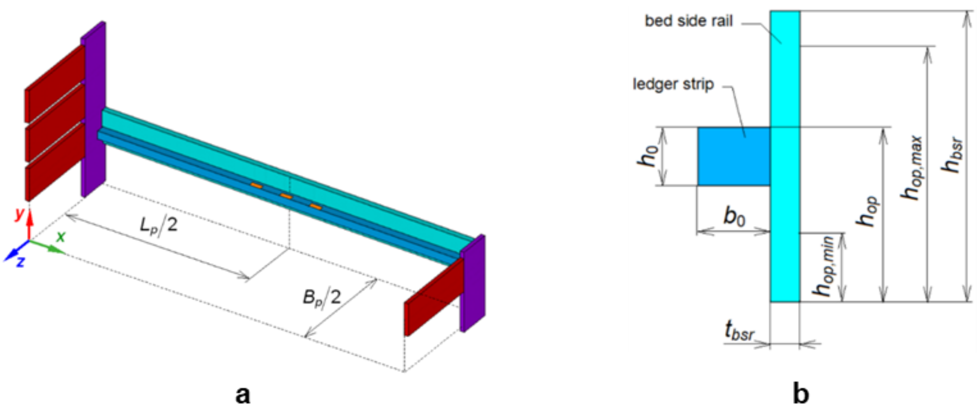

Fig. 9. Half computational model of the single bed analyzed: a – assignment of physical properties to the components – based on the component color; b – cross-section dimensions of the bedside rail

Table 8. Mechanical Properties of the Analyzed Wood Species

Mechanical Properties		Oak	Spruce
Young's modulus (GPa)	E_L	13.0	10.0
	E_T	0.92	0.45
	E_R	1.58	0.80
Shear modulus (GPa)	G_{LR}	1.15	0.60
	G_{LT}	0.80	0.65
	G_{RT}	0.40	0.04
Poisson's ratio (–)	μ_{LR}	0.044	0.041
	μ_{LT}	0.027	0.033
	μ_{RT}	0.330	0.350

Source of data: (Niemz *et al.* 2023)

Mechanical properties, listed in Table 8, are assigned to the bed components in the computational model so that the orientation of the wood fibers in the bed components (Table 7) is consistent with the global coordinate system of the computational model (Fig. 9a) created in the FEA software used.

The design strength values of both wood species (spruce, oak) are determined using the characteristic strength values in EN 338:2016 and using Eq. 6. In Eq. 6, the parameters $k_{mod} = 0.7$, and $\gamma_M = 1.3$ were used to determine the strength design values (Table 9).

The results of stress-strain analyses for the bed's dimensional parameters (Table 6) and mechanical properties (Table 8), as well as the load corresponding to a 250 kg person, are presented in the following section of the paper. Deformations and stresses for the oak bedside rail ($h_{bsr} \times t_{bsr}$ = 200 mm × 25 mm) are presented; these include vertical deflection u_y (Fig. 10), lateral deformation u_z (Fig. 11), and tensile stress s_x (Fig. 12).

Table 9. Strength Design Properties for the Considered Types of Wood

Strength Characteristics			Strength Properties (MPa)	
			spruce	oak
Characteristic strength value	bending	$f_{m,k}$	30.0	50.0
	tensile	$f_{t,0,k}$	19.0	30.0
		$f_{t,90,k}$	0.4	0.6
	compression	$f_{c,0,k}$	24.0	30.0
		$f_{c,90,k}$	2.7	6.2
	shear	$f_{v,k}$	4.0	4.5
Corresponding design value of resistance	bending	$f_{m,d}$	16.2	26.9
	tensile	$f_{t,0,d}$	10.2	16.2
		$f_{t,90,d}$	0.2	0.3
	compression	$f_{c,0,d}$	12.9	16.2
		$f_{c,90,d}$	1.5	3.3
	shear	$f_{v,d}$	2.2	2.4

Source of data: EN 338:2016

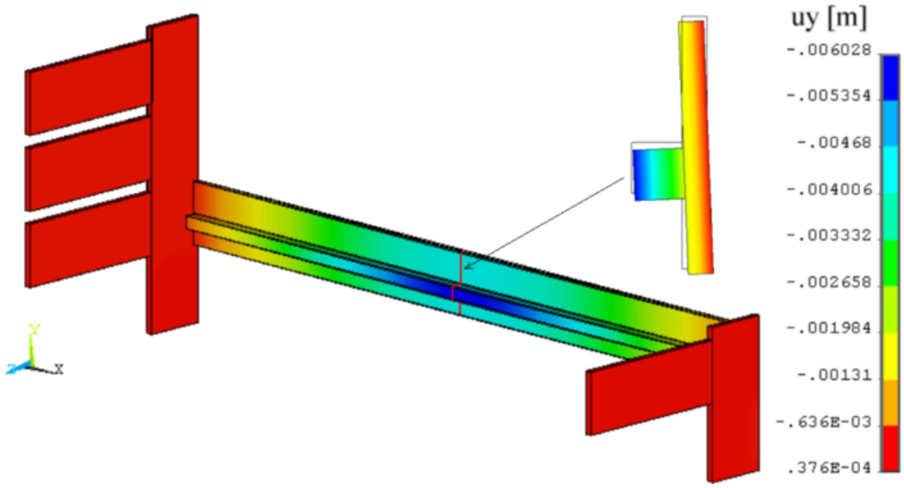

Fig. 10. Vertical deflection u_y of the bedside rail (oak wood) (L_p = 2400 mm; B_p = 1410 mm; h_{bsr} = 200 mm; t_{bsr} = 25 mm; h_{op} = 100 mm; m_b = 250 kg)

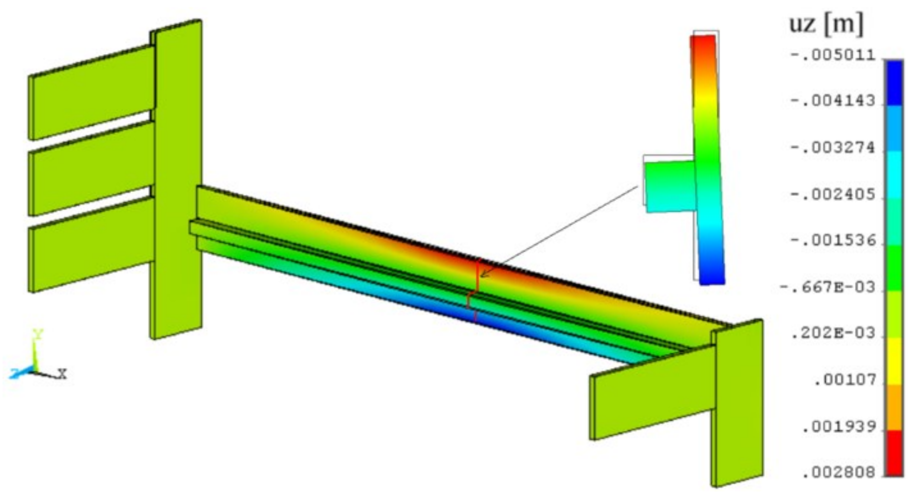

Fig. 11. Lateral deflection u_z of the bedside rail (oak wood) (L_p = 2400 mm; B_p = 1410 mm; h_{bsr} = 200 mm; t_{bsr} = 25 mm; h_{op} = 100 mm; m_b = 250 kg)

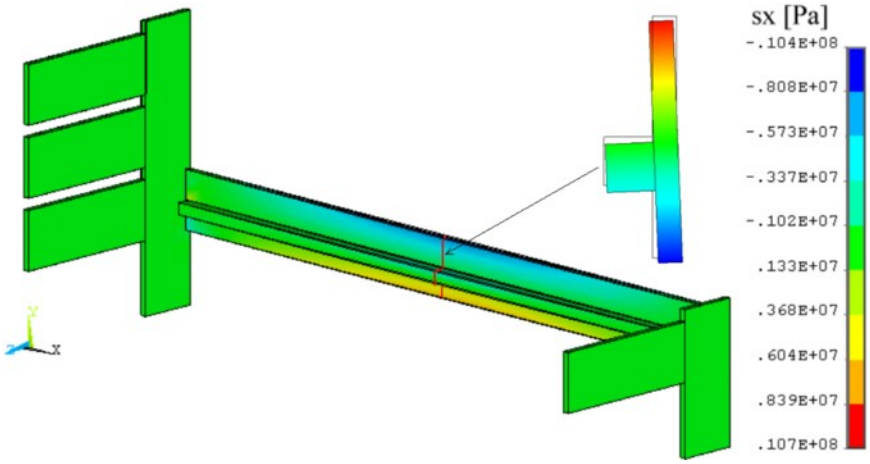

Fig. 12. Tensile stress s_x, of the bedside rail (oak wood) (L_p = 2400 mm; B_p = 1410 mm; h_{bsr} = 200 mm; t_{bsr} = 25 mm; h_{op} = 100 mm; m_b = 250 kg)

The dimensions of the cross-sectional area of the bed bedside rail ($h_{bsr} \times t_{bsr}$) have a crucial influence on its vertical deflection. The dependencies of the vertical deflection of the center of bedside rail (oak) on the thickness of t_{bsr} (for h_{bsr} = 200 mm) and on the heights of h_{bsr} (for t_{bsr} = 20 mm) for the whole range of considered positions h_{op} are shown in Fig. 13a and Fig.13b, respectively.

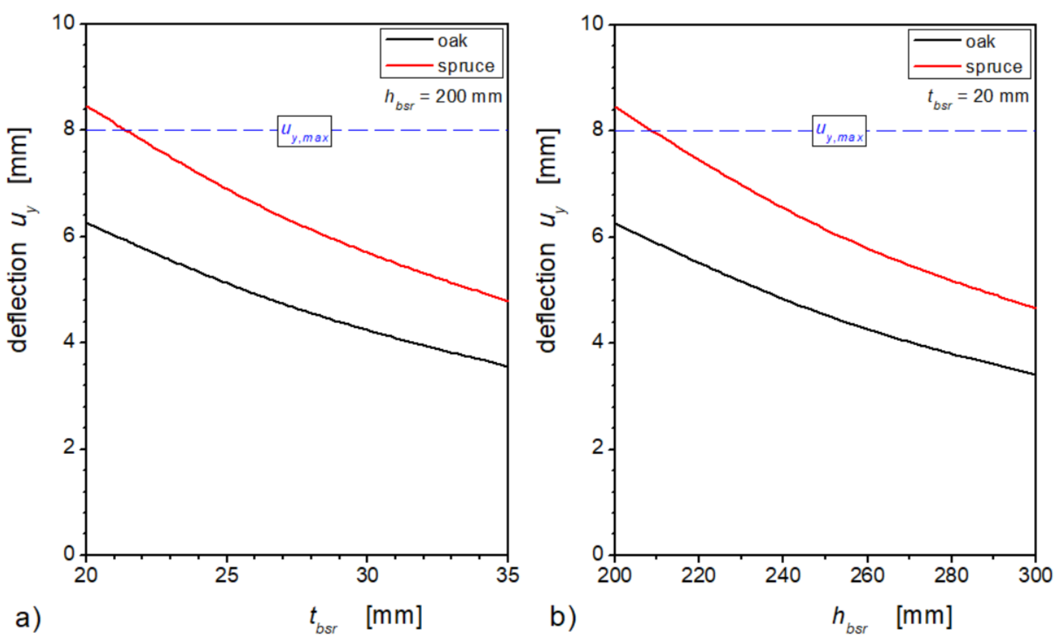

Fig. 13. Vertical deflection, u_y, at the center of the bedside rail (oak and spruce wood) (L_p = 2400 mm; B_p = 1410 mm; m_b = 250 kg)

The effect of the slat support position (h_{op}) on the lateral deflection of the bed bedside rail is shown in Fig. 14. The influence of the wood type (oak, spruce) and the thickness of the t_{bsr} on the vertical and lateral deflection of the bedside rail (h_{bs} = 200 mm) at the upper point of the slat support, which is in the position h_{op} = 100 mm, is presented in Fig. 15.

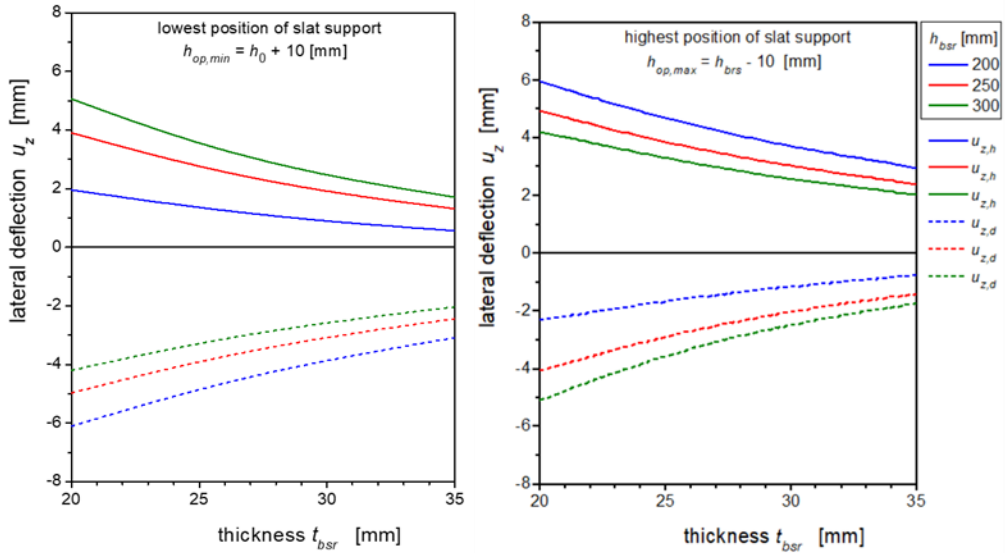

Fig. 14. Lateral deflection u_z in the center of the bed bedside rail (oak) – lowest/highest slat support position (L_p = 2400 mm; B_p = 1410 mm; m_b = 250 kg)

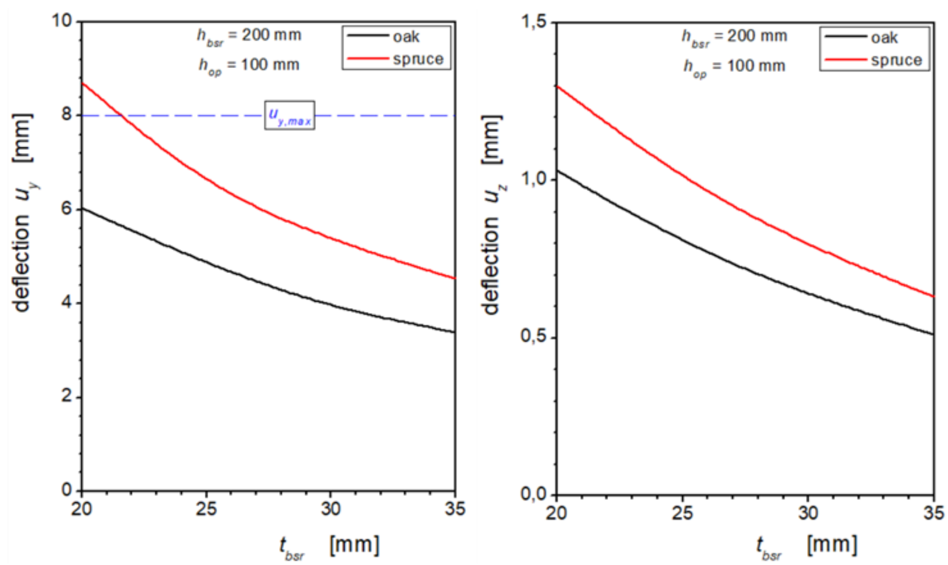

Fig. 15. Vertical u_y and lateral u_z deflection on the slat support, at the center of the bed bedside rail (L_p = 2400 mm; B_p = 1410 mm; m_b = 250 kg)

The lateral deformation of the bedside rail (cross-section $h_{bsr} \times t_{bsr}$ = 200 mm × 20 mm) for different values of h_{op} is shown in Fig. 16. The structural position of the slat support governs the critical state of lateral deformation in the bedside rail. A low support configuration induces an outward lateral displacement at the rail's lower edge, which can lead to slat disengagement and subsequent structural failure. In contrast, positioning the support at the top of the rail produces an inward lateral deflection along the rail's upper edge. This inward movement acts as a stabilizing mechanism, effectively preventing the slats from falling out.

The tensile stress s_x (Fig. 17) depends on the cross-section ($h_{bsr} \times t_{bsr}$) of the side board of the bed, but also on the position of the slat support h_{op}.

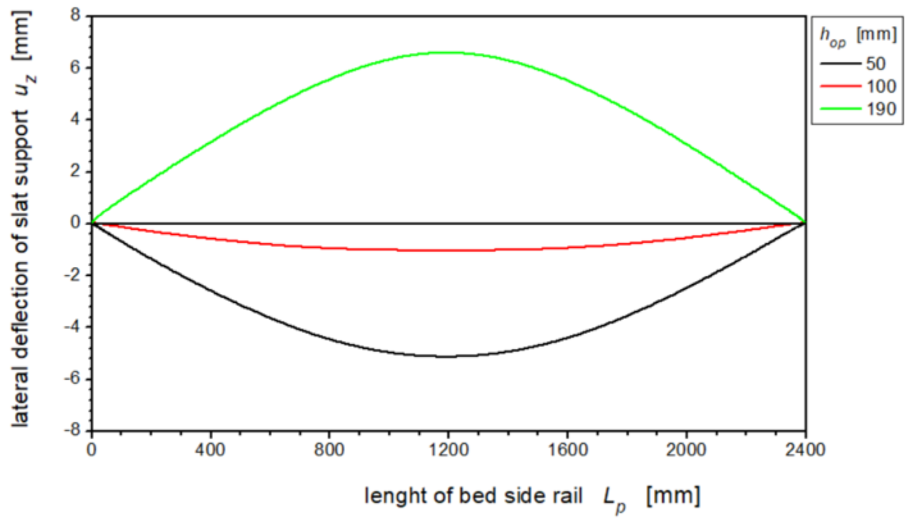

Fig. 16. Lateral deflection u_z of the bedside rail - for oak (L_p = 2400 mm; B_p = 1410 mm; h_{bsr} = 200 mm; t_{bsr} = 20 mm; m_b = 250 kg)

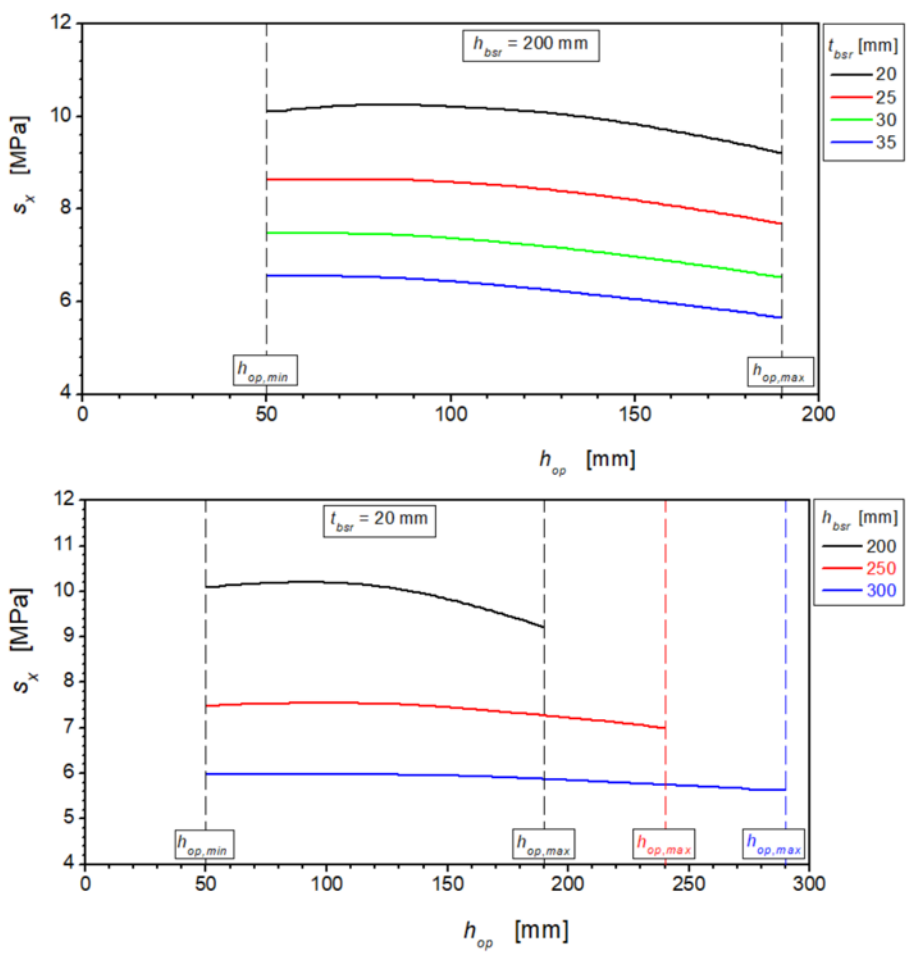

Fig. 17. Maximum value of tensile stress, s_x, in the bedside rail – for oak (L_p = 2400 mm; B_p = 1410 mm; m_b = 250 kg)

The maximum values of deflections of the bedside rail (L_p = 2400 mm; B_p = 1410 mm; m_b = 250 kg) were calculated for the smallest cross-sectional dimensions considered $h_{bsr} \times t_{bsr}$ = 200 mm × 20 mm and for h_{op} = 50 mm. The maximum vertical deflection, u_y, of the bedside rail is 6.2 mm for oak and 8.2 mm for spruce. The maximum value of lateral deflection u_z (pushed outwards) is 5.2 mm for oak and 6.8 mm for spruce.

Discussion

The anthropometric data collected between 1980 and 2025 confirm a high degree of homogeneity among the studied populations, justifying the application of unified design standards for both the Czech Republic and the Slovak Republic. Student's t-tests revealed no statistically significant differences ($p > 0.05$) in key dimensions, most notably in body height ($p = 0.813$ for women; $p = 0.477$ for men). This stability confirms that ergonomic parameters for worktops and seating determined for one population remain fully applicable to the other. However, although differences in body mass were not statistically significant, the lower p-values observed in women ($p = 0.099$ for weight; $p = 0.132$ for BMI) suggest an emerging trend toward greater morphological diversification, warranting close monitoring in future design practice. These longitudinal observations underscore a pronounced secular trend characterized not only by a moderate increase in average stature but, more critically, by a disproportionately rapid escalation in body mass (Duranková *et al.* 2019). Consequently, conventional load-bearing specifications—such as the 120 kg limit for standard seating—are becoming increasingly inadequate for a more diverse user demographic with higher BMIs.

This regional trend aligns with Western European patterns, though a 10– to 15–year delay is associated with post-communist socioeconomic changes (Popkin 2006). Similar dynamics occurred in neighboring Poland, where Łopuszańska *et al.* (2015) recorded weight increases of +1.2 kg/decade for men and +1.4 kg/decade for women – close to the +1.4 and +1.6 kg/decade identified in this study. In contrast, Western nations reached these stabilization phases much earlier; for instance, male height plateaued in the Netherlands 15 years before it did in Central Europe (Schönbeck *et al.* 2013). This delay reflects the regional nutrition transition, influenced by rapid deindustrialization after 1990 (Henson and Sekuła 1994) and by increased car ownership, which shifted regional transport patterns toward Western norms (Pucher and Buehler 2008). However, while stature growth has slowed in the Czech and Slovak populations, BMI values continue to rise, with no evidence of stabilization (Figs. 2, 5, 6). Unlike in France, where public health programs stabilized obesity rates in the 2000s (Lioret *et al.* 2009; Olds *et al.* 2011), the absence of similar interventions in Central Europe suggests continued increases in body mass. These findings provide an empirical basis for the update to structural strength standards for modern furniture proposed in this study.

The literature highlights a shortage of high-capacity furniture on the market, with standard weight limits restricted to the range 110 to 150 kg, creating a gap in seating and bed design (Réh *et al.* 2019; Starchon *et al.* 2024). Addressing this capacity gap in the high-load-bearing furniture segment (especially beds) does not require heavy, massive constructions. Through structural optimization and materials engineering, high-load furniture can remain lightweight and visually subtle. Furthermore, integrating adjustable parameters—such as seat height or firmness—helps mitigate ergonomic issues associated with increasingly sedentary habits. The data in Table 10 quantify this anthropometric mismatch, demonstrating a clear divergence between current regulatory standards and contemporary population parameters.

Table 10. Gap Analysis between Conventional Standards and Recommended Single-bed Dimensional Parameters

Parameter	Current Standard	Recommended (this study)	Gap
Length	200 cm (EN 1334:1996)	220 to 240 cm	+20 to 40 cm
Width (single)	90 cm (EN 1334:1996)	100 to 141 cm	+10 to 51 cm
Load capacity	110 kg (EN 1725:2023)	250 kg	+130 kg

The "gap" shown in Table 10 suggests that furniture manufactured to existing standards is effectively obsolete for a significant portion of the Central European population. These data provide an empirical argument for transitioning to adaptive furniture design, in which the "design standard" is regularly redefined to prioritize the safety and comfort of contemporary users. The empirical findings for young Czechs and Slovaks, along with published data for the Polish population, confirm that these secular changes represent a broader regional trend. These empirical observations carry practical significance for manufacturers of wooden furniture.

To evaluate the structural suitability of the analyzed wood species in wooden bed design, the computed deflections were verified against the serviceability limit state criterion. According to the structural design guidelines for timber elements specified in Eurocode 5 (EN 1995-1-1:2004), the maximum allowable deflection for structural members under variable loading is limited to $L/300$. For the considered bedside rail span (L_p = 2400 mm), this stiffness threshold corresponds to a deflection limit of 8.0 mm. The finite element analysis demonstrated that the oak rail satisfies these requirements, with its maximum vertical deflection (u_y = 6.2 mm) remaining well within the safety margin. Conversely, the spruce rail (u_y = 8.2 mm) marginally exceeded the Eurocode 5 permissible limit. This underscores the influence of the material's lower modulus of elasticity (E) and indicates that, while the 200 × 20 mm cross-section is structurally adequate for premium hardwoods, it requires geometric optimization, such as increasing the rail's thickness or depth.

These mechanical evaluation results demonstrate the need to revise current regulatory frameworks. Specifically, the reference load specification in EN 1725:2023 for domestic wooden beds should be increased from the currently assumed single-user body mass of approximately 110 kg (1100 N) to a minimum of 250 kg to ensure structural safety for higher user percentiles. The documented increase in population BMI indicates that conventional design standards no longer reflect contemporary user requirements (the so-called "retro-normative" design standards). Consequently, updated strength standards and optimized structural dimensions are required to maintain long-term safety and functional durability.

Study Limitations

This study has several limitations. First, the age restriction (18 to 25 years) excludes older cohorts whose body composition is affected by sarcopenia or vertebral compression. Second, the available empirical data were limited to height, weight, and BMI, omitting parameters such as shoulder breadth, hip width, and sitting height; consequently, specific bed dimensions were derived from the cited literature. Furthermore, the absence of body composition metrics (fat *vs*. lean mass) limits the interpretation of BMI. Finally, sample size imbalance across measurement periods (particularly the small 2007 to 2009 cohort) affects the statistical power of the analysis.

CONCLUSIONS

1. This 45-year anthropometric study of over 8,000 young adults in the Czech and Slovak Republics demonstrates that secular biological changes in the regional population have outpaced current furniture design standards.
2. Comparative statistical analysis reveals that the Czech and Slovak populations maintain a high degree of somatic homogeneity, showing no statistically significant differences in body height, mass, or *Body Mass Index* (BMI) ($p > 0.05$). This long-term similarity, rooted in a shared socioeconomic history and congruent contemporary lifestyle transitions, justifies maintaining unified furniture dimensions and structural standards across both markets, allowing for standardized production and uniform safety protocols.
3. The data confirm a secular trend marked by decelerating height growth alongside a steady increase in body mass. Since 1980, the average body mass has increased by 6.2 kg in men and 7.1 kg in women (+1.4 and +1.6 kg per decade), whereas mean height increased by only 3.2 to 3.8 cm. Consequently, existing industry standards no longer meet the ergonomic and structural needs of the current population.
4. To accommodate the 95th percentile of the contemporary population, the following regulatory and design adjustments are recommended:
    a. Extension of the nominal bed length specified in EN 1334:1996 from 200 cm to a minimum of 220 cm, with a recommended standard length of 240 cm.
    b. Extension of the minimum single-bed width specified in EN 1334:1996 from 90 cm to a minimum of 100 cm (with a recommended width of 141 cm to provide optimal ergonomic comfort.
    c. An increase in the reference load baseline in EN 1725:2023 from approximately 110 kg (1100 N) to a minimum characteristic design capacity of 250 kg.
5. Finite element simulations show that supporting a 250 kg static load does not require excessive timber volume. While oak components of standard dimensions fully satisfy Eurocode 5 serviceability limit states ($u_{max} \leq L/300$), lower-density softwoods such as spruce require targeted cross-sectional optimization to achieve the required rigidity without increasing dead weight.
6. To eliminate the identified anthropometric mismatch, technical standards should be updated using current biometric datasets, standardized load-capacity labeling should become mandatory, and national anthropometric trends should be reviewed every 10 years.

Ultimately, these findings provide a clear empirical framework for updating furniture strength standards and structural design rules to better align with modern demographic requirements.

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Conflict of Interest

The authors have no relevant financial or non-financial interests to disclose.

Use of Generative AI

The authors declare that no generative AI tools or AI-assisted technologies were used in the conceptualization, writing, data collection, data analysis, or reference collation for this study. Google Gemini was employed solely to generate the illustrative human figures representing different historical periods and the bed pictograms in the Graphical Abstract. All generated images were subsequently reviewed and approved by the authors. The authors retain full responsibility for the content of the publication.

REFERENCES CITED

Bai, Y., Kamarudin, K. M., and Alli, H. (2024). "A systematic review of research on sitting and working furniture ergonomic from 2012 to 2022: Analysis of assessment approaches," *Heliyon* 10(7), e28384. https://doi.org/10.1016/j.heliyon.2024.e28384

Boas, F. (1912). "Changes in the bodily form of descendants of immigrants," *American Anthropologist* 14(3), 530-562. https://doi.org/10.1525/aa.1912.14.3.02a00080

Cardoso, H. F. V., and Caninas, M. (2010). "Secular trends in social class differences of height, weight and BMI of boys from two schools in Lisbon, Portugal (1910-2000)," *Economics & Human Biology* 8(1), 111-120. https://doi.org/10.1016/j.ehb.2009.04.005

Cole, T. J. (2003). "The secular trend in human physical growth: A biological view," *Economics & Human Biology* 1(2), 161-168. https://doi.org/10.1016/S1570-677X(02)00033-3

Daniel, R. M. (2024). "Measure and mis-measure: Rethinking anthropometry in interior design," *Journal of Interior Design* 49(1), 17-34. https://doi.org/10.1177/10717641231195261

Duranková, S., Csanády, A., Surmanková, E., Ždiľová, A., and Bernasovská, J. (2019). "Age and sex differences and allometry in anthropometric variables in young adults from Central Europe (Slovakia)," *Anthropologie* 58(1), 1-13. https://doi.org/10.26720/anthro.19.09.30.1

Eckelman, C. A. (1988). "Performance testing of furniture. Part II. A multipurpose universal structural performance test method," *Forest Products Journal*, 38(4), 13-18.

Eckelman, C. A. (2003). *Textbook of Product Engineering and Strength Design of Furniture*, Purdue University, West Lafayette, IN, USA.
Eckelman, C. A., Uysal, M., and Haviarova, E. (2016). "Statistical lower tolerance limits for rectangular mortise and tenon joints," *BioResources* 11(3), 7162-7171. https://doi.org/10.15376/biores.11.3.7162-7171
EN 1334. (1996). "Domestic furniture – Beds and mattresses – Methods of measurement and recommended tolerances," European Committee for Standardization (CEN), Brussels, Belgium.
EN 1725. (2023). "Furniture – Beds – Safety, strength and durability requirements," European Committee for Standardization (CEN), Brussels, Belgium.
EN 1995-1-1. (2004). "Eurocode 5: Design of timber structures – Part 1–1: General – Common rules and rules for buildings," European Committee for Standardization (CEN), Brussels, Belgium.
EN 338. (2016). "Structural timber – Strength classes," European Committee for Standardization (CEN), Brussels, Belgium.
Erdil, Y., Kasal, A., and Eckelman, C. (2005). "Bending Moment Capacity of Mortise and Loose-Tenon Joints," *Forest Products Journal* 55(12), 209-213. https://wfs.swst.org/index.php/wfs/article/view/668
Gažarová, M., Bihari, M., Lorková, M., Lenártová, P., and Habánová, M. (2022). "The Use of Different Anthropometric Indices to Assess the Body Composition of Young Women in Relation to the Incidence of Obesity, Sarcopenia and the Premature Mortality Risk," *International Journal of Environmental Research and Public Health* 19(19), article 12449. https://doi.org/10.3390/ijerph191912449
Gejdoš, M., and Hitka, M. (2022). "The Impact of the Secular Trend of the Slovak Population on the Production of Wooden Beds and Seating Furniture," *Forests* 13(10), article 1599. https://doi.org/10.3390/f13101599
Gustafsson, S. I. (1995). "Furniture design by use of the finite element method," *Holz als Roh- und Werkstoff*, 53(4), 257-260. https://doi.org/10.1007/s001070050084
Gustafsson, S. I. (1997). "Optimising ash wood chairs," *Wood Science and Technology* 31(4), 291-301. https://doi.org/10.1007/BF00702616
Henson, S., and Sekuła, W. (1994). "Market reform in the Polish food sector: impact upon food consumption and nutrition," *Food Policy* 19(5), 419-442. https://doi.org/10.1016/0306-9192(94)90021-3
Hignett, S., and Lu, J. (2010). "Space to care and treat safely in acute hospitals: Recommendations from 1866 to 2008," *Applied Ergonomics* 41(5), 666-673. https://doi.org/10.1016/j.apergo.2009.12.010
Hitka, M., Gejdoš, M., Klement, I., and Simanová, Ľ. (2022). "Dimensional solution for beds from wood composites for the bariatric population," *BioResources* 17(4), 6656-6667. https://doi.org/10.15376/biores.17.4.6656-6667
Hitka, M., Lagaňa, R., Naď, M., Klement, I., and Sydor, M. (2024). "Analysis of the lamella dimensions of the bed slat for the bariatric respondent: A modelling approach," *Wood Material Science & Engineering* 19(1), 19-26. https://doi.org/10.1080/17480272.2023.2221792
Hitka, M., Sedmák, R., Joščák, P., and Ližbetinová, L. (2018). "Positive secular trend in Slovak population urges on updates of functional dimensions of furniture," *Sustainability* 10(10), 3474. https://doi.org/10.3390/su10103474
İmirzi, H. Ö., Smardzewski, J., and Döngel, N. (2015). "Method for substitute modulus determination of furniture frame construction joints," *Turkish Journal of Agriculture*

and Forestry 39, 775-785. https://doi.org/10.3906/tar-1406-92
ISO 19833 (2018). “Furniture — Beds — Test methods for the determination of strength and durability,” International Organization for Standardization, Geneva, Switzerland.
ISO 7250-1 (2017). “Basic human body measurements for technological design — Part 1: Body measurement definitions and landmarks,” International Organization for Standardization, Geneva, Switzerland.
Jasińska, A., Sydor, M., and Hitka, M. (2024). “Optimizing dimensions in furniture design: A literature review,” *BioResources* 19(3), 4727-4748. https://doi.org/10.15376/biores.19.3.4727-4748
Kasal, A. (2006). “Determination of the strength of various sofa frames with finite element analysis,” *Gazi University Journal of Science* 19(4), 191-203. https://izlik.org/JA36LX79JP
Kasal, A. (2008). “Bending moment and shear force capacities of the T-type doweled furniture joints reinforced with different sizes of corner blocks,” *Journal of the Faculty of Engineering and Architecture of Gazi University* 23(2), 273-282. https://hdl.handle.net/20.500.12809/4953
Kasal, A., Eckelman, C. A., Haviarova, E., Erdil, Y. Z., and Yalcin, İ. (2015). “Bending moment capacities of L-shaped mortise and tenon joints under compression and tension loadings,” *BioResources* 10(4), 7009-7020. https://doi.org/10.15376/biores.10.4.7009-7020
Keys, A., Fidanza, F., Karvonen, M. J., Kimura, N., and Taylor, H. L. (1972). “Indices of relative weight and obesity,” *Journal of Chronic Diseases* 25(6-7), 329-343. https://doi.org/10.1016/0021-9681(72)90027-6
Likos, E., Haviarova, E., Eckelman, C. A., Erdil, Y. Z., and Ozcifci, A. (2012). “Effect of tenon geometry, grain orientation, and shoulder on bending moment capacity and moment rotation characteristics of mortise and tenon joints,” *Wood and Fiber Science* 44(4), 462-469. https://wfs.swst.org/index.php/wfs/article/view/1484
Lioret, S., Touvier, M., Dubuisson, C., Dufour, A., Calamassi-Tran, G., Lafay, L., Volatier, J.-L., and Maire, B. (2009). “Trends in child overweight rates and energy intake in France from 1999 to 2007: Relationships with socioeconomic status,” *Obesity* 17(5), 1092-1100. https://doi.org/10.1038/oby.2008.619
Łopuszańska, M., Lipowicz, A., Kołodziej, H., Szklarska, A., and Bielicki, T. (2015). “Self-reported versus measured body height and weight in Polish adult men: The risk of underestimating obesity rates,” *Anthropologischer Anzeiger* 72(3), 263-277. https://doi.org/10.1127/anthranz/2015/0467
Matwiej, Ł., Wiaderek, K., Jarecki, W., Orlikowski, D., and Wieruszewski, M. (2025). “Modelling upholstered furniture frames using the finite element method,” *Applied Sciences* 15(2), article 926. https://doi.org/10.3390/app15020926
Nawi, A. M., and Yusof, F. M. (2024). “Form, function, and comfort: Rethinking product design through the lens of ergonomics and aesthetics,” *International Journal of Research and Innovation in Social Science* VIII(IX), 1358-1373. https://doi.org/10.47772/IJRISS.2024.8090112
Ng, S. W., and Popkin, B. M. (2012). “Time use and physical activity: A shift away from movement across the globe,” *Obesity Reviews* 13(8), 659-680. https://doi.org/10.1111/j.1467-789X.2011.00982.x
Niemz, P., Sonderegger, W., and Gorbacheva, G. (2023). “Elastic and inelastic properties of wood and wood-based materials,” in: *Springer Handbook of Wood Science and Technology*, P. Niemz, A. Teischinger, and D. Sandberg (eds.), Springer, Cham,

Switzerland, pp. 399-439. https://doi.org/10.1007/978-3-030-81315-4_8

Olds, T., Maher, C., Zumin, S., Péneau, S., Lioret, S., Castetbon, K., Bellisle, F., De Wilde, J., Hohepa, M., Maddison, R., Lissner, L., Sjöberg, A., Zimmermann, M., Aeberli, I., Ogden, C., Flegal, K., and Summerbell, C. (2011). "Evidence that the prevalence of childhood overweight is plateauing: Data from nine countries," *International Journal of Pediatric Obesity* 6(5-6), 342-360. https://doi.org/10.3109/17477166.2011.605895

Pérez-Gosende, P. (2019). "Evaluation of classroom furniture design for Ecuadorian university students: An anthropometry-based approach," *Advances in Science, Technology and Engineering Systems Journal* 4(6), 163-172. https://doi.org/10.25046/aj040620

Popkin, B. M. (2006). "Global nutrition dynamics: The world is shifting rapidly toward a diet linked with noncommunicable diseases," *American Journal of Clinical Nutrition* 84(2), 289-298. https://doi.org/10.1093/ajcn/84.2.289

Pucher, J., and Buehler, R. (2008). "Making cycling irresistible: Lessons from the Netherlands, Denmark and Germany," *Transport Reviews* 28(4), 495-528. https://doi.org/10.1080/01441640701806612

Réh, R., Krišťák, Ľ., Hitka, M., Langová, N., Joščák, P., and Čambál, M. (2019). "Analysis to improve the strength of beds due to the excess weight of users in Slovakia," *Sustainability* 11(3), article 624. https://doi.org/10.3390/su11030624

Schönbeck, Y., Talma, H., Van Dommelen, P., Bakker, B., Buitendijk, S. E., HiraSing, R. A., and Van Buuren, S. (2013). "The world's tallest nation has stopped growing taller: The height of Dutch children from 1955 to 2009," *Pediatric Research* 73(3), 371-377. https://doi.org/10.1038/pr.2012.189

Simek, M., Haviarova, E., and Eckelman, C. (2010). "The effect of end distance and number of ready-to-assemble furniture fasteners on bending moment resistance of corner joints," *Wood and Fiber Science* 42(1), 92-98. https://wfs.swst.org/index.php/wfs/article/view/1717

Siu, K. W. M. (2005). "Pleasurable products: Public space furniture with userfitness," *Journal of Engineering Design* 16(6), 545-555. https://doi.org/10.1080/09544820500273383

Smardzewski, J. (1998). "Numerical analysis of furniture constructions," *Wood Science and Technology* 32(4), 273-286. https://doi.org/10.1007/BF00702895

Smardzewski, J. (2015). *Furniture Design*, Springer International Publishing, Cham, Switzerland. https://doi.org/10.1007/978-3-319-19533-9

Smardzewski, J., Lewandowski, W., and İmirzi, H. Ö. (2014). "Elasticity modulus of cabinet furniture joints," *Materials & Design* 60, 260-266. https://doi.org/10.1016/j.matdes.2014.03.066

Starchoň, P., Hitka, M., Gejdoš, M., and Miklošík, A. (2024). "Evolving anthropometric traits of Slovak consumers and their impact on furniture and furniture marketing," in: *Proceedings of the 15th International Conference on Applied Human Factors and Ergonomics (AHFE 2024)*, AHFE International, Nice, France, pp. 198-208. https://doi.org/10.54941/ahfe1004946

Stubbs, C. O., and Lee, A. J. (2004). "The obesity epidemic: Both energy intake and physical activity contribute," *Medical Journal of Australia* 181(9), 489-491. https://doi.org/10.5694/j.1326-5377.2004.tb06406.x

Sweatt, K., Garvey, W. T., and Martins, C. (2024). "Strengths and limitations of BMI in the diagnosis of obesity: What is the path forward?" *Current Obesity Reports* 13(3), 584-595. https://doi.org/10.1007/s13679-024-00580-1

Tanner, J. M. (1981). *A History of the Study of Human Growth*. Cambridge University Press, Cambridge, UK.

Wiggermann, N., Smith, K., and Kumpar, D. (2017). "What bed size does a patient need? The relationship between body mass index and space required to turn in bed," *Nursing Research* 66(6), 483-489. https://doi.org/10.1097/NNR.0000000000000242

Wolański, N. (1984). "Current problems of the secular trend in human populations," in: *Human Growth and Development*, J. Borms, R. Hauspie, E. A. Sand, C. Susanne, and M. Hebbelinck (eds.), Springer US, Boston, MA, pp. 225-233. https://doi.org/10.1007/978-1-4684-4658-2_18

Woo, E. H. C., White, P., and Lai, C. W. K. (2016). "Ergonomics standards and guidelines for computer workstation design and the impact on users' health: A review," *Ergonomics* 59(3), 464-475. https://doi.org/10.1080/00140139.2015.1076528

World Health Organization (WHO) (2000). *Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation*, WHO Technical Report Series 894, Geneva, Switzerland. https://europepmc.org/article/MED/11234459

World Health Organization (WHO) (2008). *Waist Circumference and Waist-Hip Ratio: Report of a WHO Expert Consultation*, Geneva, Switzerland. https://www.who.int/publications/i/item/9789241501491

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