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Changes in the mechanical parameters of hair in a group of women in reproductive age

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Abstract

OBJECTIVE: Hair quality and scalp characteristics are considered to be a significant marker of health. This marker is reflected in mechanical properties of hair. To investigate these properties, hair samples have been collected among women of different age and then analyzed. The thickness, Young's modulus of elasticity and ultimate strength limit were the main observed parameters.
METHODS: The diameter of each hair has been measured using an optical microscope equipped with a digital camera. The hair was then clipped into the uniaxial tensile testing device. Each sample has been stretched to failure at a speed of 2 mm/min and force vs. elongation was recorded. The mechanical results were converted with respect to the diameter and Stress-Strain curve was obtained for each sample. In addition, all the analyzed samples were divided into two groups in dependence on the age, namely samples from women younger than 35 and over 35 years of age. All the measured parameters were statistically evaluated.
RESULTS: Young's modulus, yield and elongation parameters showed no significant difference among samples. On the other hand there was a significant difference among the samples in ultimate strength values. Findings from group analysis showed that women under 35 years show about 5 times greater variability in hair strength than that of women above that age.
CONCLUSION: The results of our study indicate that hair tendency to grow persists up to 30 years of age, then slowly decreases and then achieves a steady state around 60 years of age.

INTRODUCTION

Hair is a complex fibrous heterogeneous material. It is highly influenced by many factors such as ethnicity, hygiene, chemical treatment or the environment (Zhenxing & Gaosheng 2009). Its main component is keratin. It contains about 95% of this protein Keratin amino acids create bundles that are assembled into chain filaments. Hair can be thought of as the amount of twisted thin fibers that are chained together with each other.

Human hair has two basic functions. The first one is mainly the protection against sunburn, abrasion and thermal losses. The second one is primar-

ORIGINAL ARTICLE

ily cosmetic (Robbins 2002). The hair is of great social importance for a man. In the Middle Ages only kings and nobles had long hair. Hair is an important biological material, which varies depending on ethnic origin or age (Benzarti *et al.* 2011). The character of hair is constantly changing from prenatal development to old age and the same follicle produces even under physiological conditions gradually different types of hair. Children's hair is in average softer, rounder, less modulated (with less marrow) and lighter than adults' (Bogaty 1969). The fact that hair varies among individuals play a significant role in the forensic biomechanics. Nowadays it is used for gathering the DNA information and thus helps to reconstruct the crime scene of car, pedestrian or bicycle accidents, for example to establish a contact place for the pedestrian throw formulas (Fanta 2013).

There exists a methodology in a Polish laboratory (Biomolmed, www.biomol.pl), which deals with human metabolism research and argues that many pathological states of the organism is closely associated with changes in concentrations of trace elements in tissues. It has been proven that the best method for finding values of trace elements in the body is their determination in hair and nails. Hair and nails are located on the skin surface and are excluded from metabolic processes. Nails are less suitable material than hair due to difficult exclusion of exogenous contamination. In contrast, hair is permanent neutral tissue, which is not subject to biological changes. Outer keratin container completely prevents loss of internal components, but also the penetration of external contaminants inside, which ensures stability of the chemical composition. Hair samples are collected in a non-invasive way. Hair can be kept with unchanged chemical composition (www.biomol.pl).

Both hair health and appearance is also affected by several hormones. One of the hormones that is involved in the process of hair growth is prolactin. The process of intensive production of the hormone and its receptor correlates with the period of hair growth. The exact role of prolactin in hair growth still remains unknown. It has been proved that abnormally high level of prolactin (this state is called hyperprolactinemia) causes hair loss. as is the case with higher levels of androgens (male hormones) (Foitzik *et al.* 2006). Testosterone, which plays significant role by the hair loss in men, can play this role in women also, especially after menopause. Another frequent cause of hair loss is thyroid disorder.

It is obvious that the most common cause of hair loss is the effect of male hormones on the scalp, both for men and women (Price 1999).

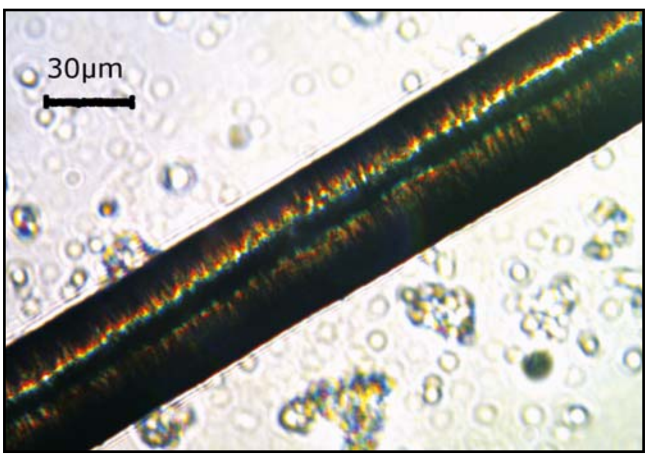

Fig. 1. Location of marrow in the middle of hair.

Anatomy

Hair, whose average thickness ranges from 60 to 80 μm, consists of three layers: the marrow, cortex and cuticle (Bartošová *et al.* 1982). Each part has a different structure and function.

Hair marrow – medulla – is located in the middle of the hair (Figure 1) (Benzarti *et al.* 2011) and is formed along the entire length only in thick terminal hair (relatively long, well pigmented hair). In fine hair it may be fragmented or is present only in certain segments (Figure 2) of hair shaft, or missing completely (Figure 3). Hair marrow is composed of large, usually pigmented cells with large intracellular vacuoles. Connections between cells are free, cells are divided by distinct intercellular spaces, which probably affect the

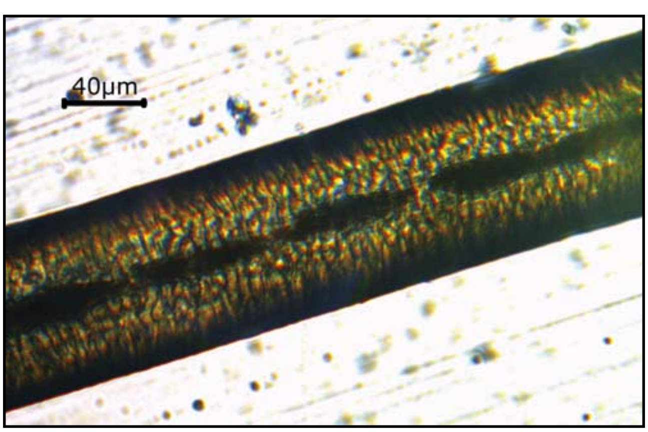

Fig. 2. Segmented hair marrow.

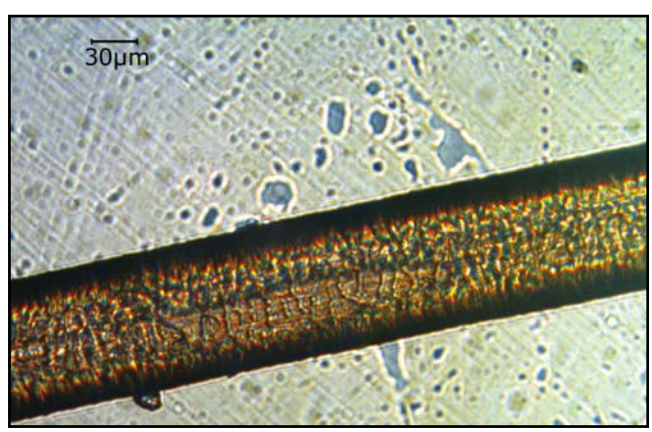

Fig. 3. Missing marrow in hair.

refraction of light, and thus the tone of the hair. The medulla cells are keratinized. Medulla is often found in animal hairs and is used to regulate body temperature. Among humans, this need has become secondary (Benzarti *et al.* 2011).

Hair cortex is the most powerful part of the hair. It comprises a mass of mutually bound cornified cells that contain longitudinally arranged melanin granules in pigmented hair. Various numbers of fine tubes were found among the cell cortex, filled with fluid in follicular segment of hair and with air in loose segment of hair shaft. It takes up to 90% of weight of the hair. It consists of a complex of fibrous system affecting the mechanical properties of hair (Benzarti *et al.* 2011).

Hair cuticle is formed by one row of translucent cells without pigment, showing signs of keratinization (cornification), when an originally soft cellulose protein material prekeratin changes into a solid mass keratin. Free edges of the hair cuticle cells are variously shaped and are facing up to the free ends of the hair. Cuticle protects the inside of the hair against external environment and the damage caused by daily treatment. Cuticle has a thickness of 3–5 μm and takes up 10% of the hair weight (Benzarti *et al.* 2011).

Macroscopic hair variations

Hair is very variable in color, length, shape and growth rate. Morphological evaluation criteria in addition to these characters notice also the distribution of different types of hair, depending on the age and sex of the individual. The hair character is constantly changing from prenatal development to old age and the same follicle produces gradually different types of hair even under physiological conditions.

Hair can be basically divided into the prenatal lanugo and postnatal vellus, intermedia and terminal hair. This division respects shape variations, as well as the time factor in hair growth in humans.

Lanugo – the first generation hair, created in utero, are soft, shiny, without pigment and marrow. In postnatal life, the lanugo appears only under pathological circumstances.

Postnatal vellus – constitutes the bulk of hair of infants and young children, when during the last months of pregnancy lanugo falls out and is replaced by vellus, the second generation hair. That is fine and thin, but often already pigmented and grows to a maximum length of 2 cm.

Intermedia hair – replaces the fine vellus. It is stronger, deeply pigmented and forms a relatively greater density scalp (haired part of the skin) in older children. Among some children aged two to three years may be a change in the type and color of hair remarkably fast. For adolescents in early puberty, the changes in the distribution and character of hair is most noticeable.

Terminal hair – appears at that time in different locations and replaces the intermediate type scalp or fine vellus on the body, is relatively long, well pigmented and contain medulla fragmentally or across whole length of the shaft. Coarse hair of teenage boys scalp is usually more modulated than subtle girls scalp. The first terminal hairs, fully formed before puberty, are the eyelashes (cilia) and eyebrows (supercilii), which gradually thicken from childhood and do not change much in adulthood.

Change of intermediate scalp into the terminal can be gradual, subtle or very striking if both the color and the shape of the hair changes. Mostly also the physical properties of hair change, their flexibility, ductility and toughness increases. However, the arrangement of hair in multimember groups does not change as well as their growth in rows or strands. In addition, the direction of hair growth, founded in embryo, does not change and remains characteristic for each individual in certain locations. The thickness of scalp hair rises rapidly and continuously during the third to fourth year of life, less until the tenth year and by the twelfth year remains almost entirely constant. The terminal scalp hair is affected by regressive changes during lifetime before other hair. For men, earlier than among women, the growth capacity of some follicles is reduced and on the forehead and scalp grows still long, but thinner hair often without pigment. At the same time, a conversion may occur of terminal follicles into shorter and less productive, which generate fine vellus type hair. All consecutive generations of all types of hair have therefore an upward growth curve in the beginning and downward later during the lifetime, although there are significant individual differences in the extent of morphological variations (Bartošová *et al.* 1982).

Hair growth phases

Each hair has three main stages of growth. The first phase is the growth (anagen) phase, which lasts two to seven years. Approximately 85% of the hair on the head is at this stage. In the anagen phase of hair growth hair comes from the matrix at the bottom of the hair follicle.

The second phase is the katagen phase, sometimes called the transitional phase. It takes about two weeks and about 1% of the hair is at this stage. In this phase of hair growth the papilla gradually dies, which has been involved in the development and supply of hair.

Third (telogen) phase lasts three to four months and about 10–15% of the hair is in this stage. During this stage the hair is released from the papilla and slowly moves up the sebaceous glands, where it remains until it falls out.

The growth of human hair does not take place in waves, i.e. synchronously. Replacing the hair scalp and other body hair is asynchronous, mosaic-like. This means that while one hair grows and is in the anagen, the other in the same location in the telogen is ready to fall out. In the course of life six to seven generations of hair replace each other is in the same follicle.

Following the intrauterine and postnatal hair replacement two cycles are coming in childhood and pubertal age. Under physiologic conditions, the second decade of human life represents a peak period in terms of intensity of growth and pigmentation of hair. In adulthood is the hair changing less noticeably and the anagen in the scalp follicles is reduced with increasing age.

Given that the cycle of hair growth in adult age takes at least 1000 days, under physiological conditions fall out around 100 hairs every day. However, there are too many individual differences. The number of anagenic and telogenic follicles always varies by age and area of the body. For example, 615 active scalp follicles per 1 cm^2 were found on persons from twenty to thirty years of age, about 485 active follicles between 30–50 years of age and an average of 435 active follicles per 1 cm^2 of scalp among 80–90 years old people. Although the replacement of hair is continuous between the 30th and 50th year, a replacement often begins of thick terminal hair for thinner hair without pigment at this time (Bartošová *et al.* 1982). Grey hair is stiff, more wiry and unruly (Hay & Wall 2011). The work of Hollfelder *et al.* (1995) confirms this fact and adds that unpigmented hair is more sensitive to the sunshine. In the sixth decade of life the anagen period is shortened from three years average to 17–94 weeks. That accelerates hair replacement at the expense of its quality.

Mechanical properties of hair

The mechanical properties of hair shaft can be changed primarily by various internal factors, such as genetic, nutritional, metabolic, or secondary external factors (Bartošová *et al.* 1982). From nutritional perspective the amino acids methionine, cysteine, and cystine are essential for normal hair growth because of their oxredox potential. Nutritional status of these amino acids can be strongly influenced by diet or modified by creatine supplementation (Petr *et al.* 2011).

Mechanical properties of hair – strength, ductility and flexibility – are conditional on hair structure and molecular arrangement of the hair keratin. They are mainly dependent on the ultrastructure of the hair cortex, which due to its composition belongs to mechanically anisotropic materials, because it consists of elastic prolongable fibers and hygroscopic and relatively rigid matrix. Adding these different properties of the two components of keratin enhances its strength and flexibility. In a humid environment, hair becomes more flexible, because of disruption of less stable hydrogen bonds in the matrix and swells due to matrix hydration. Ultimate strength values of a wet hair are smaller than of a dry hair. To achieve the desired strength of keratin fibers a special structure is created by peptide bonds between amino acids. This causes limited mobility, so it turns into a spiral. That is why the hair is longer when wet and after drying returns to its original length.

The hair strength is measured by the maximum load which the hair can bear before it breaks. The hair ductility is a length, by which the hair length increases at maximum load. Flexibility is the most important mechanical property, it is the ability to extend under tension and deform by rotation and return to its original length and assume its original shape after the application of force. Both types of flexibility are measured in the hair: elasticity in tension is evaluated by Young's modulus and elasticity in torsion is measured by torsion module (Bartošová *et al.* 1982). Further assessed parameters are fracture strain, ultimate strength, yield strength and the Poisson ratio (Zhenxing & Gaosheng 2009) which is giving context to the longitudinal stretching and transverse constriction caused by it.

OBJECTIVES

I. Pursuant a newly proposed method, set the basic viscoelastic hair parameters.
II. Find the viscoelastic hair parameters dependence on the of women's age.

METHODOLOGY

Mechanical properties of hair are also dependent, beside the length and thickness, on the penetration of water in molecules of keratin, thus the relative humidity and temperature in which the hair samples are examined (Benzarti *et al.* 2011).

Samples of hair were obtained from 37 women of different ages and exactly one hair was measured from each of them. The hair was always cut from the same place (the nape area) using sharp scissors close to the head.

First, an optical microscope (W. Watson & Sons) equipped with a digital camera (MI-DCT1300 color CMOS) was adopted to measure a shaft diameter of each hair. The measurement has been repeated in 15 regions within the first 3 cm of each hair. One measurement in every 2 mm length of hair, in other words a transverse dimension of the hair was determined under the microscope, then the sample was shifted by 2 mm and the following transverse dimension was determined in the center of the visual field of the microscope again.

Second, the hair was placed into the tensile testing device Deform type 2 (made by Pemar spol. s r.o.) (see Figure 4), which is suitable for the measurement of small forces under low speeds in biological materials. With a strain gauge of 20 N maximum load and special grips for fixing fibers the measuring machine allows to perform determination of conventional deformation curve and measurement of relaxation or cyclic load of a sample. The stroke of the tensile testing device at its grips is 215 mm at maximum, so we use hair samples up to the length of 5 cm. The device is controlled via its Ethernet interface by a multi-platform homebuilt software Trhey!. The sensitivity is 1 mN.

Individual hair samples had been tested at a speed of 2 mm/min until failure. From the converted deformation curves (Figure 5), i.e. dependency of the true stress on the relative deformation (true strain), mechanical properties (yield strength, ultimate strength and fracture strain) of individual hairs have been determined.

A load curve is divided into three parts (see Figure 5):

- First part – elastic (1a) – the part where the deformation is fully reversible and the sample is able to return to its original shape and dimension when external forces cease. In this region of the curve a Hook area is located where the tension is directly proportional to the deformation and therefore the slope of the line determines a Young's module. The second part is non-linear (1b) and ends by yield strength (A), by which the maximum elastic deformation is defined. Deformations beyond this point on the curve are already plastic and after the application of external forces the sample remains permanently deformed. At this point the breaking curve passes in the plastic area of deformation.

The moment of the beginning of deformation is determined from the equation of the line interpolating breaking curve in the Hook area. The constant in this equation determines the intersection of the line with the axis of deformation. By this value we move all the deformation data observed on the deformation curve afterwards.

- The second part (2) in which irreversible changes already take place in the sample and where even application of a constant force may lead to increasing deformation, simply put the area beyond yield strength, which is characterized by viscoplastic deformation. The shape of the curve in this area is greatly influenced by the deformation speed and at higher speeds (from 10%/min up for hair) may be the start of that second phase characterized by a negative slope.

- Third part (3) is the area of reinforcement before rupture where the slope of the breaking curve increases again (B). Steady increase in tension leads to rupture of the sample (Benzarti *et al.* 2011).

Dawber & Messenger (1997) reported that in the area of 30–70% irreversible changes occur and prolongation by 80% causes rupture of the hair. Our experience, however, shift the onset of irreversible changes before area (2) beyond 6–7% of relative deformation. The fracture strain, i.e. a position of point B on the axis of deformation, is according to our measurements for most nations around 48–52% and around 40% for the Czechs.

Young's modulus (E) we find from the Hook (linear) area of a load curve approximated by a linear function. Yield strength is determined by the coordinates of the intersection of the linear approximation of the load curve in a Hook area and a beginning of a plastic zone. Ultimate strength is the maximum tension before a rupture of a hair, which we determine together with the fracture strain as the coordinates of the end point of the load curve, when the coordinate on the axis of independent variables is the fracture strain [%] and the coordinate on the axis of the dependent variables gives ultimate strength [MPa].

Fig. 4. Deform Type 2 shredder.

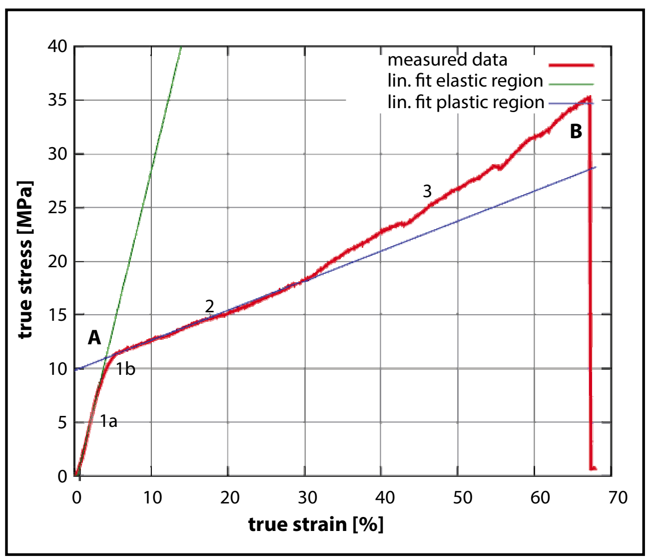

Fig. 5. Load curve obtained from the tensile test of a hair

RESULTS

The resulting data was processed and subsequently interpreted in graphical form. We evaluated various mechanical parameters depending on the age of probands.

Dependence of the individual quantities on time was approximated by an irrational function ($\alpha, \beta \in R$, in the case of a rational function $\alpha, \beta \in N$) of the form

$$g(t) = \frac{a \times t^{\alpha} - b}{c \times t^{\beta} + d} + e \qquad (1)$$

Irrational function arises from a rational in a way that we look for non-integer coefficients α and β, while in the case of rational function they would be solely positive (Mošna 2010). Equation 1 – non-diverging function by which the detected process can be described in its entirety. The function *g* has the dimensions of the approximated function, thus for example for ultimate strength in MPa, in case of approximation the constants *a, b, e* have the same dimension MPa, constants *c, d* are dimensionless, *t* is the relative dimensionless time. We will further perform normalization of time when the timeline is expressed in multiples of years, it is dimensionless, the constants α and β are dimensionless. We will further deal with the case when $\alpha<\beta$. In this case, the constant *e* indicates the value to which approaches the approximation function for a late period of life. The value for a low age is lowered in comparison with the age of the value of *b/d*. The ratio *a/c* determines the significance of the increase in value of the approximated function in middle age. The values of these parameters found by fitting for each variable are displayed in Table 1.

Concordance between measured and calculated values is expressed by two statistical criteria, i.e. the coefficient of determination and coefficient of variation (Nash & Sutcliffe 1970).

$$CD = 1 - \frac{\Sigma(Q_m - Q_v)^2}{\Sigma(Q_m - \overline{Q}_m)^2} \qquad (2)$$

$$CV = \frac{\sqrt{\frac{\Sigma(Q_m - Q_v)^2}{n}}}{\overline{Q}_m} \qquad (3)$$

Description of equations 2 and 3: *CD* – coefficient of determination; *CV* – coefficient of variation; Q_m – measured values (unit is given by the approximated variable); Q_v – calculated values (unit is given by the approximated variable); $\overline{Q}_m$ – mean value of the measured data (unit is given by the approximated variable); *n* – number of measurements

If all the measured and approximated values are on an approximation curve, the coefficient of determination CD is equal to 1 and the coefficient of variation CV is 0 (Chow *et al.* 1988).

Furthermore, we performed a group analysis as follows. After exclusion of one outlier, we divided the rest of the measured data by the age of the probands into two groups: under 35 years of age and over 35 years of age. In both groups, we assumed a normal (Gaussian) distribution for all six of the mechanical parameters (diameter of the hair shaft, Young's modulus, yield strength in % and in MPa, fracture strain, ultimate strength) of hair and using them we performed the basic statistical tests on the parameters of the normal distribution. The test results that came out positive at the 5% level of significance are shown in Table 2.

In the Table 3 is the statistical evaluation of group analysis for mechanical parameters, namely Young's modulus [GPa] and the fracture strain [%]. Assessed data are not statistically conclusive at a significance level of 5%.

Figures 6–9 show that the material parameters of hair – yield strength, ultimate strength, fracture strain and Young's modulus in tension exhibit the same character of dependence on the age of a woman. The function describing these parameters is generally monotonically increasing to around the age of 35 years and monotonically decreasing with decreasing slope above the age of 35 years. This dependence is most conclusive for the maximum hair elongation, with a determination coefficient of 0.23 and variation coefficient of 0.15. For other variables is this dependence more weak or inconclusive (Table 3).

DISCUSSION

Hair exchange is a dynamic, continuous process that begins during embryonic development and with advancing age, especially during senescence, the physiological tendency is a decrease of hair growth curve.

This whole study is based on an important assumption – that all generations of women examined grew up under the same external conditions and there are no developmental changes, thus it may be assumed that

Tab. 1. Calculated values of the coefficients.

	CD	CV	a [1]	b [1]	c.10^6 [1]	d [1]	e [1]	α [1]	β [1]
RMS v RP [1]	0.10	0.35	3.25	42.4	7485.38	1.99	2.03	1.0	2.0
RMS v T [1]	0.13	0.34	1.47	1.0	27.3	0.97	4.09	1.25	2.89
RMP v RP [1]	0.23	0.15	3.28	–4.3	47.5	2.06	44.2	1.25	2.89
RMP v T [1]	0.14	0.35	1.3	1.42	5.71	0.19	3.3	1.25	2.89
E [GPa]	0.012	0.27	5.58	81.67	0.46	14.74	1.17	1.0	2.0

CD – coefficient of determination; CV – coefficient of variation; RMS in RP – relative yield strength in relative elongation; RMS in T – relative yield strength in pressure; RMP in RP – relative ultimate strength in relative elongation; RMP in T – relative ultimate strength in pressure; E – Young's modulus in tension; a, b, c, d, e, α, β – constants (see above)

Tab. 2. Statistical evaluation of group analyzes.

	Yield strength [MPa]			Ultimate strength [MPa]	
	below 35 years	**older**		**below 35 years**	**older**
mean	65.69	55.61	mean	268.09	231.20
std. deviation	18.30	13.04	std. deviation	74.05	37.13
observations	22	14	observations	22	14
t stat	1.79		t stat	1.98	
p (T <= t)	0.04		*p* (T <= t)	0.03	
t crit	1.69		t crit	1.69	

mean – the mean value of the examined group; std. deviation – standard deviation from the average; observations – number of examined persons; t stat – calculated character value; *p* – level of significance; t crit – critical value of a character determined from tabulated values

Tab. 3. Statistical evaluation of group analysis.

	Young's modulus [GPa]			Maximal elongation [%]	
	below 35 years	**older**		**below 35 years**	**older**
mean	1.36	1.32	mean	113.11	112.90
std. deviation	0.11	0.35	std. deviation	232.21	16.77
observations	22	14	observations	22	14
t stat	0.38		t stat	0.04	
p (T <= t)	0.35		*p* (T <= t)	0.48	
t crit	1.69		t crit	1.69	

mean – the mean value of the examined group; std. deviation – standard deviation from the average; observations – number of examined persons; t stat – calculated character value; *p* – level of significance; t crit – critical value of a character determined from tabulated values

women now 30-year-old will have similar mechanical properties in 30 years as women now 60-year-old. In line with the work of Benzarti *et al.* (2011) who states that a statistical difference in stiffness of hair between individuals of different ages is meaningless, our study concludes that there is no dependence for selected sample of women between hair stiffness (Young's modulus) and age of women. In other material parameters of hair which Benzarti *et al.* (2011) did not attend to, we have observed a certain dependence with age. In particular the linear dependence of the hair diameter and extremal dependencies between yield strength, ultimate strength and fracture strain have been found.

All successive generations of all types of hair during the life have in the beginning an upward growth curve and later downward growth curve (Bartošová *et al.* 1982). The results of our study show that the upward trend of hair growth curve persists until about 30 years, then slowly declines and around 60 years of age levels off at an approximately constant level.

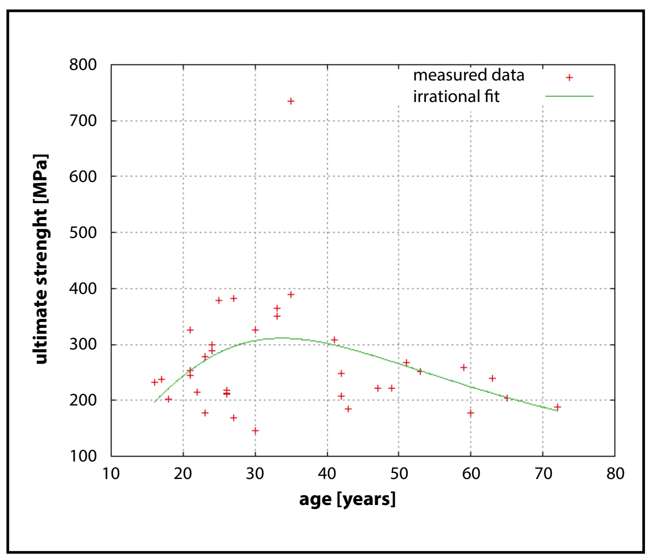

Fig. 6. Dependence of ultimate strength [MPa] on a woman's age – approximation by a rational function. The coefficients of approximation equation No. 1 are in Table 1.

CONCLUSION

Hair in certain areas differs in not only the length, texture and color, but also in the diameter (which fluctuates along the hair) and shape. Number and distribution of follicles established during embryonic development are about the same for all the people, but genetic factors determine a wide range of variations (Bartošová *et al.* 1982).

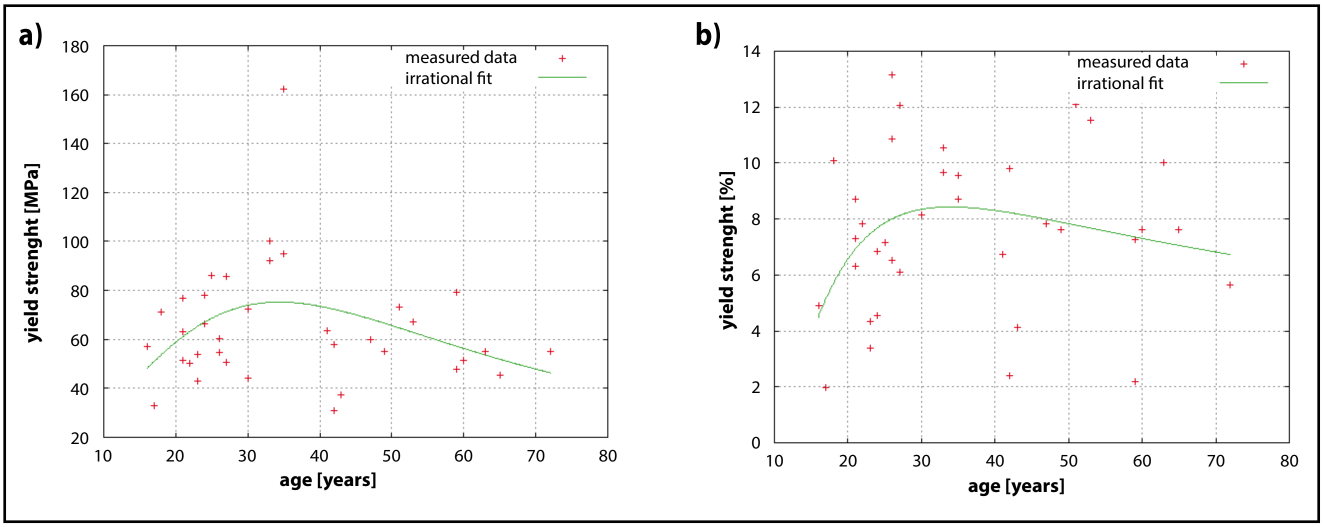

Fig. 7. a) Dependence of yield strength [MPa] on a woman's age – approximation by a rational function. The coefficients of approximation equation No.1 are in Table 1. **b)** Dependence of yield strength (in percentage of elongation of hair) on a woman's age – approximation by a rational function. The coefficients of approximation equation No. 1 are in Table 1.

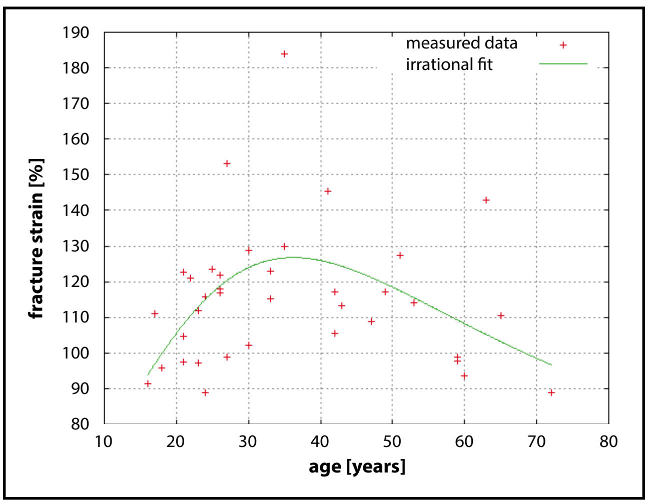

Fig. 8. Dependence of fracture strain [%] on a woman's age – approximation by a rational function. The coefficients of approximation equation No. 1 are in Table 1.

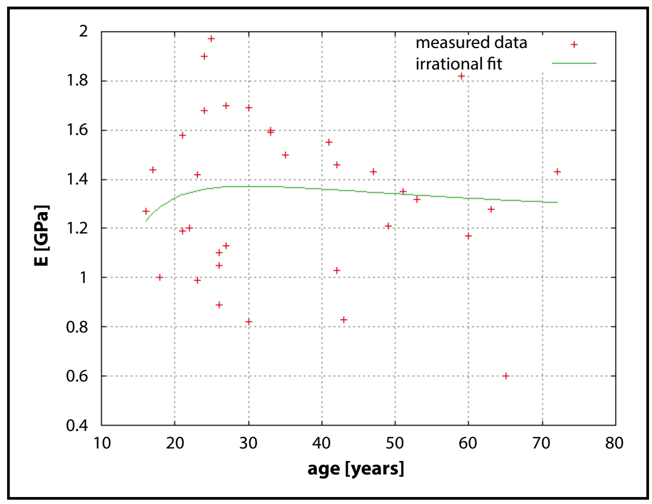

Fig. 9. Dependence of Young's modulus in tension [GPa] on a woman's age – approximation by a rational function. The coefficients of approximation equation No. 1 are in Table 1.

Table 2 shows that at the 5% significance level, we can say that the hair of women older than 35 years has lower yield strength compared to that of women younger than 35 years. Likewise, from the data at the 5% level of significance we can say that the hair ultimate strength for women older than 35 years is lower than the one for those younger than this age. The findings of the group analysis revealed the fact that women under 35 years show about 5 times greater variability in the strength of hair than women over 35 years. Young people, i.e. under 35 years of age have both strong and weak hair, while the old people i.e. over 35 years have only weak hair.

Appearance of the first gray hair is associated with reduced production of melanin. Melanocytes, which are responsible for hair and skin color produce melanin (dark pigment). Hair turns gray because over time melanocytes cease to work and are replaced in the hair bulbs with air bubbles (Majerová 2010). On average, the first gray hair appears on women around 34 years of age (www.trichologie.cz). All these effects do cause changes of the mechanical parametres that we have dealt with in this paper. Bartošová *et al.* (1982) reported that a greater tendency for thinning hair above the forehead and scalp and for hair graying occurs in caucasian men earlier than in men of Japanese ethnicity. Excessive stress or traumatic experience can greatly speed up the graying, but not overnight, as is sometimes claimed.

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