Load-carrying Capacity and the Size of Chair Joints Determined for Users with a Higher Body Weight

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Market globalization, with its accompanying higher living standards, food availability, and sedentary jobs noticeably affects the eating habits and lifestyles of people. Therefore, the body weight of populations is increasing globally. These changes must be taken into account when various everyday items (furniture, clothes, and shoes) are designed. Population-based studies dealing with measuring the height and body weight of adult male populations were analyzed (body mass index categories: 25 kg/m^2 to < 30 kg/m^2 (overweight), > 30 kg/m^2 (obese), > 35 kg/m^2 (severely obese)). Because of the analysis of anthropometric parameters in Central Europe, especially Slovakia, it is necessary to produce chairs with two weight categories for the common population (normal weight up to 110 kg) and a population with a higher weight. The aim of this research was to investigate the effect of the body weight of users on the load capacity and dimensions of structural elements of chairs. Following the static analysis of the load-carrying capacity of several chair types, it was calculated that the only suitable construction type for users with a higher weight is the construction with stretchers. The cross-section of the leg space and side rail increased by 20% and 25%, respectively, in the case of a 150-kg user and tenon dimensions of 10 mm × 60 mm × 30 mm.

Keywords: Load-carrying capacity; Size of chair joint; Chair; Weight of the population

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INTRODUCTION

Economic growth has resulted in intensive market globalization as well as higher living standards, food availability, and sedentary jobs. Moreover, the eating habits and lifestyles of individuals have been noticeably affected by these economic changes. Therefore, the body weight of the global population has increased (Freedman *et al.* 2010; Stevens *et al.* 2012; Gomula *et al.* 2015; Benda-Prokeinová *et al.* 2017). The increasing prevalence of overweight and obesity has been defined as global pandemics in many countries (Wang and Beydoun 2007; Stevens *et al.* 2012). Data from 369 national and 591 local research studies were used by Finucane *et al.* (2011) to define the trends in the changes in Body Mass Index (BMI) throughout the world from 1980 to 2008. Another study evaluated the results of 450 national studies to determine the trend in childhood obesity and excess weight from 1990 to 2020 (de Onis *et al.* 2010). Data from both studies, as well as many others, has shown overall weight gain in recent decades, although the analyses in some countries indicated the implementation of stabilization strategies in several populations (Flegal *et al.* 2010; Rockholm *et al.* 2010; Stamatakis *et al.* 2010). Data from various research studies performed in the USA mentioned that an increasing rate of obesity could cause a decrease in the average life expectancy (Olhansky *et al.* 2005). This confirms the global health epidemic of overweight and obesity (Thankappan 2001; Thang and Popkin 2003; Lu *et al.* 2016). Many research studies have shown that young people at an early age suffer from weight-related health problems (Cardoso and Padez 2008; Cardoso and Caninas 2010; Smpokos *et al.* 2011; Bielecki *et al.* 2012). Subsequently, this problem becomes more serious among young adults who gain weight too fast (Thompson 2008). Some studies have shown the problem from another point of view, namely how to succeed in long-term weight maintenance. For women, exercise has been associated with successful weight maintenance, but having two or more children, frequent consumption of sweet drinks, irregular eating, a history of dieting (intentional weight loss), and a low life satisfaction were connected with weight gain. Previous research studies into male weight found that weight gain was associated with irregular eating, a history of dieting, and smoking (Gejdoš *et at.* 2018; Kärkkäinen *et al.* 2018).

Industries, especially those in which consumption plays an important role as the main economic factor, are affected by the weight gain trend. For example, various sectors of the automotive, aviation, furniture manufacturing, clothing, and footwear industries are all affected by these trends. These changes must be taken into account when various everyday items (furniture, clothes, and shoes) are designed. These trends have recently been applied in American manufacturing. For example, school furniture manufacturers are now making larger desk chairs for students; American hospitals are spending billions to accommodate oversized patients; furniture companies have introduced "plus size" living collections, *etc*. The effort of producers to optimize and standardize products must correspond to the statistical data associated with the body sizes of consumers. Chairs are a product where anthropometric proportions of users must be taken into account. Anthropometry plays an important role in defining chair size and construction (Klement and Marko 2008; Kotradyová 2009; Lorincová and Potkány 2015).

Many research studies have been focused on the calculation and experimental testing of furniture construction since 1980. Authors have investigated the calculations associated with chairs, especially for the weakest point of joints (Kamenický 1978; Marinova and Genchev 1994; Eckelman 2003; Gaff 2014; Igaz *et al*. 2014; Gaff *et al*. 2017b). Branowski *et al.* (2018) dealt with new furniture joints and evaluated the load limit capacity and stiffness and failure mechanisms for the bending of two new types of furniture joints, one with an adhesive bonded flat cross fastener and the other with a frictional eccentric fastener. The study found that the two new fasteners were suitable for making furniture joints with a more advantageous load capacity and stiffness compared with the thread connection. Grič *et al.* (2017) tested frame joints made with Finnish birch plywood and birch battenboard. The joints were tested under tensile and compression bending. The results showed that the joints made with birch plywood reached higher load carrying capacities and stiffness values than the joints made with birch battenboard with the same thicknesses. The half lap joint made from Finnish plywood reached the ultimate load carrying capacity and stiffness under both compression and tensile bending. Kasal *et al.* (2016a) investigated the relationship between the static front to back loading capacity of chairs and the moment capacities of the joints used in their side frames, and also determined the effect of tenon sizes on the front to back loading capacity of chairs. Tenons that were 30 mm, 40 mm, and 50 mm in width, 30 mm, 40 mm, and 50 mm in length, and 7 mm thick were used. For assembling the joints, the study used adhesives with 65% polyvinylacetate. The results showed that the front to back loading capacity increased when the tenon width or length increased. According to those results, the strength of chairs could be reasonably predicted from the strength of the joints. Similar research was done by Kılıç *et al.* (2018), in which the effects of tenon size and its influence on the front to back loading performance of Scots pine (*Pinus sylvestris* L.) were investigated. The first result was the same as that of Kasal *et al.* (2016a). A chair became stronger as the tenon width or length increased, but it was found that the chair strength was also affected by its length. A comparison of the results with acceptable design loads showed that 40-mm × 50-mm × 7-mm tenons could be used in households, while chairs with 50-mm × 50-mm × 7-mm tenons could be used in services. The study conducted by Ishii and Miyajima (1981) determined the effect of the linear relationship between the tenon length and width on the bending moment capacity. Based on the study by Wilczynski and Warmbier (2003), the effect on the joint strength from the tenon length is more effective compared with that from the tenon width. Additionally, the effect of the tenon thickness can be considered minor.

The calculations should be performed using the appropriate method, such as the finite element method (FEM). The FEM is used to set or estimate the load capacity of individual joint dimensions. Moreover, the critical stress points can be determined using this method. The most frequent method applied in the literature to calculate the stress and strain in wood chairs is the FEM (Smardzewski 1998; Smardzewski and Prekrad 2002; Pousette 2006; Gaff *et al*. 2015; Gašparík and Gaff 2015; Gaff *et al*. 2016; Kasal 2016b; Gaff *et al.* 2017a). Recently, the finite volume method has become popular (Demirdžić *et al.* 2000; Horman *et al.* 2009). Literature has shown an agreement between the data collected by calculation and experimental testing. For example, Horman *et al.* (2010) dealt with the numerical analysis of stress and strain conditions of a three-dimensional furniture skeleton construction and its joints. For the calculations, the study used the finite volume method. The agreement between the results of the calculation and experimental data was considered satisfactory. The studies by Gustafsson (1995) and Gustafsson (1996) can be considered interesting because of the structural analysis of chairs using modern software tools.

Besides the supplementary load, the load related to body weight plays an important role in static analysis and furniture testing (Smardzewski 2015). European Standards associated with seating furniture (STN EN 1728 2013; STN EN 12520 2017) for domestic use are based on users with body weights of up to 110 kg. However, current standards follow anthropometric data that is more than 30 years old and before the era of dramatic increase in body weight started; therefore, these standards should be updated. Due to the dramatic increase in the body weight of populations, a value of 110 kg in valid standards can be considered inadequate. In the USA, the 95th, 98th, and 99th percentiles for the body weight of men were 114.6 kg, 131.61 kg, and 141.17 kg respectively in 2002 (Harrison and Robinette 2002). A similar trend exists in Europe. There are many standards for testing chairs (especially office and school types) that have taken into account the major increase in the body weight of populations. For example, the National Standards Institute (ANSI) in the USA has accepted the standard BIFMA X5.11 (2015) for a body mass greater than 253 lb (115 kg) and up to 400 lb (181 kg), which equated to the 99.5th percentile of men in the USA. In 2012, a newly developed safety and performance Standard for educational seating, BIFMA X6.1 (2012), was accepted. The Standard clearly identified the need for a more current anthropometric database of children in North America. There are three chair sizes: A (seat height less than 352 mm, user weight 35 kg – 95th percentile for 6-year-old males), B (352 mm to 425 mm, 75 kg – 95th percentile for 12-year-old females), and C (more than 425 mm, 115 kg – 95th percentile for adult males) (Bellingar and Benden 2015). In Australia, certifications for "heavy duty" office chairs are available. Most certified fixed height chairs in Australia and New Zealand are tested to meet the requirements of AS/NZS

4688 (2000). This standard is not for more than occasional use by people weighing over 100 kg. The standard AFRDI 142 (2012) has four levels: 135 kg for a single shift (8-h shift operations), 135 kg for multiple shifts, 160 kg for a single shift, and 160 kg for multiple shifts. The standard AFRDI 151 (2014) is designed to supply chairs intended to be used by people heavier than 100 kg (four options – 135 kg, 160 kg, 185 kg, and up to 300 kg). In Europe, SATRA, is an independent research and testing organization established in the UK in 1919 as a furniture testing facility (ISO 17025 2017). SATRA provides a comprehensive and unrivalled chair testing service that can be applied to most seating designs. However, for bariatric or heavy-duty use, the current UK and European test Standards have no provisions for extra loads and forces that may occur. For office pedestal chairs, SATRA has developed a test method that incorporates BS 5459-2 (2008), but with loads and cycles for persons weighing only up to 225 kg (SATRA 2018).

The aim of this research was to investigate the effect of the body weight of users on the load capacity and dimensions of structural elements of chairs. This information can be subsequently used in practice by the manufacturers and designers in the furniture industry.

ANALYSIS APPROACH BASED ON REPORTED MATERIAL PROPERTIES

Experimental Subjects

Population-based studies dealing with measuring the height and body weight of the adult population were analyzed. Categories were selected according to the rules associated with the determination of the BMI: 25 kg/m^2 < 30 kg/m^2 (overweight), > 30 kg/m^2 (obese), and > 35 kg/m^2 (severely obese). Publicly-available sources were analyzed with requests to various national organizations. A sampling unit consisting of 71816 male respondents was used to analyze the increase in weight of the Slovak population from 1993 to 2017. The data associated with the sampling unit was collected from the Public Health Authority of the Slovak Republic. The data from individual years in the studied period was analyzed. To describe the weight gain trend, third-degree polynomials were used to determine the basic relationships between the analyzed data.

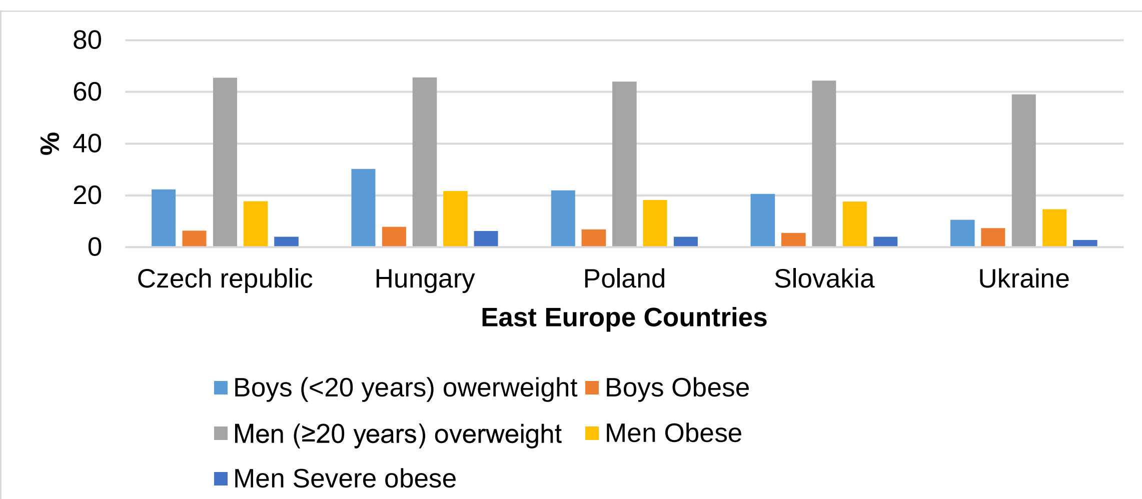

Fig. 1. Regional and national estimates of the prevalence of overweight and obesity by age in 2016

Figure 1 shows that 64% of men were overweight, 18% were obese, and 4% were severely obese in Slovakia in 2016. The results showed that 400,000 men suffered from obesity and 90,000 suffered from severe obesity in 2017. The weight of approximately 46,000 men with severe obesity was more than 110 kg (Ng *et al.* 2014; Di Cesare *et al.* 2016; HEALTH 2016; STATISTICS 2017; WHO 2017).

The data collected from the Public Health Authority of the Slovak Republic (Fig. 2) shows that from 1993 to 2017, an increase in the weight of men occurred in all of the weight categories and the 5th percentile increased by 10 kg (from 100 kg to 110 kg).

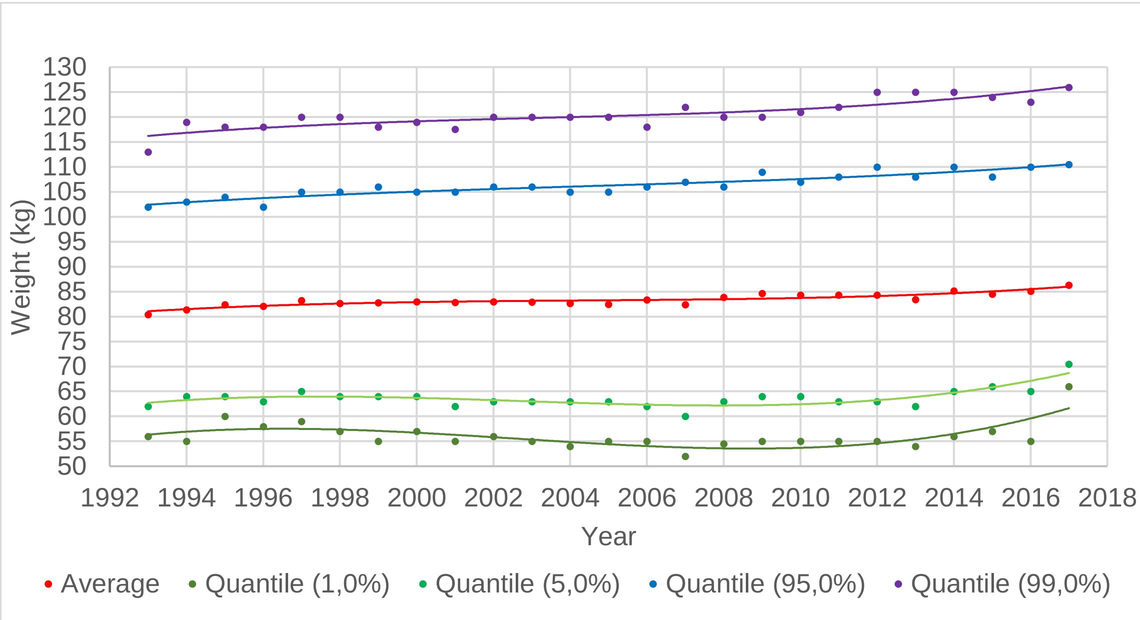

Fig. 2. Development of the average body weight and percentiles for men from 1993 to 2017

The data from the Public Health Authority of the Slovak Republic and other available sources (HEALTH 2016; PHASR 2017; STATISTICS 2017) show that the weight of approximately 113,000 Slovak men was higher than 110 kg in 2017. Moreover, the weight of 11% of these men was more than 130 kg. The situation in other European countries is very similar. Because of the aforementioned reasons, the use of 110 kg in current standards associated with the testing of chairs (STN EN 1728 2013; STN EN 12520 2017) can be considered inadequate. Following the weight analysis of men in Slovakia and other European countries and in addition to improving existing standards aimed at testing chairs, it is necessary to develop new standards that focus on people weighing over 150 kg.

For research, three body weights of a users were considered. Seventy kilograms was the average body weight used for many years as a base weight for furniture testing, 110 kg is a weight used for furniture testing according to the standards STN EN 12520 (2017) and STN EN 1728 (2013). 150 kg is the weight, we recommend following the results of development of the average body weight for men from 1993 to 2017 in East Europe Countries (Fig. 1, Fig. 2).

Assumed Materials and Construction

The three chair constructions that are used most often were chosen for the static analysis of chair joints. All of them were frame constructions with removable seating boards (Fig. 3). Basic construction I consisted of front and back legs jointed by rails. Braces were embedded in the rails in construction II. Construction III consisted of front and back legs jointed with rails and side stretchers.

Full dimensions of the chair meets ergonometrics requirements for seating furniture. In calculation following dimensions were used: height of the seat = 450 mm, width of the seat w = 480 mm, depth of the seat d = 460 mm. The software SCIA was used to calculate internal forces and moments necessary for designing joints. Conditions were limited by material, load and supporting construction. Beech sawn timber as the most often used material to produce chair was selected for calculation. Material constants used to calculate data associated with European beech (*Fagus sylvatica*) are as follows:

- Density ($kg.m^{-3}$): $\varsigma = 684$
- Young's Modulus (MPa): $E_X = 16670.0$, $E_Y = 1130.0$, $E_Z = 630.0$;
- Poisson's Ratio (-) $\mu_{XY} = 0.044$, $\mu_{YZ} = 0.33$, $\mu_{XZ} = 0.027$;
- Shear Modulus (MPa) $G_{XY} = 1200.0$, $G_{YZ} = 190.0$, $G_{XZ} = 930.0$

The material constants are valid when the relative moisture content is w=12%, air conditioning was run at the temperature of t=20 °C, and $\varphi = 60$ (Požgaj *et al.* 1997). In calculation, joints were defined as semi-rigid. It allows a certain rotation, and at the same time it also provides some rigidity. Internal bending moments are evaluated in each joint of the construction.

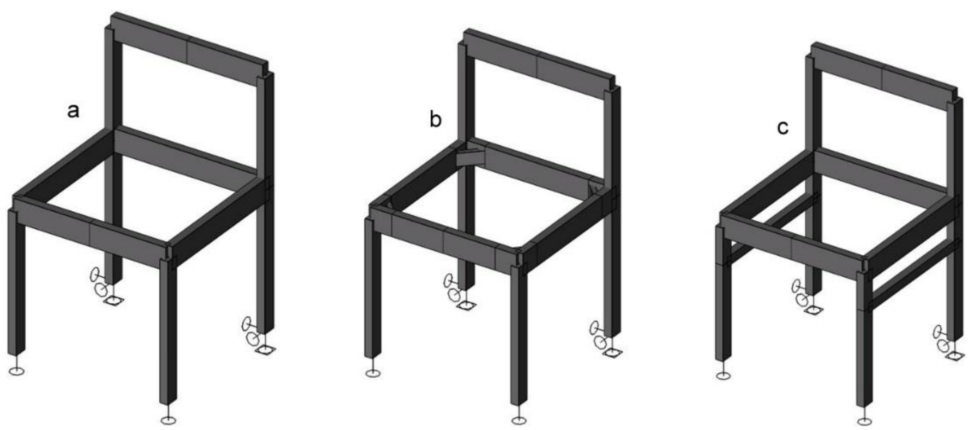

Fig. 3. Analyzed chair constructions: a) Type I – Legs jointed with rails, b) Type II – Corner joints supplemented with braces, and c) Type III – Legs jointed with rails and side stretchers

The static analysis of the three chair constructions was based on the use of glued tenon joints. The calculation followed the chairs manufactured in a standard way with the cross-section of the back and front legs being 42 mm × 25 mm, the cross-section of the side, front, and back rails being 70 mm × 24 mm, and a tenon thickness of 8 mm (1/3 of the element) (Fig. 4).

The static loading schemes (Fig. 5) were based on the STN EN 1728 (2013) and STN EN 12520 (2017) standards for testing chairs. Because the tenon joints were glued, all of the nodes of the structural elements were considered fixed in the calculation program. Three basic loading schemes were selected for the static analysis of the joints. The mentioned schemes were based on the loading types most frequently used in furniture testing laboratories.

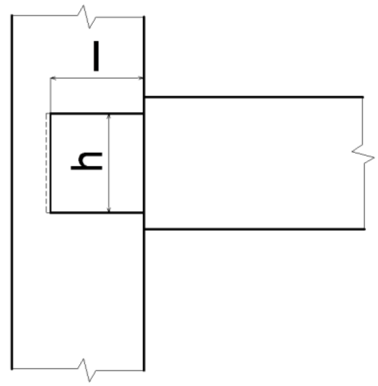

Fig. 4. Geometric parameters of tenon joints stressed in the angular plane; l – tenon length, h– tenon thickness, w – tenon height, and B1, B2, and A – sizes of the structural elements

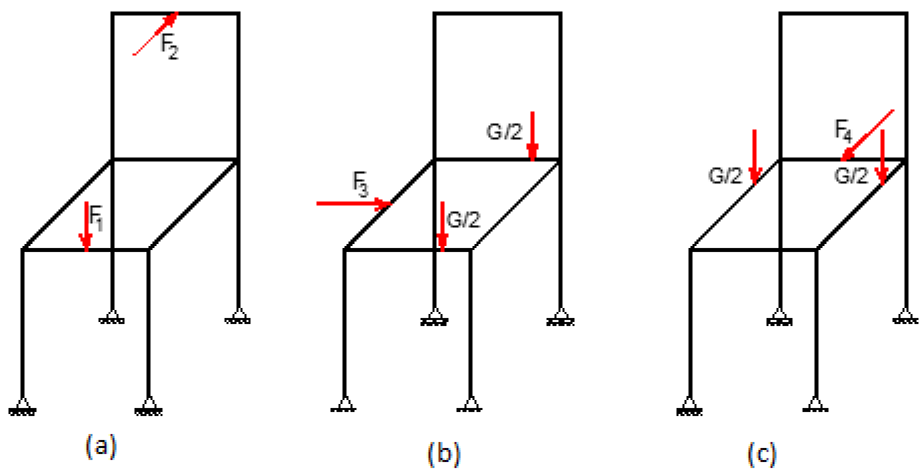

Fig. 5. Static analysis for individual load conditions; F_1, F_2, F_3, and F_4 – loads, G – weight of a user; (a) Load condition 1 – Loading of the front rail and seat back, (b) Load condition 2 – Side loading, and (c) Load condition 3 – Back loading

The loads corresponding to the individual weights of users (70 kg, 110 kg, and 150kg) are shown in Table 1. When the weight was 70 kg and 150 kg, the load was calculated using linear extrapolation from the forces corresponding to the weight of 110 kg.

Table 1. Loads for Individual Loading Schemes and Various User Weights

No.	User Weight (kg)	Load of Seating Board and Seat Back		Static Load of Front Legs		Static Load of Side Legs	
		F_1 (N)	F_2 (N)	F_3 (N)	G (N)	F_4 (N)	G (N)
1	70	827	286	254	636	191	636
2	110	1300	450	400	1000	300	1000
3	150	1775	613	545	1363	409	1363

F_1 – Force acting on a seating board; F_2 – Force acting on the seat back; F_3 – Loading of the front legs; F_4 – Loading of the side legs; and G – Loading of the seating board

RESULTS AND DISCUSSION

The most stressed construction joints in the individual chair type constructions were determined by following the static analysis, internal forces, and bending moment diagram. The bending moments corresponded with loads of 70 kg, 110 kg, and 150 kg, and the most stressed joints are detailed in Table 2. Based on the results, the degree of safety (*n*) of the proposed joints can be calculated. Moreover, the strength of the joints can be assessed in terms of their load capacity for all of the load conditions. The most stressed chair nodes are shown in Fig. 6.

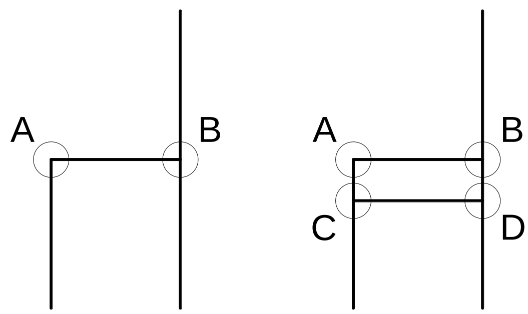

Fig. 6. Most stressed nodes in the constructions

The bending moments that stressed the joints in individual chair types and loads are given in Table 2. The bending moment values were important for designing the tenon joints of the chairs.

Table 2. Bending Moments Stressing the Joints in Individual Chair Types and Loads

User Weight (kg)	Chair Type I			Chair Type II			Chair Type III		
	Load Condition			Load Condition			Load Condition		
	1	2	3	1	2	3	1	2	3
	M_B (Nm)	$M_A = M_B$ (Nm)	M_A (Nm)	M_B (Nm)	$M_A = M_B$ (Nm)	M_A (Nm)	M_B/M_D (Nm)	M_A/M_C (Nm)	M_A/M_C (Nm)
70	148	55	74	146	55	74	84	55	39
							60	40	53
110	232	87	116	230	87	116	132	87	62
							94	63	84
150	**317**	119	158	**313**	119	158	**179**	**119**	84
							128	86	**114**

M_A – Bending moment acting on node A; M_B – Bending moment acting on node B; M_C – Bending moment acting on node C; and M_D – Bending moment acting on node D

Table 2 and Fig. 6 show the joint between the side rail and back leg (node B) when the load condition is 1, and the static load was applied on the front rail and seat back, which is the most stressed structural element of chair construction I. Compared with construction I, the bending moments on the nodes for construction II were similar. The joint between the side rail and back leg (node B) was the most stressed part in construction II. When designing construction II, load condition 1 was the most critical. Designing chair construction II was the most difficult. Each joint had to be designed individually because of various cross-sections of the side rails and stretchers. Based on the results given in Table 2, it was found that another joint was always stressed in various load conditions. The joint between the side rail and back leg (node B) was the most stressed for load condition 1. The joint between the side rail and front leg (node A) was the most stressed during side loading and the joint between the side stretcher and front leg (node C) was the most stressed during back loading. When the cross-sections of the front and back legs are the same (42 mm × 25 mm), the size of the tenon joint on both ends of the side rail would be the same. This meant that the joints in nodes A and B would be equal and the bending moment corresponding with load condition 1 would be an essential design factor. The same situation was observed for nodes C and D, which meant that the bending moment corresponding with load condition 1 for the joints between the stretcher and back and front legs would be an essential design factor as well.

The following analysis was aimed at determining the most stressed joints in chair constructions I and III, especially the joint between the side rail and back leg, as well as the joint between the side stretcher and back leg.

When calculating the minimum joint load capacity (M_{un}, Nm), the n is taken into account. The n for the chairs was 3 (Kamenický 1980). The equation used was as follows:

$$M_{\mathrm{un}} = nM_{\mathrm{i}} \tag{1}$$

where M_i is the stress of the joint (Nm). The average load capacity of the used joints (M_u) was calculated using the formulas given in Table 3. The formulas used to calculate joint load capacity were created according to the experimental results (Kamenický 1980). The M_{un} values for the critical nodes are given in Table 4 and must be achieved in construction types I and III with a required n of 3.

Table 3. Formulas for Calculating the Average Load-carrying Capacity of the Joints Stressed in the Angular Plane by the Bending Moments for Tenon Thickness 8 mm

Tenon Length (mm)	M_u (Nm)
25	7.45*w* - 53.92
30	9.03*w* - 75.40
35	10.16*w* - 83.60
40	11.04*w* - 90.40
45	12.00*w* - 106.00
50	12.62*w* - 112.50

w – Tenon width (mm)

Table 4. Minimum Load-carrying Capacity for the Most Stressed Nodes

Type of Construction	User Weight (kg)	M_i (Nm) in nodes	M_{un} (Nm) for n = 3
I	70	148.00 (B)	444.00
I	110	232.00 (B)	696.00
I	150	317.00 (B)	951.00
III	70	84.00 (B)	252.00
		60.00(D)	180.00
III	110	132.00 (B)	396.00
		94.00 (D)	282.00
III	150	179.00 (B)	537.00
		128.00 (D)	384.00

Letter in parentheses indicates the node the stress is acting on

Tables 5 and 6 show the tenon sizes required for Chair 1 and Chair III, according to the analysis.

Table 5. Tenon Size for Chair I

Node	User Body Weight (kg)	M_u for n = 3 (Nm)	Required M_{un} (Nm)	**Tenon Size (mm)**		
				Thickness	**Width**	**Length**
B	70	444.00	526.00	8	60	35
			505.68	8	58	35
			465.04	8	54	35
			572.00	8	60	40
			590.00	8	58	**45**
			568.98	8	54	**50**
	110	696.00	**572.00**	8	60	**40**
			590.00	8	58	**45**
			568.98	8	54	**50**
	150	951.00	**572.00**	8	60	**40**
			590.00	8	58	**45**
			568.98	8	54	**50**

Table 6. Tenon Size for Chair III

Node	User Body Weight (kg)	M_u for n = 3 (Nm)	Required M_{un} (Nm)	**Tenon Size (mm)**		
				Thickness	**Width**	**Length**
B	70	252.00	526.00	8	60	35
			505.68	8	58	35
			465.04	8	54	35
			572.00	8	60	40
			590.00	8	58	**45**
			568.98	8	54	**50**
	110	396.00	526.00	8	60	35
			505.68	8	58	35
			465.04	8	54	35
			572.00	8	60	40
			590.00	8	58	**45**
			568.98	8	54	**50**
	150	537.00	**526.00**	8	60	35
			505.68	8	58	35
			465.04	8	54	35
			572.00	8	60	**40**
			590.00	8	58	**45**
			568.98	8	54	**50**

Setting the tenon thickness by considering the leg dimensions (leg thickness of 25 mm and tenon thickness of 8 mm (1/3 of the leg thickness) in this study) is the most effective step when designing the dimensions. The tenon dimensions for chair I, depending on the minimum and average load-carrying capacities, are given in Table 5. The bolded values were not suitable for the minimum required load-carrying capacity or chair leg thickness. The tenon dimensions shown in Table 6 were suitable for the aforementioned minimum required load-carrying capacity in construction type III.

The increase in the weight of a user resulted in a limited range of tenon dimensions for construction type I. When the weight of a user was 150 kg, no tenon was suitable for the most stressed joint. In construction type III, no tenon dimensions were suitable for the joint between the side stretchers and legs for the load capacity or the dimensions of the structural elements. All of the joint dimensions were suitable for the joint between the stretcher and legs for the load capacity. Only the tenons with a length of 35 mm and 40 mm were suitable for the leg thickness. The tenons with a thickness of 10 mm and 12 mm were suited for the load capacity (Table 7). However, the dimensions of the structural elements could be affected. Thus, a leg thickness of 25 mm was not suitable, and the leg thicknesses of 30 mm to 36 mm were suitable.

The load-carrying capacities for the tenon thicknesses of 10 mm and 12 mm were calculated using the following formula (Kamenický 1980),

$$M_{\mathrm{uh}} = 0.125 h M_{\mathrm{u8}} \quad (2)$$

where h is the thickness of the tenon (mm), M_{u8} is the average load-carrying capacity for a tenon thickness of 8 mm (Nm), and M_{uh} is the average load-carrying capacity for tenon thickness h (Nm)

Table 7. Tenon Dimensions of Chair III for Users with a Weight up to 150 kg

Node	User Body Weight (kg)	M_u for n = 3 (Nm)	Required M_{un} (Nm)	**Tenon Dimensions (mm)**		
				Thickness	**Width**	**Length**
B	150	537.00	583.00	10	60	30
			581.30	10	54	35
			591.24	12	52	30
			575.64	12	46	35

Construction III was only suitable for higher load capacities. Joint B, the joint between the side rail and back leg, was the most stressed joint. The static analysis determined that tenons with a thickness of 10 mm were suitable. A leg with the dimensions 42 mm × 25 mm and a side rail with the dimensions 70 mm × 24 mm were assumed at the beginning of the study. In accordance with the rules for designing joints (Fig. 4) and following the load-carrying capacity values given in Table 7, a user with a weight of 150 kg and tenon dimensions of 10 mm × 60 mm × 30 mm resulted in a change in the leg dimensions from 42 mm × 25 mm to 42 mm × 30 mm. The side rail dimensions changed from 70 mm × 24 mm to 70 mm × 30 mm as well. Therefore, the cross-section of the leg increased by 20% and the cross-section of the side rail increased by 25%.

CONCLUSIONS

1. The weight of the population has been increasing remarkably. In Slovakia, the 95th percentile of the weight of men has increased from 102 kg to 110 kg over the last 25 years (130,000 of men weigh over 110 kg).
2. Chairs are designed for the current adult population weighing 110 kg as the load-carrying capacity. Following the analyses of the selected anthropometric parameters, it was determined that the load-carrying capacity of chairs must be designed for users weighing over 150 kg. Following the weight analysis of men in Slovakia and other European countries and in addition to improving the existing standards aimed at testing chairs, it is necessary to develop new standards for people weighing over 150 kg.
3. Following the static analysis of the load-carrying capacity of chairs, it was found that the only suitable construction type for users with a higher weight is the construction with stretchers. The leg cross-section dimensions increased by 20% and the side rail dimensions increased by 25% in the cases when a user weighed 150 kg and the tenon dimensions were 10 mm × 60 mm × 30 mm.
4. Furniture of all types must be designed with respect to anthropometric proportions, especially weight and height, and not only for the current population, but also for the future population. It is suitable to produce chairs for the normal population (normal weight being up to 110 kg) and higher weight population (higher weight being up to 150 kg).

ACKNOWLEDGMENTS

This research was supported by the grants for "Updating of anthropometric database of Slovak population" (APVV-16-0297) and "Lowering of formaldehyde emission from wood based panels by environmental progressive modification of polycondensation adhesives with biopolymers from leather waste, natural nanofillers, additives and activators" (APVV-14-0506), and "Mechanical resistance of glued wooden composites against dynamic stress" (VEGA No. 1/0626/16).

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Article submitted: April 30, 2018; Peer review completed: June 28, 2018; Revised version received and accepted: July 4, 2018; Published: July 10, 2018
DOI: 10.15376/biores.13.3.6428-6443